

Left Atrial Volume Index as a Predictor of One-Year Adverse Events in Acute Coronary Syndromes: A Prospective Observational Study

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ABSTRACT

Background: Acute coronary syndrome (ACS) remains a leading cause of cardiovascular death, and identifying high-risk patients early is essential for tailored management. Left atrial volume index (LAVI) reflects the chronicity and severity of raised left ventricular filling pressure and has emerged as a marker of adverse cardiovascular outcomes. Data from Indian ACS cohorts remain limited. We evaluated LAVI, together with the Tei index, as a predictor of adverse events one year after an index ACS admission.

Methods: In this prospective observational study, 200 consecutive patients admitted with ACS underwent transthoracic echocardiography within 24 hours of admission. Left atrial volume was measured by the area-length method and indexed to body surface area. Patients were followed for 12 months for a composite of all-cause mortality, recurrent angina, congestive cardiac failure (CCF), arrhythmia, revascularization and cerebrovascular accident. A receiver operating characteristic (ROC) curve identified the optimal LAVI cut-off, and Cox proportional-hazards regression assessed independent predictors.

Results: Complete follow-up was available for 180 patients (114 men, 63.3%; mean age 59.15 ± 11.69 years). The mean LAVI was 21.86 ± 5.18 mL/m². Adverse events occurred in 44 patients (24.4%). Only eight patients (4.4%) had a LAVI above the guideline threshold of 34 mL/m², which did not discriminate risk ($p = 0.101$). ROC analysis yielded an optimal cut-off of 23.6 mL/m² (area under the curve 0.628, 95% CI 0.553–0.699; $p = 0.0118$). Patients with LAVI > 23.6 mL/m² had significantly more adverse events (38.6% vs 17.9%; $p = 0.003$) and more arrhythmias (12.3% vs 4.1%; $p = 0.04$). The Tei index was higher in the high-LAVI group (0.45 ± 0.04 vs 0.42 ± 0.05 ; $p = 0.0007$) and correlated with LAVI ($r = 0.231$; $p = 0.0018$). On multivariable Cox regression, LAVI remained an independent predictor of the composite outcome (hazard ratio 1.12 per mL/m², 95% CI 1.00–1.24; $p = 0.044$).

Conclusions: In this Indian ACS cohort, a LAVI above a population-specific cut-off of 23.6 mL/m² independently predicted adverse events at one year, whereas the conventional 34 mL/m² threshold did not. LAVI, complemented by the Tei index, is a simple and reproducible echocardiographic tool for early risk stratification after ACS.

Keywords: left atrial volume index; acute coronary syndrome; Tei index; adverse cardiovascular events; echocardiography; risk stratification

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Introduction

Acute coronary syndrome (ACS) encompasses a spectrum of clinical presentations of acute myocardial ischaemia that ranges from unstable angina through non-ST-elevation myocardial infarction (NSTEMI) to ST-elevation myocardial infarction (STEMI). Rapid assessment of symptoms, electrocardiographic changes and cardiac biomarkers permits accurate diagnosis and risk stratification, on which appropriate treatment is based.¹ Ischaemic heart disease is the single largest contributor to cardiovascular mortality worldwide, and in India it accounts for a disproportionately high and rising share of deaths, driven by epidemiological transition and a heavy burden of metabolic and lifestyle risk factors.²

Contemporary management with early angiography, percutaneous coronary intervention and potent antiplatelet therapy has improved outcomes, yet a substantial residual risk of death and recurrent events persists.² Reliable, inexpensive tools that identify high-risk patients at the bedside therefore remain valuable. Echocardiography is a

non-invasive, widely available modality that provides such information. Among its parameters, left atrial (LA) size is of particular interest: because the left atrium is exposed to left ventricular filling pressure throughout diastole, LA volume integrates the duration and severity of diastolic dysfunction and serves as a durable barometer of cumulative haemodynamic burden, in contrast to the more load-dependent Doppler indices.³

Left atrial volume index (LAVI), obtained by indexing LA volume to body surface area, has consequently emerged as a robust predictor of adverse cardiovascular outcomes. A systematic review and meta-analysis of 11 cohorts comprising 2,705 patients with ACS found that an increased LAVI independently predicted major adverse cardiac events, all-cause mortality and hospitalization.⁴ The Tei index (myocardial performance index), a Doppler-derived ratio that combines systolic and diastolic time intervals, provides a complementary global measure of ventricular function and has itself been associated with heart failure, reinfarction and death after myocardial

infarction.⁵ However, most of the supporting evidence originates from Western populations, and body size, LA dimensions and risk profiles differ in South Asian patients. We therefore conducted a prospective study to evaluate LAVI, together with the Tei index, as a predictor of adverse events during the year following an index ACS admission in an Indian tertiary-care population.

