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Admission Immature Platelet Fraction Is Associated with Acute Coronary Syndrome Category but Not with Angiographic Disease Extent: A Cross-Sectional Study

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ABSTRACT: Immature platelet fraction (IPF), a marker of platelet turnover, may reflect thrombotic activity in acute coronary syndrome (ACS). This study evaluated the association of admission IPF with ACS clinical severity and angiographic coronary artery disease burden. In this cross-sectional study, 117 consecutive adults hospitalized with ACS at a tertiary referral hospital in Indonesia were enrolled. IPF was measured on admission before coronary angiography. Angiographic vessel count was available in 98 patients. Associations between IPF and ACS categories or angiographic findings were evaluated using nonparametric tests and proportional-odds ordinal logistic regression adjusted for prespecified clinical covariates. Median IPF increased progressively across ACS categories, from 5.30% in unstable angina pectoris to 6.20% in non–ST-elevation myocardial infarction and 8.60% in ST-elevation myocardial infarction (P = .002; Jonckheere–Terpstra P < .001). After adjustment, each 1% increase in IPF was independently associated with a higher ACS category (odds ratio, 1.14; 95% confidence interval, 1.05–1.25; P = .004). In contrast, IPF was not associated with the number of diseased coronary vessels (P = .44; adjusted odds ratio, 0.99; 95% confidence interval, 0.91–1.08; P = .82), multivessel disease, high-risk coronary anatomy, or left-main stenosis.Admission IPF was independently associated with the clinical severity of ACS but not with the angiographic extent of coronary artery disease, suggesting that IPF reflects the acute thrombotic presentation rather than the underlying anatomical burden of atherosclerosis.

1. INTRODUCTION

Coronary heart disease remains a leading cause of death and disability worldwide, and acute coronary syndrome (ACS) is among its most urgent manifestations.[1,2] ACS comprises unstable angina pectoris (UAP), non–ST-elevation myocardial infarction (NSTEMI), and ST-elevation myocardial infarction (STEMI), which differ in electrocardiographic presentation and evidence

of myocardial injury.[1] Risk scores such as GRACE reflect clinical presentation, haemodynamic status, and myocardial injury rather than platelet turnover.[3]

Platelets are central to thrombus formation after plaque disruption, and increased platelet consumption stimulates release of younger, RNA-containing platelets from the bone marrow. These immature or reticulated platelets are larger, metabolically more active, and more reactive than mature platelets, with increased thromboxane production and glycoprotein IIb/IIIa expression.[4-6] The immature platelet fraction (IPF) quantifies this population on automated hematology analysers using the same sample as a routine full blood count.[7]

Higher IPF has been reported in ACS than in stable coronary disease or healthy populations, with values tending to rise from UAP to NSTEMI to STEMI,[8-11] and a meta-analysis found higher IPF across ACS categories despite heterogeneity between studies.[12] Immature platelet indices have also been associated with cardiovascular mortality and major adverse cardiovascular events.[13-15]

Evidence on coronary anatomy is limited and comes from separate angiographic cohorts. In 1,789 patients undergoing angiography, IPF was associated with neither the presence nor the extent of coronary artery disease, although it was associated with low TIMI flow and bifurcation lesions.[16] Active smoking has been associated with higher IPF without a corresponding anatomical association,[17] and smaller studies in NSTEMI report similar null findings.[18] No study has evaluated both relationships within the same ACS cohort.

We therefore investigated admission IPF in a consecutive ACS cohort. The primary objective was to determine whether IPF was associated with the ordered categories UAP, NSTEMI, and STEMI after adjustment for prespecified covariates. The secondary objective was whether IPF was associated with the angiographic number of diseased vessels in the same patients.

2. MATERIALS AND METHODS

2.1 Study design and setting

This cross-sectional study was conducted at Dr. Wahidin Sudirohusodo General Hospital, Makassar, Indonesia, between March and June 2026. Admission IPF was related to two outcomes in the same cohort: the clinical category of ACS at presentation and the angiographic extent of obstructive coronary disease.

2.2 Participants

Adults aged 18 years or older admitted with UAP, NSTEMI, or STEMI were screened consecutively. ACS was diagnosed by the attending physician from clinical presentation, electrocardiography, and cardiac biomarkers. Eligible patients underwent admission blood sampling including IPF and gave written informed consent. Patients were excluded for hemoglobin <10 g/dL, platelet count $<120 \times 10^3/\mu L$, or any condition or treatment known to alter thrombopoiesis or platelet indices, including chronic hematological disease, recent transfusion, previous ACS, prior bypass grafting, post-cardiac-arrest status, malignancy, pregnancy, corticosteroid or cytotoxic therapy, and acute infection. Clinical analyses included all patients with valid clinical data. The primary angiographic analysis was restricted to patients with an exact vessel-count classification; those with an indeterminate count contributed to binary sensitivity analyses where ascertainable.

