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ORIGINAL ARTICLE

The optimal definition and prediction nomogram for left ventricular remodelling after acute myocardial infarction

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Abstract

Aims Left ventricular (LV) remodelling after acute myocardial infarction (AMI) is associated with heart failure and increased mortality. There was no consensus on the definition of LV remodelling, and the prognostic value of LV remodelling with different definitions has not been compared. We aimed to find the optimal definition and develop a prediction nomogram as well as online calculator that can identify patients at risk of LV remodelling.

Methods and results This prospective, observational study included 829 AMI patients undergoing percutaneous coronary intervention from January 2015 to January 2020. Echocardiography was performed within the 48 h of admission and at 6 months after infarction to evaluate LV remodelling, defined as a 20% increase in LV end-diastolic volume (LVEDV), a 15% increase in LV end-systolic volume (LVESV), or LV ejection fraction (LVEF) $<$ 50% at 6 months. The impact of LV remodelling on long-term outcomes was analysed. Lasso regression was performed to screen potential predictors, and multivariable logistic regression analysis was conducted to establish the prediction nomogram. The area under the curve, calibration curve and decision curve analyses were used to determine the discrimination, calibration and clinical usefulness of the remodelling nomogram. The incidences of LV remodelling defined by LVEDV, LVESV and LVEF were 24.85% (n = 206), 28.71% (n = 238) and 14.60% (n = 121), respectively. Multivariable Cox regression models demonstrated that different definitions of LV remodelling were independently associated with the composite endpoint. However, only remodelling defined by LVEF was significantly connected with long-term mortality (hazard ratio = 2.78, 95% confidence interval 1.41–5.48, P = 0.003). Seven variables were selected to construct the remodelling nomogram, including diastolic blood pressure, heart rate, AMI type, stent length, N-terminal pro brain natriuretic peptide, troponin I, and glucose. The prediction model had an area under the receiver operating characteristics curve of 0.766. The calibration curve and decision curve analysis indicated consistency and better net benefit in the prediction model.

Conclusions LV remodelling defined by LVEDV, LVESV and LVEF were independent predictors for long-term mortality or heart failure hospitalization in AMI patients after percutaneous coronary intervention. However, only remodelling defined by LVEF was suitable for predicting all-cause death. In addition, the nomogram can provide an accurate and effective tool for the prediction of postinfarct remodelling.

Keywords Acute myocardial infarction; Definition; Left ventricular remodelling; Percutaneous coronary intervention; Prediction nomogram

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Introduction

After acute myocardial infarction (AMI), the left ventricular (LV) undergoes remodelling characterized by continuous changes in LV structure and function, which manifest as LV enlargement, decreased LV ejection fraction (LVEF) or regional wall motion abnormalities.[1] LV post-infarct remodelling has been associated with adverse clinical outcomes.[2,3] However, the accurate criterion of LV remodelling is still uncertain, and a consensus definition of LV remodelling has been lacking.[4] Some studies used the changes in LV end-diastolic volume (LVEDV),[5] LV end-systolic volume (LVESV)[6] or LVEF[7] as the determination for LV remodelling, and others put forward some new remodelling parameters, such as LV mass index[8] and wall motion score index.[9] Several LV remodelling definitions primarily emanate from the era of thrombolysis, before the advent of primary percutaneous coronary intervention (PCI) and guideline-directed medication therapy, without any correlation to hard clinical events.[4,10] Accordingly, there is a need for the development of an optimal prognosis-based definition of LV remodelling following AMI.

Assuming that the optimal definition of remodelling is closely associated with poor outcomes, early detection of patients likely to suffer from LV remodelling may help to optimize therapeutic strategies intended for preventing or reverting LV remodelling and its subsequent adverse endpoints.[11] Due to the growing number of measured parameters generated by patient care, machine learning approaches could improve prediction accuracy and limit overfitting, compared to traditional statistical methods.[12] Without preconceived ideas based on known pathophysiology mechanisms or previous studies, it could identify new potential predictors.

