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Original Research Article

PREDICTORS OF MAJOR ADVERSE CARDIOVASCULAR EVENTS AFTER ACUTE CORONARY SYNDROME

Ritu Bhatia[1], Dilip Kumar Ratnani[2] Hitesh Yadav [3], Devesh Rajani [4]

[1]*Department of Cardiology, N.M.Wadia Institute of cardiology and Narindra heart clinic, Pune, Maharashtra, India*
[2]*Department of Cardiology, Professor, Shri Shankaracharya Institute of Medical Sciences, Bhilai, Chhattisgarh, India*
[3]*Department of Cardiology, GBH American Hospital and Vasudev Heart Clinic, Udaipur, Rajasthan, India*
[4]*Assistant Professor, Department of General Medicine, Era's Lucknow Medical College, Lucknow, Uttar Pradesh, India*

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Corresponding Author:
Dr. Ritu Bhatia,
Department of Cardiology, N.M.Wadia Institute of cardiology and Narindra heart clinic, Pune, Maharashtra, India.
Email: Ritudhawanbhatia@gmail.com

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ABSTRACT

Background: Despite advances in reperfusion and pharmacotherapy, patients with acute coronary syndrome (ACS) remain at substantial risk of recurrent major adverse cardiovascular events (MACE), and identifying readily available bedside predictors can refine risk stratification. The objective is to evaluate the clinical, laboratory, electrocardiographic, echocardiographic, and angiographic characteristics of patients with ACS and to identify independent predictors of MACE during 12 months of follow-up.

Materials and Methods: In this single-centre, retrospective, observational cohort study, 412 consecutive patients admitted with ACS were analysed. MACE was defined as a composite of all-cause death, non-fatal myocardial infarction, stroke, unplanned revascularisation, and heart-failure hospitalisation. Univariable and multivariable logistic regression identified independent predictors; Kaplan-Meier analysis and the area under the ROC curve assessed the GRACE score. A P value below 0.05 was considered significant.

Results: MACE occurred in 98 patients (23.8%). Independent predictors were advancing age (adjusted odds ratio [OR] 1.38 per decade), diabetes mellitus (OR 1.92), Killip class greater than one (OR 2.14), LVEF below 40% (OR 2.46), eGFR below 60 mL/min/1.73m² (OR 1.89), and a GRACE score above 140 (OR 2.27). The GRACE score discriminated MACE well (area under the curve 0.78).

Conclusion: A small set of routinely recorded variables independently predicts 12-month MACE after ACS and can support pragmatic, resource-efficient risk stratification.

Keywords: Acute Coronary Syndrome, Myocardial Infarction, Risk Factors, Prognosis, Heart Failure.

INTRODUCTION

Cardiovascular disease remains the leading cause of death worldwide, accounting for nearly a third of all global mortality, and ischaemic heart disease constitutes its largest single component.[1,2] Acute coronary syndrome (ACS) encompasses a clinical spectrum that ranges from unstable angina through non-ST-elevation myocardial infarction (NSTEMI) to ST-elevation myocardial infarction (STEMI), unified by the common pathophysiological substrate of acute myocardial ischaemia, most often precipitated by atherosclerotic plaque rupture or erosion with superimposed thrombosis.[3] The diagnosis rests on the integration of ischaemic symptoms, dynamic electrocardiographic changes, and the rise and fall of cardiac troponin, as codified in the Fourth Universal Definition of Myocardial Infarction.[3]

Over the past three decades, the widespread adoption of early invasive strategies, primary percutaneous coronary intervention, potent dual antiplatelet therapy, high-intensity statins, and neurohormonal blockade has markedly reduced the

early case fatality of ACS.[4,5,6] Nevertheless, survivors continue to face a considerable residual burden of recurrent ischaemic events, heart failure, and death in the months and years after the index admission.[12,14] The composite of major adverse cardiovascular events (MACE) is therefore widely used as a pragmatic measure of this residual risk and as a primary endpoint in both clinical trials and observational cohorts.[6]