2.3 Clinical variables and outcome definitions

The primary clinical outcome was ACS category, ordered as UAP, NSTEMI, and STEMI. This ordering was specified to represent increasing acute myocardial injury at presentation and was not intended to represent long-term prognosis. Age, sex, ever-smoking status, hypertension, diabetes mellitus, dyslipidemia, obesity, family history of coronary heart disease, symptom-to-admission time, and GRACE score were recorded at admission from clinical assessment and medical records. Risk factors were defined by documented diagnosis, current treatment, or standard laboratory and clinical thresholds, given in Methods S1. The GRACE score was calculated from admission data and analyzed as a continuous variable. Symptom-to-admission time was recorded in hours from the reported time of symptom onset.

2.4 Angiographic assessment

Coronary angiography was performed and interpreted by the attending interventional cardiologist, who did not have access to the IPF result at the time of the procedure. The primary angiographic outcome was the number of major epicardial vessels, left

anterior descending, left circumflex, and right coronary arteries, with stenosis ≥70%, giving a count of 0 to 3. Left-main stenosis was recorded separately. Four alternative definitions were examined in sensitivity analyses: multivessel disease, high-risk anatomy, left-main stenosis ≥50%, and the summary classification documented in the catheterization report. Definitions are given in the footnote to Table S3. Where the report classification differed from per-vessel grading, the per-vessel classification was used for the primary analysis and the report-based classification as a sensitivity analysis.

2.5 Laboratory measurements

Approximately 2 mL of venous blood was collected into an EDTA tube at admission, before angiography and, when feasible, before antiplatelet loading. Treatment was not delayed for research sampling. IPF was measured on the fluorescent platelet channel of a Sysmex XN-3000 analyser, which also provided platelet count, mean platelet volume, and hemoglobin from the same sample (laboratory reference interval for IPF 1.2–8.9%). The absolute immature platelet count (IPF#) was calculated as IPF% multiplied by platelet count and divided by 100, expressed as $\times 10^3/\mu L$ (reference interval 3.1–18.7 $\times 10^3/\mu L$). Troponin I results at the assay floor or ceiling were flagged, and relevant sensitivity analyses were repeated after excluding them.

2.6 Statistical analysis

Statistical analyses were performed using R version 4.5.3 (R Foundation for Statistical Computing, Vienna, Austria). All tests were two-sided, with $P < .05$ considered statistically significant, and complete-case analysis was applied. Continuous variables were summarized as mean ± standard deviation or median (interquartile range), and categorical variables as frequency and percentage. Group comparisons used the Mann–Whitney U, Kruskal–Wallis, chi-square, or Fisher exact test, with Holm-adjusted Dunn and Jonckheere–Terpstra tests where appropriate. Effect sizes were reported as epsilon-squared, Cramér's V, odds ratios (ORs) with 95% confidence intervals (CIs), or Spearman's correlation coefficient (ϱ).

The association between IPF and ACS category was evaluated using proportional-odds ordinal logistic regression adjusted for age, sex, symptom-to-admission time, smoking status, diabetes mellitus, and hypertension. The association between IPF and angiographic vessel count was assessed using ordinal logistic regression after grouping vessel count as 0–1, 2, and 3 vessels because of sparse observations in the zero-vessel category. Secondary analyses examined the correlation between IPF and GRACE score. Sensitivity analyses included replacement of IPF% with IPF#, additional adjustment for platelet count, mean platelet volume, and hemoglobin, exclusion of troponin I values at assay limits, application of alternative angiographic classifications, and comparison of patients who did and did not undergo angiography (Tables S2–S4). Model assumptions were evaluated using the Brant test, variance inflation factors, and diagnostic assessments of linearity, sparse cells, and influential observations (Table S5).

3. RESULTS AND DISCUSSION

3.1 Participant characteristics

A total of 117 patients with ACS were included in the clinical analysis. Angiography was performed in 102, of whom 98 had an exact vessel-count classification and formed the primary angiographic analysis set. The mean age was 58.2 ± 11.7 years and 89 patients (76.1%) were men. The presenting syndrome was UAP in 29 patients (24.8%), NSTEMI in 37 (31.6%), and STEMI in 51 (43.6%). Median symptom-to-admission time was 6.0 hours (IQR 3.0–13.0), median GRACE score 116 (IQR 84–128), and median admission IPF 7.00% (IQR 4.10–10.10). Participant characteristics are presented in Table 1.