We aimed to compare the effect of different remodelling definitions on all-cause death and hospitalization for heart failure. Furthermore, a nomogram and online calculator will be developed and validated to predict the risk of LV remodelling in patients with AMI undergoing PCI.

Methods

Study design and endpoint definitions

The present study was designed as an observational, prospective study. A total of 874 consecutive AMI patients who underwent PCI at Fujian Provincial Hospital between January 2015 and January 2020 were initially included. After exclusion of patients who died (n = 31) or developed myocardial reinfarction (n = 14) until the 6 month follow-up, a final cohort of 829 AMI patients was analysed. AMI and co-morbid disease were assessed using the International Classification of Diseases, Tenth Revision codes. Cardiovascular interventionalists follow guideline recommendations and choose the most appropriate PCI strategy. The choice of pharmaceutical therapy was at the discretion of the treating physician, in accordance with appropriate guidelines. The exclusion criteria were a known past history of cardiac insufficiency or heart failure, estimated glomerular filtration rate $\leq$ 30 mL/min/1.73 m^2, and death or myocardial reinfarction until the 6 month follow-up investigation.

After inclusion, we conducted detailed medical history assessments and physical examinations. Per protocol, echocardiography was performed within the 48 h of admission, as well as at the 6 month follow-up.

Evaluation of clinical endpoints included survival and heart failure hospitalization. Heart failure hospitalization was defined as admission to the hospital due to worsening heart failure symptoms requiring intravenous diuretic therapy. The data were collected by trained nurses using either outpatient clinical visits or telephone connections with the patients or their relatives after discharge. The declared endpoints were carefully checked afterward by reviewing the corresponding medical records. The primary study endpoint was all-cause death or heart failure hospitalization. The secondary endpoint was all-cause death.

This study was conducted in accordance with the Declaration of Helsinki, and ethical approval was obtained from the Fujian Provincial Hospital ethics committee. All patients provided written informed consent.

Echocardiographic data collection

We performed transthoracic echocardiography on all patients using echocardiography system (Philips iE33) in the left lateral decubitus position. Echocardiographic data were acquired and digitally archived for off-line analysis. LVESV, LVEDV and LVEF were calculated with Simpson's method from two-dimensional, apical, two-chamber and four-chamber views.[13]

Definitions of left ventricular remodelling

The presence of LV remodelling was defined as an increase of $\geq$20% in LVEDV from baseline to 6 month follow-up,[14,15] LVESV increased $>$15% from baseline to 6 month follow-up,[6,16] or LV systolic dysfunction with LVEF $<$50% at 6 months.[7,17]

Development and validation of the prediction nomogram

We first developed a prediction model for the prognosis-based definition of LV remodelling in AMI patients after PCI

at Fujian Provincial Hospital from January 2015 to August 2018. External validation was then performed in a second cohort from the same hospital between September 2018 and January 2020.

Risk factors for the LV remodelling prediction model were selected by the least absolute shrinkage and selection operator (LASSO) method, which is suitable for the reduction in high-dimensional data.[18,19] For each setting combination for continuous variables selected by the LASSO method, we generated a candidate model using backward elimination with Akaike information criterion (AIC) as the selection criterion.[20] We selected the model with the lowest AIC as the final prediction model. Multivariable logistic regression was used to construct a nomogram to predict the occurrence of remodelling. An axis called 'Total Points' was used to calculate the sum of the points received from the nomogram. The bottom scales were also projected downward to determine LV remodelling possibilities. An online calculator based on the selected final model was constructed from the overall data of the training cohort.

Statistical analysis

Statistical analysis was performed with R version 4.0.2. Continuous variables were presented as the mean ± standard deviation (SD) or median (interquartile range) and analysed using Student's *t* test (normally distributed) or the Mann–Whitney *U* test (nonnormally distributed). The χ^2 test or Fisher's exact test was used to compare categorical variables as counts (percentages).