Accurate risk stratification is central to contemporary ACS care because it determines the appropriate intensity of monitoring, the timing of revascularisation, and the aggressiveness of secondary prevention.[4,6] Validated multivariable instruments such as the Global Registry of Acute Coronary Events (GRACE) score and the Thrombolysis in Myocardial Infarction (TIMI) risk score were developed for this purpose and remain the most extensively validated tools in routine use.[7,8,9,10] Individual clinical variables also carry independent prognostic weight, including advanced age, diabetes mellitus, the degree of acute heart failure expressed by the Killip classification, left-ventricular systolic dysfunction, and impaired renal function.[11,15,17,18,20,23]

The burden of ACS is shifting towards low- and middle-income regions, where patients often present at a younger age, harbour a heavy load of modifiable risk factors, and reach hospital after longer pre-admission delays, all of which may influence the pattern and timing of subsequent events.[31] In such settings, constraints on long-term follow-up and on the routine availability of advanced biomarkers and imaging make it especially important to establish which simple, routinely captured variables carry the greatest prognostic weight. Robust local evidence can inform discharge planning, the allocation of scarce monitoring and rehabilitation resources, and the intensity of secondary-prevention efforts directed at those at greatest risk.

Much of the evidence underpinning these predictors derives from large international registries and randomised trial populations that may not fully reflect the case mix, treatment patterns, and follow-up realities of individual hospitals. Contemporary, locally relevant data that confirm which routinely captured variables retain independent prognostic value are therefore valuable for tailoring care at the point of delivery. Accordingly, the present study was undertaken to retrospectively evaluate the demographic, clinical, laboratory, electrocardiographic, echocardiographic, and angiographic characteristics of patients admitted with ACS, and to identify the independent predictors of MACE during 12 months of follow-up.

MATERIALS AND METHODS

This was a single-centre, retrospective, observational cohort study conducted in the department of cardiology of a tertiary-care hospital, and it was reported in accordance with the STROBE statement for observational studies. Consecutive adult patients (aged 18 years or older) admitted with a confirmed diagnosis of ACS over a defined enrolment period were screened for eligibility, and the records of those who met the criteria were reviewed.

The diagnosis of ACS, and its classification as STEMI, NSTEMI, or unstable angina, was made by the attending cardiologists in accordance with the Fourth Universal Definition of Myocardial Infarction and prevailing professional society guidelines.[3,4,5] Patients were included if they had a documented ACS diagnosis and complete baseline records permitting calculation of the variables of interest. Patients were excluded if they had type 2 myocardial infarction secondary to a non-coronary trigger, an ACS occurring as a complication of a non-cardiac procedure, malignancy with a life expectancy of less than 12 months, or insufficient documentation, or if they were lost to follow-up before the first scheduled review.

Data were extracted from admission notes, nursing charts, laboratory and imaging systems, and discharge summaries using a standardised proforma. Recorded variables comprised demographic details; cardiovascular risk factors (hypertension, diabetes mellitus, dyslipidaemia, and smoking status); previous cardiovascular history; clinical presentation, including the Killip class on admission;[15] admission heart rate, systolic blood pressure, and serum creatinine; peak high-sensitivity cardiac troponin; haemoglobin; and the electrocardiographic category. Left-ventricular ejection fraction (LVEF) was measured by transthoracic echocardiography using the modified Simpson biplane method, and coronary anatomy was characterised from invasive angiography, with multivessel disease defined as a significant stenosis (50% or greater luminal diameter) in two or more major epicardial vessels.