3.2 Association between IPF and ACS clinical presentation

Admission IPF increased across the ordered ACS categories, from a median of 5.30% (IQR 3.20–7.70) in UAP to 6.20% (IQR 3.90–9.10) in NSTEMI and 8.60% (IQR 5.60–11.65) in STEMI (Kruskal–Wallis $H = 12.215$, $\varepsilon^2 = 0.105$, $P = .002$), and the prespecified Jonckheere–Terpstra test supported a monotonic increase ($P < .001$). Distributions are shown in Figure 1A and unadjusted analyses in Table 2, Panel A.

In Holm-adjusted pairwise comparisons, IPF was higher in STEMI than in UAP ($P = .002$); the STEMI-versus-NSTEMI ($P = .09$) and NSTEMI-versus-UAP ($P = .15$) comparisons were not significant.

After adjustment for age, sex, symptom-to-admission time, smoking, diabetes mellitus, and hypertension, each 1-percentage-point increase in IPF was associated with higher odds of a higher ACS category (adjusted OR 1.142, 95% CI 1.045–1.248, $P = .004$). Only longer symptom-to-admission time was also associated with a higher category (OR 1.050 per hour, 95% CI 1.018–

1.083, P = .002). There was no evidence against proportional odds (Brant omnibus P = .10). Adjusted results are presented in Table 2, Panel B.

The association was supported by the secondary and sensitivity analyses. IPF correlated with the GRACE score ($\varrho = 0.317$, P < .001) and remained associated with ACS category when platelet count, mean platelet volume, and hemoglobin were added jointly (OR 1.167, 95% CI 1.052–1.295, P = .003). IPF# showed a similar but weaker gradient ($\varepsilon^2 = 0.056$, P = .04) and remained associated in the adjusted model (OR 1.055 per $1 \times 10^3/\mu L$, 95% CI 1.017–1.094, P = .005). Excluding troponin I values at the assay limits, the difference across ACS categories persisted (P = .05; n = 83). Details are given in Table S2.

Table 1. Participant characteristics (n = 117).

Characteristic	All patients
Demographics	
Age, years	58.2 ± 11.7
Male sex	89 (76.1%)
ACS presentation	
ACS subtype	
UAP	29 (24.8%)
NSTEMI	37 (31.6%)
STEMI	51 (43.6%)
Symptom-to-admission time, h	6.0 (3.0-13.0)
GRACE score	116 (84-128)
Cardiovascular risk factors	
Smoking	82 (70.1%)
Hypertension	81 (69.2%)
Dyslipidaemia	71 (60.7%)
Diabetes mellitus	50 (42.7%)
Obesity	16 (13.7%)
Family history of CHD	9 (7.7%)
Laboratory	
IPF, %	7.00 (4.10-10.10)
Platelet count, $\times 10^3/\mu L$	233.0 (187.0-284.0)
MPV, fL	9.40 (8.60-10.30)
Haemoglobin, g/dL	13.58 ± 2.05
Troponin I, ng/mL	2.30 (0.04-28.39)

Values are mean +/- SD (age, haemoglobin) or median (IQR) for continuous variables and n (%) for categorical variables. All variables were complete. Troponin I was censored at the assay floor and ceiling and analysed non-parametrically. IPF, immature platelet fraction; MPV, mean platelet volume; ACS, acute coronary syndrome; CHD, coronary heart disease.

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3.3 Association between IPF and angiographic disease extent

Among the 98 patients with an exact vessel-count classification, IPF did not differ by the number of diseased vessels: 5.10% (IQR 2.95–8.15) for 0 vessels, 8.40% (IQR 5.50–11.33) for 1, 6.20% (IQR 4.22–8.90) for 2, and 6.95% (IQR 3.98–10.20) for 3 (Kruskal–Wallis H = 2.709, ε^2 = 0.028, P = .44). Distributions are shown in Figure 1B and unadjusted analyses in Table 3, Panel A.

After grouping vessel count as 0–1, 2, and 3 and adjusting for age, sex, smoking, diabetes mellitus, and hypertension, IPF was not associated with a higher vessel-count category (adjusted OR 0.990 per 1-percentage-point increase, 95% CI 0.912–1.076, P = .82). Older age (OR 1.052 per year, 95% CI 1.012–1.093, P = .01) and smoking (OR 4.480, 95% CI 1.459–13.752, P = .009) were associated with a higher category. There was no evidence against proportional odds (Brant omnibus P = .28). Adjusted results are presented in Table 3, Panel B.

Null findings were also obtained for multivessel disease (P = .27), high-risk anatomy (P = .71), left-main stenosis (P = .32), the catheterization-report classification (P = .73), and IPF# (P = .70); these analyses are given in Table S3.