The relationship between different definitions of LV remodelling and all-cause mortality and heart failure hospitalization was discussed by Kaplan–Meier survival analysis. Univariable Cox regression was used to analyse potential risk factors for endpoint events. Those variables significant by univariable Cox regression and clinically relevant were incorporated into the multivariable analysis. The optimal definition of LV remodelling was obtained by Cox regression using multivariable models. Subgroup analysis was conducted to determine whether there was an interaction across groups.

The prediction nomogram for LV remodelling was developed by the LASSO method and multivariable logistic analysis. The visual prediction model was externally validated (temporal validation). The receiver operating characteristic curve, area under the receiver operating characteristic curve (AUC), and calibration curve were used to assess the predictive accuracy and conformity of the prediction model. Decision curve analysis (DCA) reflected the net benefit of the model for patients. Two-sided $P < 0.05$ was considered as statistically significant.

Results

General characteristics

A total of 829 patients were analysed (mean age 62.89 ± 11.71 years, 84.20% men). The median LVEF, LVEDV and LVESV for the overall population were 57.00 (53.00, 60.00) mL, 89.00 (76.00, 106.00) mL and 37.84 (31.39, 48.60) mL, respectively, within 48 h of admission. Patients who developed LV remodelling were more likely to have STEMI, a history of diabetes mellitus and atrial fibrillation. They also had higher heart rate, systolic blood pressure, stent length, cardiac troponin I, N-terminal pro brain natriuretic peptide (NT-proBNP) and glucose but lower diastolic blood pressure on admission. LV postinfarct remodelling occurred in 14.60% (*n* = 121), 24.85% (*n* = 206) and 28.71% (*n* = 238) of patients according to LVEF, LVEDV and LVESV, respectively (*Tables 1*, *S1* and S2).

Prognostic value of different definitions of left ventricular remodelling

All 829 patients could be followed for long-term outcomes. During a median follow-up of 35 (interquartile range: 18 to 48) months, 94 (11.34%) and 48 (5.79%) patients developed primary and secondary endpoints, respectively. LV remodelling according to three definitions was significantly associated with all-cause death and hospitalization for heart failure (*Figure 1*). After adjustment for covariables, multivariable Cox analysis demonstrated that different definitions of remodelling were independently associated with the primary endpoint (*Table 2*). However, only remodelling defined by LVEF was associated with all-cause death (hazard ratio = 2.78, 95% confidence interval 1.41–5.48, *P* = 0.003). In most subgroups, no significant interaction effect between LV remodelling defined by LVEF and long-term mortality was found (*Figure S1*). The findings suggested that LV remodelling defined by LVEF may be the optimal prognosis-based definition.

Screening for risk factors and remodelling nomogram development

The training cohort consisted of 580 patients who were hospitalized at Fujian Provincial Hospital in Fuzhou, China, between 1 January 2015 and 31 August 2018. In the validation cohort, 249 patients were hospitalized at the same hospital between 1 September 2018 and 1 January 2020. All patient data, including demographics, medical history, procedure performed and laboratory measurements, in the two groups are given in *Table* S3.

Table 1 Baseline clinical characteristics of non-remodellers and remodellers defined by LVEF