Estimated glomerular filtration rate (eGFR) was calculated using the CKD-EPI creatinine equation, and a value below 60 mL/min/1.73m² was taken to indicate renal impairment.[17] Anaemia was defined according to World Health Organization haemoglobin thresholds, and diabetes mellitus was defined by a prior physician diagnosis, the use of glucose-lowering therapy, or qualifying glycaemic indices. The GRACE risk score was computed for each patient from the standard component variables and categorised as low (below 109), intermediate (109 to 140), or high (above 140) risk.[7,10]

The primary outcome was the occurrence of MACE within 12 months of the index admission, defined as a composite of all-cause death, non-fatal myocardial infarction, stroke, unplanned coronary revascularisation, and hospitalisation for heart failure. For patients with more than one event, only the first qualifying event was counted in the composite. Follow-up data were obtained from

outpatient records, repeat-admission records, and structured telephone contact where necessary.

All laboratory values were taken from the first sample obtained after admission, and the peak troponin was the highest value recorded during the index hospitalisation. Where a variable was missing for an individual patient, that patient was excluded from the analyses involving the affected variable rather than having values imputed. The sample comprised all eligible patients presenting during the study window, and no formal a priori sample-size calculation was performed, because the analysis was exploratory and constrained by the number of consecutive admissions. Each component of the composite outcome was verified against source documents, and deaths were classified as cardiac or non-cardiac where the cause could be established; for the primary analysis the composite used all-cause mortality to avoid misclassification.

Statistical analysis was performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation or as median with interquartile range according to their distribution, and categorical variables as frequencies and percentages. Patients who developed MACE were compared with those who did not, using the Student t test or the Mann-Whitney U test for continuous data and the chi-square or Fisher exact test for categorical data. Variables associated with MACE on univariable logistic regression at a threshold of *P* below 0.10, together with established prognostic factors, were entered into a multivariable logistic regression model to identify independent predictors, expressed as odds ratios (OR) with 95% confidence intervals (CI). Time-to-event data were displayed with Kaplan-Meier curves stratified by GRACE category and compared with the log-rank test, and the discriminatory performance of the GRACE score was assessed using the area under the receiver-operating-characteristic (ROC) curve. A two-sided *P* value below 0.05 was considered statistically significant.

RESULTS

A total of 412 patients with ACS were included. The mean age of the cohort was 59.8 ± 11.2 years, and 298 patients (72.3%) were men. STEMI was the presenting syndrome in 200 patients (48.5%), with NSTEMI and unstable angina accounting for the remainder. Diabetes mellitus was present in 164 patients (39.8%) and hypertension in 258 (62.6%). During the 12-month follow-up, MACE occurred in 98 patients, corresponding to a cumulative incidence of 23.8%.

The composition of the first MACE is shown in [Figure 1]. All-cause death was the most frequent component (31 events, 31.6% of MACE), followed by non-fatal myocardial infarction (24 events), heart-failure hospitalisation (18 events), unplanned revascularisation (16 events), and stroke (nine events).

Most events clustered in the first half of the follow-up period, with the majority of deaths and recurrent infarctions occurring within the first six months, consistent with the well-recognised early hazard after an index ACS. When stratified by presentation, the crude incidence of MACE was numerically higher among patients presenting with STEMI than among those with NSTEMI or unstable angina, although the multivariable analysis indicated that, this difference was largely explained by differences in age, left-ventricular function, and haemodynamic status at presentation rather than by the electrocardiographic category itself.

Baseline characteristics stratified by MACE status are summarised in [Table 1]. Compared with event-free patients, those who developed MACE were significantly older and had a higher prevalence of diabetes mellitus, previous myocardial infarction, STEMI presentation, Killip class greater than one, LVEF below 40%, eGFR below 60 mL/min/1.73m², anaemia, and multivessel disease, as well as a higher mean GRACE score (all $P \leq 0.016$). Sex, hypertension, dyslipidaemia, and smoking status did not differ significantly between the groups.

On univariable logistic regression [Table 2], advancing age, diabetes mellitus, previous myocardial infarction, STEMI presentation, Killip class greater than one, LVEF below 40%, eGFR below 60 mL/min/1.73m², anaemia, multivessel disease, and a GRACE score above 140 were each significantly associated with MACE. The strongest univariable associations were observed for a GRACE score above 140 (OR 3.92, 95% CI 2.40 to 6.40), LVEF below 40% (OR 3.59, 95% CI 2.22 to 5.81), and Killip class greater than one (OR 3.49, 95% CI 2.10 to 5.80).