Admission IPF was similar in patients who did and did not undergo angiography (median 7.10% versus 6.95%, P = .79). Non-catheterised patients were older, had lower hemoglobin, and included fewer men, but with only 15 such patients these comparisons were treated as descriptive (Table S4).

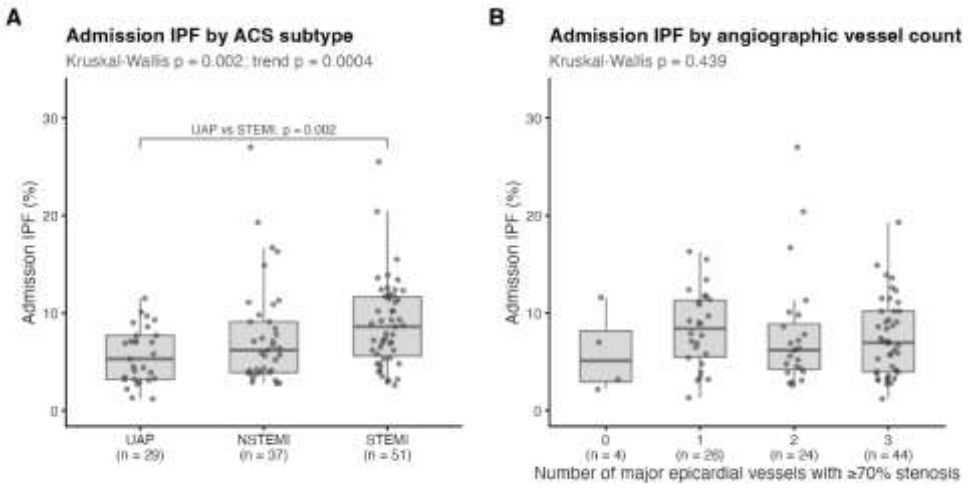

Figure 1. Admission immature platelet fraction (IPF) by clinical and angiographic category. **(A)** IPF by ACS subtype (n = 117); the bracket marks the only pairwise comparison significant after Holm adjustment. **(B)** IPF by the number of major epicardial vessels with stenosis ≥70% (n = 98). Boxes show the median and interquartile range, whiskers extend to 1.5 × IQR, and individual patients are overlaid as jittered points. The two panels share a common y-axis so that they are directly comparable. NSTEMI, non–ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction; UAP, unstable angina pectoris.

Table 2. Admission IPF and ACS subtype (n = 117).

Analysis	Estimate	N	P value
Panel A. IPF by ACS subtype			
UAP	5.30 (3.20-7.70)	29	
NSTEMI	6.20 (3.90-9.10)	37	
STEMI	8.60 (5.60-11.65)	51	
Kruskal-Wallis (omnibus)	H = 12.215, ε^2 = 0.105	117	0.002

Jonckheere-Terpstra (trend)	Monotonic increase UAP < NSTEMI < STEMI	117	0.0004
UAP vs NSTEMI (Dunn, Holm)	Z = 1.455	66	0.146
UAP vs STEMI (Dunn, Holm)	Z = 3.417	80	0.002
NSTEMI vs STEMI (Dunn, Holm)	Z = 2.009	88	0.089
Panel B. Ordinal model: ACS subtype ~ IPF + age + male sex + symptom-to-admission time + smoking + diabetes + hypertension			
IPF	OR 1.142 (1.045-1.248)	117	0.004
Age	OR 1.012 (0.980-1.046)	117	0.462
Male sex	OR 2.265 (0.820-6.253)	117	0.115
Symptom-to-admission time	OR 1.050 (1.018-1.083)	117	0.002
Smoking	OR 0.987 (0.372-2.617)	117	0.979
Diabetes mellitus	OR 1.132 (0.541-2.367)	117	0.743
Hypertension	OR 0.690 (0.305-1.558)	117	0.372

Panel A: median (IQR) of IPF by subtype; Kruskal-Wallis omnibus test with ε^2 effect size; Jonckheere-Terpstra test for a monotonic trend (permutation p-value, the exact distribution being unavailable with ties); Dunn post-hoc comparisons with Holm adjustment. Panel B: proportional-odds ordinal logistic regression; the IPF odds ratio is per 1-percentage-point increase in IPF. Proportional-odds assumption (Brant omnibus): $\chi^2 = 12.15$, df = 7, p = 0.096. Full diagnostics are in Supplementary Table S5. OR, odds ratio; CI, confidence interval; IPF, immature platelet fraction.

Table 3. Admission IPF and the number of diseased coronary vessels (n = 98).