Variable	Non-remodellers (n = 708)	Remodelers (n = 121)	P value
Demographics			
Age, years	62.70 ± 11.67	63.96 ± 11.93	0.285
Age >75 years, n (%)	94 (13.28)	23 (19.01)	0.125
Gender, male, n (%)	598 (84.46)	100 (82.64)	0.710
BMI, kg/m^2	24.29 ± 3.17	24.00 ± 3.13	0.357
Medical history, n (%)			
Diabetes mellitus	233 (32.91)	48 (39.67)	0.178
Hypertension	460 (64.97)	76 (62.81)	0.721
Atrial fibrillation	41 (5.79)	13 (10.74)	0.066
Current smoker	363 (51.27)	55 (45.45)	0.278
AMI type, STEMI	358 (50.56)	94 (77.69)	<0.001
Previous infarct	16 (2.26)	3 (2.48)	0.749
Anaemia	70 (9.89)	15 (12.40)	0.497
Procedure performed			
Heart rate, b.p.m.	75.91 ± 13.24	82.18 ± 15.77	<0.001
SBP, mmHg	129.88 ± 21.64	120.47 ± 23.27	<0.001
DBP, mmHg	76.55 ± 13.97	71.70 ± 15.24	0.001
Multivessel disease, n (%)	609 (86.02)	97 (80.17)	0.125
Infarct location LAD or LM, n (%)	649 (91.67)	111 (91.74)	1.000
Time from symptom onset to primary PCI (h)	6.33 ± 2.54	7.01 ± 1.87	0.010
Number of stents	1.41 ± 0.77	1.48 ± 0.88	0.441
Stent length, mm	38.77 ± 23.95	41.80 ± 26.31	0.237
Laboratory measurements			
Peak cTnI, ug/L	13.09 (2.18–70.06)	106.35 (6.40–353.81)	<0.001
cTnI, ug/L	2.49 (0.32–15.83)	5.97 (0.43–72.78)	0.010
NT-proBNP, pg/mL	555.00 (199.60–1373.50)	1104.00 (340.30–2457.00)	<0.001
Triglyceride, mmol/L	1.44 (1.08–2.05)	1.18 (0.88–1.83)	0.002
Cholesterol, mg/dL	79.20 (66.96–94.18)	80.64 (66.78–99.00)	0.465
HDL-C, mg/dL	17.10 (14.40–20.34)	18.54 (15.66–21.78)	0.005
LDL-C, mg/dL	52.47 (41.40–66.64)	52.92 (43.74–68.76)	0.371
Glucose, mmol/L	4.15 ± 1.41	4.45 ± 1.69	0.061
ALT, U/L	35.30 (22.00–54.00)	52.00 (27.00–86.00)	<0.001
AST, U/L	53.00 (26.00–156.25)	211.00 (34.00–438.00)	<0.001
Total bilirubin, μmol/L	12.12 (8.78–16.34)	13.59 (9.64–19.35)	0.030
Albumin, g/dL	3.96 ± 0.39	3.90 ± 0.42	0.139
Serum creatinine, mg/dL	0.93 ± 0.50	0.96 ± 0.39	0.471
eGFR, mL/min/1.73 m^2	94.73 ± 27.41	91.15 ± 28.21	0.196
WBC, 10^9/L	9.34 ± 3.50	11.10 ± 4.21	<0.001
Platelet, 10^9/L	226.88 ± 64.13	237.11 ± 89.90	0.232
Echocardiographic parameters			
LVEF, %	57.00 (54.00–60.00)	50.00 (42.00–56.00)	<0.001
LVEDV, mL	86.00 (75.00–103.25)	109.00 (89.00–128.00)	<0.001
LVESV, mL	36.59 (30.96–45.38)	54.60 (38.85–69.30)	<0.001
Medical therapy, n (%)			
Antiplatelet	703 (99.29)	118 (97.52)	0.098
Beta-blocker	596 (84.18)	95 (78.51)	0.157
ACEI/ARB	581 (82.06)	95 (78.51)	0.422
Statin	704 (99.44)	119 (98.35)	0.214

ACEI/ARB, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; ALT, alanine aminotransferase; AMI, acute myocardial infarction; AST, aspartate aminotransferase; BMI, body mass index; cTnI, cardiac troponin I; DBP, diastolic blood pressure; eGFR, estimated glomerular filtration rate; HDL-C, high-density lipoprotein-cholesterol; LAD, left anterior descending; LDL-C, low-density lipoprotein-cholesterol; LM, left main; LVEDV, left ventricular end diastolic volume; LVEF, left ventricular ejection fraction; LVESV, left ventricular end systolic volume; SBP, systolic blood pressure; STEMI, ST-segment elevation myocardial infarction; WBC, white blood cell.

Of the above features, 41 features were reduced to 10 potential predictors on the basis of 580 patients in the training cohort and had nonzero coefficients in the LASSO regression model (*Figure 2*). After backward elimination and model selection based on the lowest AIC (AIC = 278.6), seven prognostic indicators, including diastolic blood pressure, heart rate, ST-segment elevation myocardial infarction (STEMI), stent length, NT-proBNP, TnI peak and glucose, were included in the final model for the construction of the nomogram. The results of the logistic regression analysis among the above features are given in *Table* S4. The nomogram is presented in *Figure 3*, and an online calculator is available at https://fjmuzz.shinyapps.io/ZuzSicenomapp/.