In the multivariable model [Table 3 and Figure 3], seven variables retained independent prognostic significance: advancing age (adjusted OR 1.38 per 10-year increase), diabetes mellitus (1.92), Killip class greater than one (2.14), LVEF below 40% (2.46), eGFR below 60 mL/min/1.73m² (1.89), a GRACE score above 140 (2.27), and multivessel disease (1.71, borderline). Previous myocardial infarction, STEMI presentation, and anaemia were no longer independently associated with MACE after adjustment, suggesting that their univariable effects were largely mediated by the other covariates.

Kaplan-Meier analysis demonstrated a clear gradient of MACE-free survival across the three GRACE risk strata. [Figure 2] At 12 months, MACE-free survival was approximately 92% in the low-risk group, 78% in the intermediate-risk group, and 58% in the high-risk group, with a highly significant difference between strata (log-rank P = 0.0005).

Taken together, the regression models indicate that a parsimonious combination of age, a marker of acute haemodynamic compromise (Killip class), a measure of chronic cardiac reserve (LVEF), a

measure of renal function (eGFR), the presence of diabetes, and an integrated risk estimate (GRACE) captured most of the prognostic information available at the bedside. The progressive separation of the Kaplan-Meier curves and the moderate-to-good area under the ROC curve reinforce that these readily available variables, rather than any single laboratory marker, drive medium-term risk in this population.

The GRACE score showed good discrimination for 12-month MACE, with an area under the ROC curve of 0.78 [Figure 4], supporting its continued use as a practical summary measure of baseline risk in this population.

The data underlying [Figures 1, 2, and 4], together with all odds ratios, are reported in full within the text and in [Tables 1 to 3].

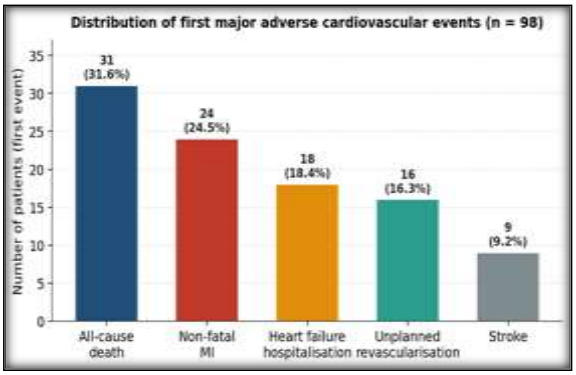

Figure 1: Distribution of the first major adverse cardiovascular event among the 98 patients reaching the composite endpoint (death 31; myocardial infarction 24; heart failure 18; revascularisation 16; stroke 9)

Table 1: Baseline characteristics according to MACE status

Variable	MACE (n=98)	No MACE (n=314)	P value
Age, years (mean ± SD)	64.8 ± 11.2	58.3 ± 10.6	0.0003
Male sex	70 (71.4)	228 (72.6)	0.810
Diabetes mellitus	54 (55.1)	110 (35.0)	0.0006
Hypertension	68 (69.4)	190 (60.5)	0.110
Dyslipidaemia	45 (45.9)	132 (42.0)	0.500
Current smoker	42 (42.9)	138 (43.9)	0.850
Previous myocardial infarction	26 (26.5)	42 (13.4)	0.003
STEMI presentation	58 (59.2)	142 (45.2)	0.016
Killip class greater than one	39 (39.8)	50 (15.9)	0.0002
LVEF below 40%	44 (44.9)	58 (18.5)	0.0001
eGFR below 60 mL/min/1.73m²	41 (41.8)	62 (19.7)	0.0004
Anaemia (WHO criteria)	33 (33.7)	58 (18.5)	0.002
Multivessel disease	63 (64.3)	128 (40.8)	0.0007
GRACE score (mean ± SD)	148 ± 32	118 ± 28	0.0001

Values are n (%) unless otherwise stated. SD, standard deviation; STEMI, ST-elevation myocardial infarction; LVEF, left-ventricular ejection fraction; eGFR, estimated glomerular filtration rate; GRACE, Global Registry of Acute Coronary Events; WHO, World Health Organization.