Analysis	**Estimate**	**n**	**p**
Panel A. IPF by number of diseased vessels			
0-vessel disease	5.10 (2.95-8.15)	4	
1-vessel disease	8.40 (5.50-11.33)	26	
2-vessel disease	6.20 (4.22-8.90)	24	
3-vessel disease	6.95 (3.98-10.20)	44	
Kruskal-Wallis (omnibus)	H = 2.709, $\varepsilon^2 = 0.028$	98	0.439
Panel B. Ordinal model (vessel count 0-1 / 2 / 3): IPF + age + male sex + smoking + diabetes + hypertension			
IPF	OR 0.990 (0.912-1.076)	98	0.820
Age	OR 1.052 (1.012-1.093)	98	0.011
Male sex	OR 1.016 (0.316-3.262)	98	0.979
Smoking	OR 4.480 (1.459-13.752)	98	0.009
Diabetes mellitus	OR 2.098 (0.921-4.779)	98	0.078

Analysis	Estimate	n	p
Hypertension	OR 1.129 (0.483-2.637)	98	0.779

Panel A: median (IQR) of IPF by number of major epicardial vessels with at least 70% stenosis; Kruskal-Wallis omnibus test with ε^2 effect size. Panel B: proportional-odds ordinal logistic regression. The zero- and one-vessel categories were combined (0-1 / 2 / 3) because the zero-vessel group contained only four patients, which produced sparse outcome-by-predictor cells in the four-category model. The IPF odds ratio is per 1-percentage-point increase in IPF. Proportional-odds assumption (Brant omnibus): $\chi^2 = 7.43$, df = 6, p = 0.283. Full diagnostics are in Supplementary Table S5. Alternative angiographic outcome definitions are given in Supplementary Table S3. OR, odds ratio; CI, confidence interval; IPF, immature platelet fraction.

3.4 Discussion

In this ACS cohort, admission IPF increased across the ordered categories UAP, NSTEMI, and STEMI and remained associated with ACS category after adjustment, but was not associated with angiographic vessel count or with alternative definitions of obstructive disease extent. Evaluating both relationships in the same cohort suggests IPF is more closely associated with the acute clinical presentation than with the extent of obstructive anatomy. Because this contrast emerged during analysis rather than as the primary hypothesis, it is exploratory.

The progressive increase in IPF across UAP, NSTEMI, and STEMI is consistent with previous studies in different populations and analysers,[1,8-11] and with a meta-analysis reporting higher IPF across the ACS spectrum despite heterogeneity in distinguishing individual subtypes.[12] The overall comparison, ordered-trend test, and STEMI-versus-UAP comparison were significant, whereas adjacent comparisons were not after adjustment for multiple testing. These should not be read as equivalence; the principal inference rests on the overall difference and the prespecified trend. The association was not materially altered by joint adjustment for platelet count, mean platelet volume, and hemoglobin, persisted in weaker form for the absolute immature platelet count, and remained after excluding troponin I values at the assay limits. These analyses support its stability but cannot eliminate residual confounding or measurement bias.

IPF also correlated with the GRACE score. This is compatible with an association with acute clinical severity but is not independent validation of the subtype result, because GRACE and ACS subtype share information on electrocardiographic abnormality and myocardial injury, and troponin is central to distinguishing infarction from unstable angina.[19] The weaker association for IPF# may reflect variability introduced by platelet count, which was largely unrelated to ACS subtype here. Because the two indices are expressed on different scales their odds ratios are not directly comparable, but the association was not confined to one representation of the immature platelet compartment.

Admission IPF was associated with neither the number of diseased vessels nor alternative classifications based on multivessel disease, high-risk anatomy, left-main stenosis, or the catheterization-report summary, and the null pattern persisted for IPF#.

These findings agree with the angiographic study by Verdoia et al,[16] in which IPF was associated with neither the presence nor the extent of coronary artery disease, and with similar null findings in NSTEMI.[18] Nardin et al[17] likewise found higher IPF with active smoking but no anatomical association. Age and smoking were associated with a higher vessel-count category, which is plausible given their contribution to cumulative atherosclerotic risk, but does not validate the null IPF result. Interpretation should rest on the estimated association, its confidence interval, and consistency across the alternative definitions.

The anatomical conclusion is limited to the measure used. Vessel count based on a luminal stenosis threshold does not quantify plaque burden, composition, calcium, or vulnerability. In the PROSPECT study, lesions associated with subsequent events were often only mildly stenotic yet showed high-risk features on intravascular imaging.[20] These findings therefore do not establish that IPF is unrelated to coronary atherosclerosis in general, only that it was not associated with the number of vessels meeting the prespecified obstruction threshold.

One interpretation is that vessel count mainly represents chronic obstructive anatomy, whereas immature platelet turnover may track the thrombotic response accompanying an acute event. IPF could then rise with the acuity of the presenting syndrome without rising with the number of chronically obstructed vessels. This cannot be established from cross-sectional data.