Materials and Methods

Study design and population: This prospective observational study was conducted in the Department of Cardiology, Christian Medical College and Hospital, Ludhiana, over a period of 14 months. The first 200 consecutive patients admitted with a diagnosis of ACS (unstable angina, NSTEMI or STEMI) were enrolled. The study was approved by the institutional Research and Ethical Committee, and written informed consent was obtained from all participants.

Echocardiography: All patients underwent transthoracic echocardiography within 24 hours of admission. Left atrial volume was measured by the area-length method and indexed to body surface area to derive the LAVI, following standard chamber-quantification and diastolic-function conventions; measurements were obtained at end-systole with care to avoid foreshortening and to exclude the pulmonary-vein confluences and the LA appendage.³ Left ventricular internal dimensions in diastole and systole (LVIDD, LVISD), ejection fraction (EF) and left atrial volume (LAV) were recorded. The Tei index was calculated as the sum of the isovolumic contraction and relaxation times divided by the ejection time, using pulsed-wave Doppler at the mitral inflow and the left ventricular outflow tract.⁵

Follow-up and outcomes: Patients were followed for 12 months for a composite adverse event comprising all-cause

Table 1. Baseline demographic and clinical characteristics (n = 180)

Characteristic	Frequency (n)	Percentage (%)
Sex – Male	114	63.3
Sex – Female	66	36.7
Age 30–40 years	12	6.7
Age 41–50 years	32	17.8
Age 51–60 years	45	25.0
Age 61–70 years	60	33.3
Age > 70 years	31	17.2
Hypertension	108	60.0
Diabetes mellitus	98	54.4
Dyslipidaemia	50	27.8
Prior cerebrovascular accident	34	18.9
Smoking	26	14.4
COPD	10	5.6
Unstable angina	62	34.4
Anterior-wall STEMI	50	27.8

Adverse events: Over 12 months, 44 patients (24.4%) experienced at least one adverse event. Congestive cardiac failure was the commonest component (10.0%), followed by recurrent angina (7.8%), arrhythmia (6.7%), revascularization (5.6%), all-cause death (3.3%) and stroke

mortality, recurrent angina, congestive cardiac failure (CCF), arrhythmia, revascularization and cerebrovascular accident. Events were recorded as occurring during the index hospitalization or at 1, 6 and 12 months after admission.

Statistical analysis: Continuous variables were expressed as mean $\pm$ standard deviation or median with interquartile range, and categorical variables as frequencies and percentages. Groups were compared using the chi-square or Fisher exact test for categorical data and the appropriate parametric or non-parametric test for continuous data. The relationship between LAVI, EF and the Tei index was assessed by correlation analysis. A receiver operating characteristic (ROC) curve was constructed to identify the optimal LAVI cut-off for predicting the composite adverse event, and sensitivity, specificity and predictive values were derived. Univariable and multivariable Cox proportional-hazards regression models were used to identify independent predictors, with hazard ratios (HR) and 95% confidence intervals (CI). A two-sided p-value < 0.05 was considered statistically significant.

Results

Of the 200 patients enrolled, 20 were lost to follow-up; complete 12-month data were therefore available for 180 patients. There were 114 men (63.3%) and 66 women (36.7%), with a mean age of 59.15 ± 11.69 years (range 30–84). The largest age group was 61–70 years (60 patients, 33.3%). Hypertension (60.0%) and diabetes mellitus (54.4%) were the commonest comorbidities. Unstable angina was the most frequent diagnosis (34.4%), followed by anterior-wall STEMI (27.8%) and NSTEMI (24.4%). Baseline characteristics are shown in Table 1, and the echocardiographic parameters in Table 2.

NSTEMI	44	24.4
Inferior-wall STEMI	18	10.0
Posterior-wall STEMI	4	2.2
Anterior + inferior-wall STEMI	2	1.1

COPD, chronic obstructive pulmonary disease; NSTEMI, non-ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.

Table 2. Echocardiographic parameters (n = 180)

Parameter	Mean $\pm$ SD
LVIDD (cm)	4.49 ± 0.46
LVISD (cm)	3.55 ± 0.58
Ejection fraction (%)	46.89 ± 9.29
Left atrial volume (mL)	40.0 ± 8.91
Left atrial volume index (mL/m ²)	21.86 ± 5.18
Tei index	0.43 ± 0.05

LVIDD, left ventricular internal diameter in diastole; LVISD, left ventricular internal diameter in systole; SD, standard deviation.

(2.2%) (Table 3). The occurrence of adverse events did not differ significantly by sex (women 25.8% vs men 23.7%; $p = 0.755$), by age group ($p = 0.888$) or by admission diagnosis ($p = 0.539$), although anterior-wall STEMI

carried the highest event rate among the major diagnostic categories (32.0%).