Table 2: Univariable predictors of 12-month MACE

Variable	Unadjusted OR (95% CI)	P value
Age (per 10-year increase)	1.62 (1.32–1.98)	0.0002
Diabetes mellitus	2.28 (1.43–3.63)	0.0005
Previous myocardial infarction	2.33 (1.35–4.03)	0.002
STEMI presentation	1.76 (1.10–2.81)	0.018
Killip class greater than one	3.49 (2.10–5.80)	0.0001
LVEF below 40%	3.59 (2.22–5.81)	0.0001
eGFR below 60 mL/min/1.73m²	2.93 (1.79–4.79)	0.0002
Anaemia	2.24 (1.35–3.71)	0.002
Multivessel disease	2.61 (1.62–4.20)	0.0004
GRACE score above 140	3.92 (2.40–6.40)	0.0001

OR, odds ratio; CI, confidence interval. Abbreviations as in [Table 1].

Table 3: Independent predictors of MACE on multivariable logistic regression

Variable	Adjusted OR (95% CI)	P value
Age (per 10-year increase)	1.38 (1.09–1.75)	0.008
Diabetes mellitus	1.92 (1.10–3.35)	0.022
Killip class greater than one	2.14 (1.18–3.88)	0.012
LVEF below 40%	2.46 (1.40–4.32)	0.002
eGFR below 60 mL/min/1.73m²	1.89 (1.06–3.37)	0.031
GRACE score above 140	2.27 (1.28–4.02)	0.005
Multivessel disease	1.71 (1.00–2.93)	0.050

Model adjusted for all listed variables. OR, odds ratio; CI, confidence interval. Abbreviations as in [Table 1].

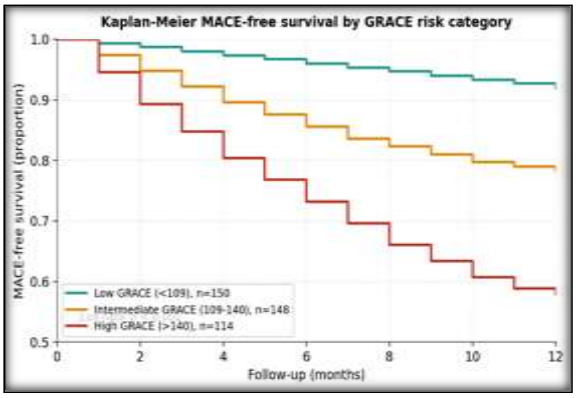

Figure 2: Kaplan-Meier estimates of MACE-free survival stratified by GRACE risk category (low, intermediate, high); log-rank P = 0.0005.

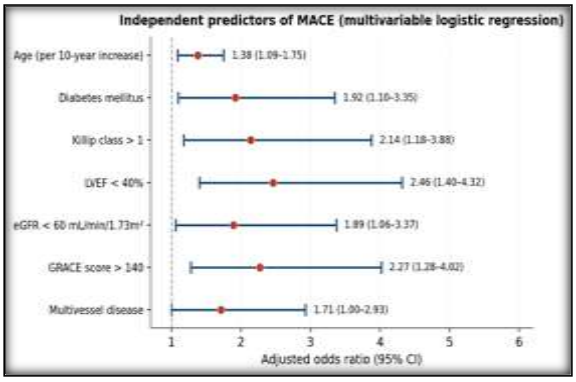

Figure 3: Forest plot of adjusted odds ratios for the independent predictors of MACE from the multivariable logistic regression model