External findings are consistent with this. In the cohort reported by Verdoia et al,[16] IPF was unrelated to overall disease extent but was associated with low TIMI flow and bifurcation lesions, which are flow- or lesion-level rather than total-obstruction

measures. Immature platelets have also been shown to be more reactive than mature platelets in STEMI,[21] with differences persisting during follow-up and antiplatelet treatment.[22]

Platelet reactivity, TIMI flow, thrombus burden, culprit-lesion morphology, and plaque characteristics were not measured here, so the external evidence provides context rather than mechanism. A single admission measurement also cannot show whether elevated IPF preceded the event or developed during the acute response. Longitudinal studies report higher platelet-turnover indices during acute STEMI than at follow-up,[22,23] although serial comparisons are influenced by treatment and recovery. The early sampling here, a median of six hours after onset, should be considered when absolute values are compared with studies sampling later.[7]

Longer symptom-to-admission time was also associated with a higher ACS category. This is difficult to interpret because onset was reported retrospectively and may be unclear when symptoms fluctuate or begin during sleep; it should be treated as an adjustment variable. A principal strength is that the clinical and angiographic associations were evaluated in the same cohort from a single admission measurement, with the clinical result tested under additional hematological adjustment, IPF# as an alternative exposure, and exclusion of troponin values at the assay limits. Several limitations apply. The cross-sectional design and single measurement preclude determination of temporal direction. This was a single-center study of 117 patients, 98 with an exact vessel-count classification; the small zero-vessel group required categories to be combined and limited precision.

Fifteen patients did not undergo angiography and differed in selected characteristics; although IPF was similar between groups, selection into the angiographic analysis cannot be excluded. The predominantly male cohort limits generalizability.

Vessel count measured obstructive luminal disease rather than plaque burden or vulnerability, and intracoronary imaging, SYNTAX score, TIMI flow, thrombus burden, and lesion morphology were unavailable. ACS subtype and GRACE score are overlapping measures of presentation severity, and no independent measure of severity or subsequent outcome was available, so the study cannot establish diagnostic thresholds, prognostic value, or treatment-guiding utility. Finally, residual confounding remains possible and IPF measurement is analyser-dependent; systematic differences between Sysmex generations have been reported, with platform-specific reference intervals.[24] Values or thresholds from this cohort should not be transferred to other platforms or populations without local validation.

4. CONCLUSION

Admission IPF increased across the ordered clinical categories UAP, NSTEMI, and STEMI and remained associated with ACS category after adjustment, but was not associated with angiographic vessel count or alternative definitions of obstructive disease extent. IPF may therefore be more closely associated with the acute clinical presentation than with chronic obstructive coronary anatomy. The exploratory cross-sectional design does not establish temporal direction, mechanism, prognostic value, or clinical utility; prospective multicenter studies with serial measurements, standardized assays, lesion-level assessment, and clinical outcomes are required.

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AUTHOR CONTRIBUTIONS

Amy Tryabto: conceptualization, investigation, data curation, formal analysis, writing – original draft. Khalid Saleh: conceptualization, supervision, writing – review and editing. Pendrik Tendean: investigation, resources, writing – review and editing. Arifin Seweng: formal analysis, methodology, validation, writing – review and editing. Syakib Bakri: supervision, writing – review and editing. Tutik Harjianti: methodology, resources, writing – review and editing.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ETHICS STATEMENT

The protocol was approved by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Hasanuddin and Dr. Wahidin Sudirohusodo General Hospital (approval 565/UN4.6.4.5.31/PP36/2026) and complied with the Declaration of Helsinki. Written informed consent was obtained from all participants or their representatives.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request. Individual-level data are not publicly available because of institutional restrictions on the sharing of patient-level clinical information.

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Supplementary

Supplementary Table S1. Participant characteristics by ACS subtype.

Characteristic	UAP (n=29)	NSTEMI (n=37)	STEMI (n=51)
Demographics			
Age, years	55.0 ± 10.5	61.0 ± 10.4	58.1 ± 12.8
Male sex	20 (69.0%)	27 (73.0%)	42 (82.4%)
Presentation			
Symptom-to-admission time, h	5.0 (1.0-8.0)	4.0 (2.0-8.0)	9.0 (4.0-24.0)
GRACE score	68 (55-84)	117 (97-130)	126 (116-132)
Cardiovascular risk factors			
Smoking	18 (62.1%)	27 (73.0%)	37 (72.5%)
Hypertension	23 (79.3%)	24 (64.9%)	34 (66.7%)
Dyslipidaemia	17 (58.6%)	23 (62.2%)	31 (60.8%)
Diabetes mellitus	15 (51.7%)	13 (35.1%)	22 (43.1%)
Obesity	4 (13.8%)	5 (13.5%)	7 (13.7%)
Family history of CHD	3 (10.3%)	1 (2.7%)	5 (9.8%)
Laboratory			
IPF, %	5.30 (3.20-7.70)	6.20 (3.90-9.10)	8.60 (5.60-11.65)
Platelet count, $\times 10^3/\mu L$	254.0 (203.0-297.0)	228.0 (199.0-284.0)	220.0 (185.0-283.5)
MPV, fL	8.90 (8.30-9.90)	9.40 (8.60-10.20)	9.50 (8.90-10.50)
Haemoglobin, g/dL	13.15 ± 1.82	13.23 ± 1.87	14.08 ± 2.21
Troponin I, ng/mL	0.01 (0.01-0.03)	2.56 (0.26-9.33)	34.58 (5.90-60.00)