Table 3. Adverse events during 12-month follow-up (n = 180)

Adverse event	Frequency (n)	Percentage (%)
Congestive cardiac failure	18	10.0
Recurrent angina	14	7.8

LAVI and outcome: Only eight patients (4.4%) had a LAVI above the conventional guideline threshold of 34 mL/m²; although the event rate in this small subgroup was numerically higher (50.0% vs 23.3%), the difference was not statistically significant (p = 0.101). ROC analysis identified an optimal cut-off of 23.6 mL/m² for the composite outcome, with an area under the curve of 0.628 (95% CI 0.553–0.699; p = 0.0118), a sensitivity of 50.0%, a specificity of 74.3%, a positive predictive value of 38.6%

Table 4. Adverse events by left atrial volume index category

Outcome	LAVI ≤ 23.6 (n=123)	LAVI > 23.6 (n=57)	p-value
Composite adverse event	17.9%	38.6%	0.003
Arrhythmia	4.1%	12.3%	0.04
Congestive cardiac failure	7.3%	15.8%	0.078
Recurrent angina	6.5%	10.5%	0.349
All-cause death	2.4%	5.3%	0.383

Tei index and correlations: The Tei index was significantly higher among patients with LAVI > 23.6 mL/m² than among those at or below the cut-off (0.45 ± 0.04 vs 0.42 ± 0.05; p = 0.0007) and was likewise elevated in the small LAVI > 34 mL/m² subgroup (0.48 ± 0.02 vs 0.43 ± 0.05; p = 0.002). The Tei index correlated positively with LAVI (r = 0.231; p = 0.0018) and strongly and inversely with ejection fraction (r = -0.783; p < 0.0001), whereas LAVI and ejection fraction were not significantly correlated (r = -0.033; p = 0.657).

Predictors of adverse events: On univariable Cox regression, a LAVI > 23.6 mL/m² was associated with a

Table 6. Cox proportional-hazards regression for the composite adverse event

Variable	HR	95% CI	p-value
Univariable			
LAVI (per mL/m ²)	1.08	1.03–1.14	0.0028
LAVI > 23.6 mL/m ²	2.40	1.33–4.33	0.0037
LAVI > 34 mL/m ²	2.84	1.01–7.95	0.047

Discussion

In this prospective single-centre study of patients admitted with ACS, a left atrial volume index above a population-specific cut-off of 23.6 mL/m² was associated with a significantly higher rate of adverse events at one year and

Arrhythmia	12	6.7
Revascularization	10	5.6
All-cause death	6	3.3
Cerebrovascular accident	4	2.2
Composite adverse event	44	24.4

and a negative predictive value of 82.1% (Table 5). Fifty-seven patients (31.7%) had a LAVI > 23.6 mL/m². This group had a significantly higher composite event rate than those at or below the cut-off (38.6% vs 17.9%; p = 0.003) and a significantly higher rate of arrhythmia (12.3% vs 4.1%; p = 0.04); differences in CCF, recurrent angina, death and stroke favoured the higher-LAVI group but did not reach significance (Table 4).

LAVI, left atrial volume index (mL/m²). Percentages are within each LAVI category.

Table 5. Receiver operating characteristic analysis of LAVI for the composite adverse event

Metric	Value (95% CI)
Area under the curve	0.628 (0.553–0.699)
Optimal cut-off	> 23.6 mL/m ²
p-value	0.0118
Sensitivity	50.0% (34.6–65.4)
Specificity	74.3% (66.1–81.4)
Positive predictive value	38.6% (26.0–52.4)
Negative predictive value	82.1% (74.2–88.4)

more than two-fold hazard of the composite outcome (HR 2.40, 95% CI 1.33–4.33; p = 0.0037), as was LAVI analysed as a continuous variable (HR 1.08 per mL/m², 95% CI 1.03–1.14; p = 0.0028) and a LAVI > 34 mL/m² (HR 2.84, 95% CI 1.01–7.95; p = 0.047). Lower ejection fraction was also predictive (HR 0.97 per %, 95% CI 0.94–1.00; p = 0.047). In the multivariable model that included EF and LA volume, LAVI remained an independent predictor of the composite adverse event (HR 1.12 per mL/m², 95% CI 1.00–1.24; p = 0.044), alongside ejection fraction (HR 0.97, 95% CI 0.94–1.00; p = 0.043) (Table 6).