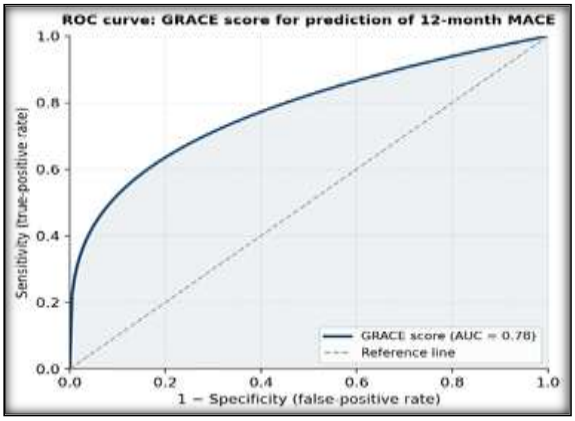

Figure 4: Receiver-operating-characteristic curve of the GRACE score for prediction of 12-month MACE (area under the curve 0.78)

DISCUSSION

In this retrospective cohort of 412 patients with ACS, nearly one in four experienced a major adverse cardiovascular event within 12 months, and a compact set of routinely available variables — advancing age, diabetes mellitus, Killip class greater than one, reduced LVEF, renal impairment, and a high GRACE score — independently predicted that outcome. These findings are concordant with the broad body of evidence from large registries and trials, and they reinforce the value of integrating simple bedside information into prognostic assessment.[7,10,12]

Age emerged as a robust independent predictor, with each additional decade increasing the adjusted odds of MACE by approximately 38%. This is consistent with registry analyses showing that older patients with ACS carry a disproportionate burden of adverse outcomes, attributable both to greater comorbidity and to the more conservative, less invasive management they often receive.[11,13] Age is also one of the most heavily weighted components of the GRACE score, which partly explains the strong performance of that instrument in the present cohort.[7,10]

Diabetes mellitus remained independently associated with MACE after adjustment, in keeping with pooled analyses demonstrating that diabetic patients with ACS experience substantially higher mortality and reinfarction rates than their non-diabetic counterparts across the entire syndrome spectrum.[18,19] The adverse prognosis reflects accelerated and diffuse atherosclerosis, endothelial dysfunction, a prothrombotic milieu, and a higher prevalence of silent ischaemia and heart failure, and it underscores the importance of meticulous glycaemic and vascular risk-factor control as part of secondary prevention.[31]

The independent prognostic effect of Killip class greater than one echoes the enduring value of this simple bedside classification, first described almost six decades ago and repeatedly validated in the contemporary era.[15,16,20] Clinical evidence of heart failure at presentation signals a larger ischaemic insult and greater haemodynamic compromise, and its prognostic power persists even within modern, predominantly invasively managed populations.[20] The related finding that an LVEF below 40% more than doubled the adjusted odds of MACE is similarly well supported, since left-ventricular systolic function is among the most powerful determinants of survival after myocardial infarction.[21,22]

Renal impairment, defined here as an eGFR below 60 mL/min/1.73m², was likewise an independent predictor. Reduced renal function is consistently linked to worse cardiovascular outcomes after myocardial infarction, with a graded relationship between the severity of dysfunction and the risk of death and recurrent ischaemic events.[23,24] The mechanisms are multifactorial and include a greater atherosclerotic burden, chronic inflammation, anaemia, fluid overload, and a tendency for these patients to be undertreated with evidence-based therapies and revascularisation.

Multivessel disease retained borderline independent significance, mirroring evidence that the extent of coronary disease beyond the culprit lesion influences prognosis and that complete revascularisation can improve outcomes in selected patients with myocardial infarction.[26,32] Anaemia and previous myocardial infarction, although

significant on univariable analysis, lost independence after adjustment; this attenuation is plausible because their effects overlap substantially with age, renal function, and overall disease burden, and because anaemia frequently coexists with chronic kidney disease.[27]