Values are mean +/- SD (age, haemoglobin) or median (IQR) for continuous variables and n (%) for categorical variables. No significance tests were performed: the subtypes differ by design in severity, so baseline comparisons are descriptive only.

IPF, immature platelet fraction; MPV, mean platelet volume; CHD, coronary heart disease.

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Supplementary Table S2. Secondary and sensitivity analyses.

Analysis	Comparison / outcome	n	Estimate	95% CI	P value
GRACE score	IPF vs GRACE (Spearman)	117	ρ = 0.317		0.0005
IPF# (absolute immature platelet count)	By ACS subtype (UAP/NSTEMI/STEMI)	117	H = 6.469, ε² = 0.056		0.039
IPF# (absolute immature platelet count)	Adjusted ordinal model, ACS subtype	117	OR 1.055	1.017-1.094	0.005
IPF# (absolute immature platelet count)	By vessel count (0/1/2/3)	98	H = 1.403, ε² = 0.014		0.705
Haematological adjustment	ACS ordinal model + platelet count + MPV + haemoglobin (10 predictors)	117	OR 1.167	1.052-1.295	0.003
Symptom onset	IPF, <=6 h	69	6.70 (4.00-9.70)		
Symptom onset	IPF, 6-24 h	32	6.95 (4.10-11.20)		
Symptom onset	IPF, >24 h	16	7.30 (6.80-8.77)		
Symptom onset	IPF across onset bands	117	H = 0.602, ε² = 0.005		0.740
Symptom onset	IPF vs onset (continuous)	117	ρ = 0.057		0.538
Troponin censoring (measurable troponin only)	IPF by ACS subtype	83	H = 6.090, ε² = 0.074		0.048
Troponin censoring (measurable troponin only)	IPF vs troponin I	83	ρ = 0.269		0.014
Troponin censoring (measurable troponin only)	IPF vs GRACE	83	ρ = 0.235		0.032

GRACE is reported as a Spearman rank correlation; no adjusted GRACE regression was fitted, so no age or other GRACE-score component is used as an adjuster. IPF# is the absolute immature platelet count (IPF% x platelet count / 100), treated as an alternative exposure, not as a covariate in the IPF% models. The haematological adjustment adds platelet count, MPV and haemoglobin together in one model, not one at a time. Troponin-censoring rows repeat the analyses after excluding patients whose troponin I fell at the assay floor or ceiling. H, Kruskal-Wallis statistic; OR, odds ratio; CI, confidence interval; MPV, mean platelet

Supplementary Table S3. Admission IPF and alternative angiographic outcome definitions.

Outcome (definition)	n (no / yes)	Test	Statistic	Effect size	IPF median (IQR), no vs yes	P value
Multivessel disease (>=2 diseased vessels)	30 / 72	Mann-Whitney U	W = 1229.5	r = -0.138	7.80 (4.95-11.33) vs 6.55 (4.00-9.43)	0.274
High-risk anatomy (left main >=50% or 3-vessel disease)	50 / 49	Mann-Whitney U	W = 1278.5	r = -0.044	6.95 (4.12-11.05) vs 6.90 (4.00-9.80)	0.711
Left-main stenosis >=50%	83 / 17	Mann-Whitney U	W = 815.0	r = -0.155	7.00 (4.05-11.00) vs 6.40 (4.00-7.70)	0.317

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Outcome (definition)	n (no / yes)	Test	Statistic	Effect size	IPF median (IQR), no vs yes	P value
Catheterisation-report classification	n = 102	Kruskal-Wallis	H = 1.281	ε^2 = 0.013	Mild CAD 7.10 (5.10-10.10); 1VD 7.70 (4.80-10.55); 2VD 5.75 (3.88-9.88); 3VD/LM 6.80 (4.25-9.38)	0.734

Unadjusted comparisons. Multivessel disease: two or more major epicardial vessels with at least 70% stenosis. High-risk anatomy: left-main stenosis of at least 50% or three-vessel disease. Left-main stenosis: at least 50% narrowing of the left main coronary artery. The catheterisation-report classification is the summary impression transcribed from the report and is shown for reproducibility only; the per-vessel vessel count in Table 3 is the primary measure. W, Mann-Whitney statistic; H, Kruskal-Wallis statistic; r, rank-biserial correlation.