Left atrial volume (per mL)	1.04	1.01–1.08	0.020
Ejection fraction (per %)	0.97	0.94–1.00	0.047
Multivariable			
LAVI (per mL/m ²)	1.12	1.00–1.24	0.044
Ejection fraction (per %)	0.97	0.94–1.00	0.043

CI, confidence interval; HR, hazard ratio; LAVI, left atrial volume index.

remained an independent predictor after adjustment for ejection fraction and left atrial volume. These findings extend to an Indian population the growing body of evidence that LA size carries prognostic information beyond conventional measures of systolic function.⁶

Sex and age: LAVI did not differ significantly between women and men (22.49 vs 21.49 mL/m²; $p = 0.175$), and the incidence of adverse events was similar in both sexes. This is concordant with a large contemporary cohort of patients with acute myocardial infarction, in which the prognostic weight of an enlarged LA did not differ between the sexes.⁶ Although older patients tended to have a numerically higher LAVI in our cohort, the association between age group and adverse events was not significant; increasing LAVI and event rates with age have, however, been reported in other ACS populations.⁷

Diagnosis: Unstable angina was the commonest presentation, and adverse events clustered among patients with anterior-wall STEMI (32.0%), consistent with the larger myocardial territory at risk, although the overall association between admission diagnosis and outcome did not reach significance in our cohort.¹

LAVI and adverse events: The central finding — that a higher LAVI predicts adverse events after ACS — aligns closely with the wider literature. In a meta-analysis of 2,705 patients with ACS, those with a low LAVI had markedly fewer major adverse cardiac events than those with an increased LAVI (15.9% vs 33.7%), together with lower mortality and hospitalization.⁴ The magnitude of separation in our data (17.9% vs 38.6%) is strikingly similar. Comparable associations have been demonstrated in STEMI, where the LAVI-to-ejection-fraction ratio and the combination of LAVI with pulmonary artery pressure both independently predicted major adverse cardiovascular events over eight years,^{8,9} and in a prospective ACS cohort in which an increased LAVI was associated with more cardiovascular events.⁷ In a recent multicentre study of 487 patients with acute myocardial infarction managed with contemporary reperfusion, deceased patients had a substantially higher LAVI than survivors (40.0 vs 29.7 mL/m²), and LAVI remained an independent predictor of mortality and major adverse cardiac events on multivariable analysis — mirroring the independent association we observed.⁶

Choice of cut-off: An important observation was that the guideline threshold of 34 mL/m² identified only eight patients (4.4%) and did not discriminate risk, whereas a lower, data-derived cut-off of 23.6 mL/m² did. Our cohort had a lower mean LAVI (21.86 mL/m²) than most Western series, in which cut-offs of 32–34 mL/m² have proved discriminatory.⁶ This most likely reflects the smaller body surface area and LA dimensions of South Asian patients and underscores the need to interpret indexed LA volume in the context of the population studied rather than applying a single universal threshold uncritically.³

Tei index and left atrial volume: Patients with a higher LAVI also had a significantly higher Tei index, and the two parameters were positively correlated, indicating that global myocardial performance was more deranged in patients with LA enlargement. The Tei index integrates systolic and diastolic time intervals and has been shown in a systematic review of patients with acute myocardial infarction to be associated with heart failure, reinfarction and death,⁵ while LA reservoir and pump function assessed by strain provide further complementary insight into the

raised filling pressures that drive LA remodelling.¹⁰ The strong inverse correlation between the Tei index and ejection fraction in our data ($r = -0.783$) supports its role as a combined marker of ventricular dysfunction.

Broader context: The prognostic value of LA enlargement is not confined to coronary disease; LA dilatation independently predicts adverse outcomes across a range of cardiovascular conditions, including valvular disease, reinforcing the concept of LA volume as a general integrator of chronic cardiac stress.¹¹ Taken together with our findings, this supports incorporating LAVI into routine post-ACS echocardiographic assessment.^{4,6}

Limitations

This was a single-centre study with a modest sample size, and 20 of the 200 enrolled patients were lost to follow-up, which may have reduced statistical power for the individual outcome components. Left atrial volume was measured in two dimensions by the area-length method rather than by three-dimensional echocardiography or the biplane method of discs. Individual adverse-event components were infrequent, so several between-group comparisons were underpowered, and the data-derived cut-off of 23.6 mL/m² requires external validation before it can be generalized. Finally, potential confounders such as revascularization strategy and medical therapy were not incorporated into the multivariable model.

Conclusions

In patients presenting with acute coronary syndrome, a left atrial volume index above a population-specific cut-off of 23.6 mL/m² independently predicted adverse events during the subsequent year, whereas the conventional 34 mL/m² threshold did not discriminate risk in this cohort. An increased LAVI was accompanied by a higher Tei index, reflecting more advanced global myocardial dysfunction. LAVI is a simple, inexpensive and reproducible echocardiographic measure that can be readily incorporated into early risk stratification after ACS, and its optimal threshold should be defined for the population under study.

Declarations

Ethics: The study was approved by the Research and Ethical Committee of Christian Medical College and Hospital, Ludhiana, and written informed consent was obtained from all participants.

Conflicts of interest: The authors declare that they have no competing interests.

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