A central observation of this study is the strong discriminatory performance of the GRACE score, with an area under the ROC curve of 0.78 and a clear stepwise separation of MACE-free survival across risk strata. This aligns with the original derivation and validation work and with more than a decade of subsequent registry experience confirming GRACE as one of the best-calibrated and most generalisable risk tools available.[7,8,10,25] Its strength lies in combining several of the individually significant predictors — age, heart rate, blood pressure, renal function, and Killip class — into a single continuous estimate, which supports its incorporation into routine practice as recommended by current guidelines.[4]

From a clinical perspective, these results endorse a pragmatic, layered approach to risk stratification in which a small number of variables captured for every ACS admission can identify patients who warrant closer surveillance, earlier and more complete revascularisation, and more intensive secondary prevention. Biomarker-based strategies incorporating natriuretic peptides and markers of inflammation can refine this assessment further, but the predictors identified here have the practical advantage of being universally and inexpensively available.[28,29,30]

The clustering of events early after the index admission underscores that the first months after ACS represent a vulnerable period during which guideline-directed medical therapy, complete revascularisation where appropriate, and structured cardiac rehabilitation exert their greatest absolute benefit.[4,6] Suboptimal adherence to secondary-prevention medications and incomplete revascularisation are recognised contributors to recurrent events, and they are potentially modifiable targets in precisely the high-risk subgroups identified here. Embedding a brief, structured risk assessment into the discharge process could therefore help to translate the present associations into actionable care.

The incidence of MACE observed in this cohort, at just under one quarter of patients over 12 months, is broadly comparable with that reported from other hospital-based ACS cohorts, although direct comparison is complicated by differences in the definition of the composite endpoint, the duration of follow-up, the proportion of patients undergoing early invasive management, and the underlying risk-factor profile of the population.[13,14] The consistency of the individual predictors with those derived from much larger international registries, despite these differences, lends external credibility to the findings and suggests that the core determinants of post-ACS risk are robust across diverse settings.

Although male patients predominated in the cohort, as is typical for ACS, sex was not associated with MACE, a finding consistent with evidence that, once differences in age and comorbidity are accounted for, sex by itself is a weak independent determinant of medium-term outcome. By contrast, the strong effect of age, together with the tendency for older and frailer patients to receive less invasive treatment, highlights the importance of avoiding unjustified therapeutic nihilism in elderly patients, who may derive substantial absolute benefit from evidence-based therapies and selective revascularisation.[11]

A particular strength of this analysis is its reliance on variables that are documented for virtually every patient with ACS, which makes the resulting risk framework readily transferable to centres without access to specialised biomarkers or advanced imaging. Future work could examine whether the addition of natriuretic peptides, high-sensitivity C-reactive protein, or measures of infarct size and microvascular obstruction improves discrimination beyond that achieved by the GRACE score and the simple clinical variables described here, and whether a locally recalibrated model performs better than the original international score.[28,29]

Several limitations should be acknowledged. The retrospective, single-centre design introduces the possibility of selection and information bias and limits generalisability to other settings and case mixes. Residual confounding from unmeasured variables cannot be excluded, and some potentially informative biomarkers were not uniformly available. The composite MACE endpoint, although clinically useful, combines outcomes of differing severity, and the modest number of events constrains the precision of the multivariable estimates, as reflected in the borderline confidence interval for multivessel disease. Finally, the 12-month horizon does not capture longer-term risk. Prospective, multicentre studies with larger samples, longer follow-up, and the incorporation of circulating biomarkers and imaging indices would help to validate and extend these findings.

CONCLUSION

In patients presenting with acute coronary syndrome, major adverse cardiovascular events remained common over 12 months despite contemporary management. Advancing age, diabetes mellitus, Killip class greater than one, a left-ventricular ejection fraction below 40%, an estimated glomerular filtration rate below 60 mL/min/1.73m², and a high GRACE score were independent predictors of these events, and the GRACE score provided good overall discrimination. Because all of these variables are routinely recorded at the time of admission, they can be combined into

a simple, resource-efficient framework to identify high-risk patients who stand to benefit most from intensified monitoring, timely revascularisation, and aggressive secondary prevention. Larger prospective studies are warranted to confirm these associations and to refine risk prediction further.

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