Supplementary Table S4. Comparison of patients who did and did not undergo angiography (n = 117).

Characteristic	Did not undergo (n=15)	Underwent (n=102)	Test	Effect size	P value
ACS subtype (STEMI/NSTEMI/UAP)	-	-	Fisher exact	Cramer V = 0.077	0.728
Male sex, n (%)	8 (53.3%)	81 (79.4%)	Fisher exact	Cramer V = 0.204	0.047
IPF, %	7.10 (4.30-9.30)	6.95 (4.03-10.17)	Mann-Whitney U	r = -0.043	0.791
Age, years	66.00 (58.50-74.50)	56.50 (49.25-65.50)	Mann-Whitney U	r = -0.350	0.029
GRACE score	116.00 (90.50-135.00)	116.00 (83.50-127.00)	Mann-Whitney U	r = -0.113	0.483
Troponin I, ng/mL	1.05 (0.01-50.00)	3.00 (0.06-24.39)	Mann-Whitney U	r = 0.153	0.341
Haemoglobin, g/dL	12.30 (10.85-13.50)	13.75 (12.50-14.80)	Mann-Whitney U	r = 0.322	0.045
Platelet count, $\times 10^3/\mu L$	220.00 (183.50-274.00)	236.50 (187.00-284.00)	Mann-Whitney U	r = 0.100	0.535

Continuous variables are median (IQR) in each group with the Mann-Whitney U test; categorical variables are n (%) with the chi-square or Fisher exact test. Only 15 patients did not undergo angiography, so these p-values are descriptive and should not be overinterpreted. Values for continuous variables are shown as the group medians; the ACS-subtype row reports the overall association only.

Supplementary Table S5. Diagnostics for the final ordinal regression models.

Model	Diagnostic	Result	P value
ACS subtype model	Proportional odds (Brant omnibus)	χ^2 = 12.1, df = 7	0.096
ACS subtype model	Multicollinearity (max VIF)	max VIF = 1.53 (Smoking)	
ACS subtype model	Sparse cells (smallest outcome x predictor cell)	min cell = 6; 0 empty cell(s)	

Model	Diagnostic	Result	P value
ACS subtype model	Influential observation (leave-one-out dfbeta on IPF)	max |dfbeta| = 0.0417 (7.56 SD), NO 53	
ACS subtype model	Linearity in the logit: IPF (quadratic LR test)	$\chi^2 = 5.24$, df = 1	0.022
ACS subtype model	Linearity in the logit: Age (quadratic LR test)	$\chi^2 = 1.27$, df = 1	0.260
ACS subtype model	Linearity in the logit: Symptom-to-admission time (quadratic LR test)	$\chi^2 = 3.09$, df = 1	0.079
Vessel-count model (0-1/2/3)	Proportional odds (Brant omnibus)	$\chi^2 = 7.43$, df = 6	0.283
Vessel-count model (0-1/2/3)	Multicollinearity (max VIF)	max VIF = 1.44 (Male sex)	
Vessel-count model (0-1/2/3)	Sparse cells (smallest outcome x predictor cell)	min cell = 4; 0 empty cell(s)	
Vessel-count model (0-1/2/3)	Influential observation (leave-one-out dfbeta on IPF)	max |dfbeta| = 0.0129 (3.18 SD), NO 88	
Vessel-count model (0-1/2/3)	Linearity in the logit: IPF (quadratic LR test)	$\chi^2 = 0.127$, df = 1	0.722
Vessel-count model (0-1/2/3)	Linearity in the logit: Age (quadratic LR test)	$\chi^2 = 0.313$, df = 1	0.576

Diagnostics are reported for the two final proportional-odds models after the covariate revision: the ACS-subtype model and the vessel-count model with the zero- and one-vessel categories combined (0-1 / 2 / 3). The original four-category vessel-count model was ill-conditioned: its zero-vessel category contained only four patients, producing sparse outcome-by-predictor cells and an uninterpretable Brant test (negative per-term statistics). It was replaced by the combined three-category model reported here. Variance inflation factors are computed from the model design matrix. For the linearity check, a quadratic term is added for each continuous predictor and tested against the linear model by likelihood ratio; a non-significant p supports an acceptable linear relationship with the log odds. VIF, variance inflation factor; LR, likelihood ratio; dfbeta, change in the IPF coefficient on leaving