Figure 1 Kaplan–Meier curves of primary endpoint events in non-remodellers and remodellers. (A) Remodelling defined by left ventricular ejection fraction. (B) Remodelling defined by left ventricular end-diastolic volume. (C) Remodelling defined by left ventricular end-systolic volume.

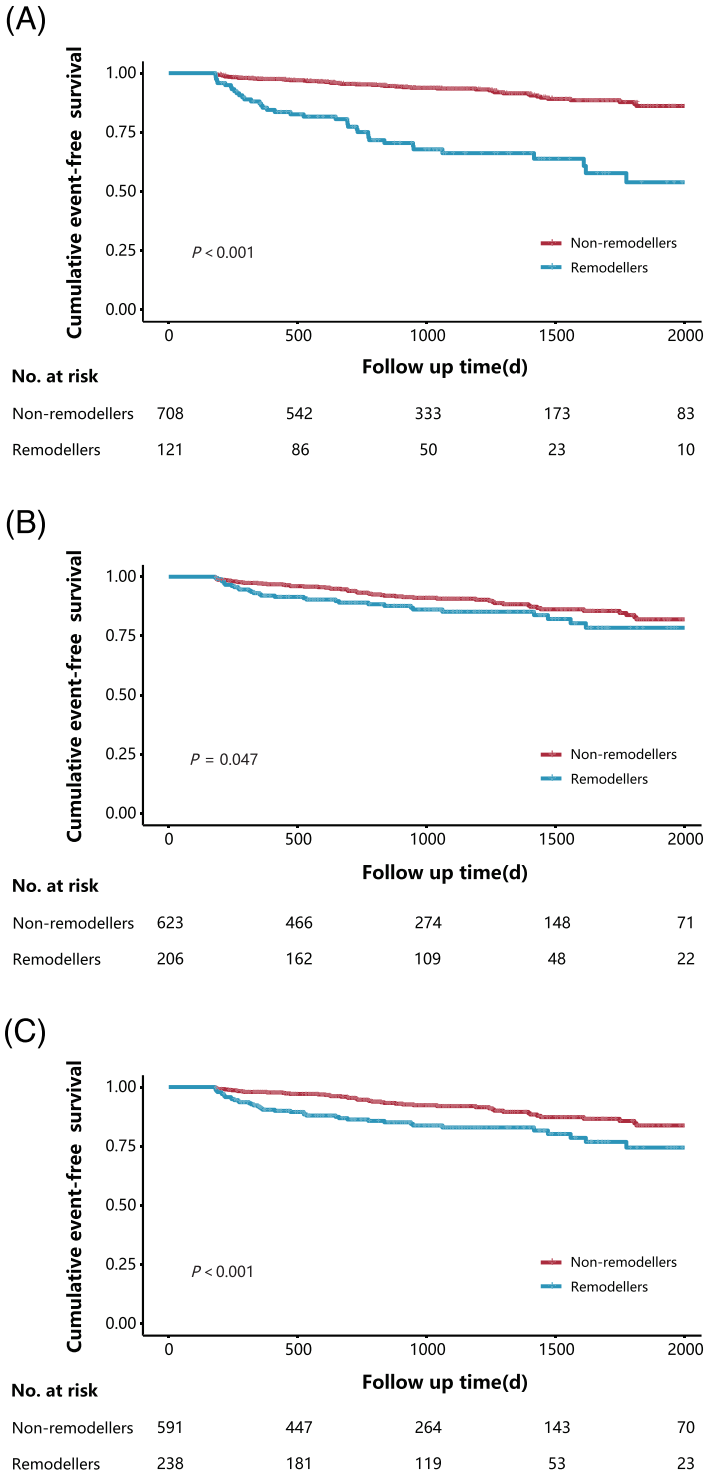
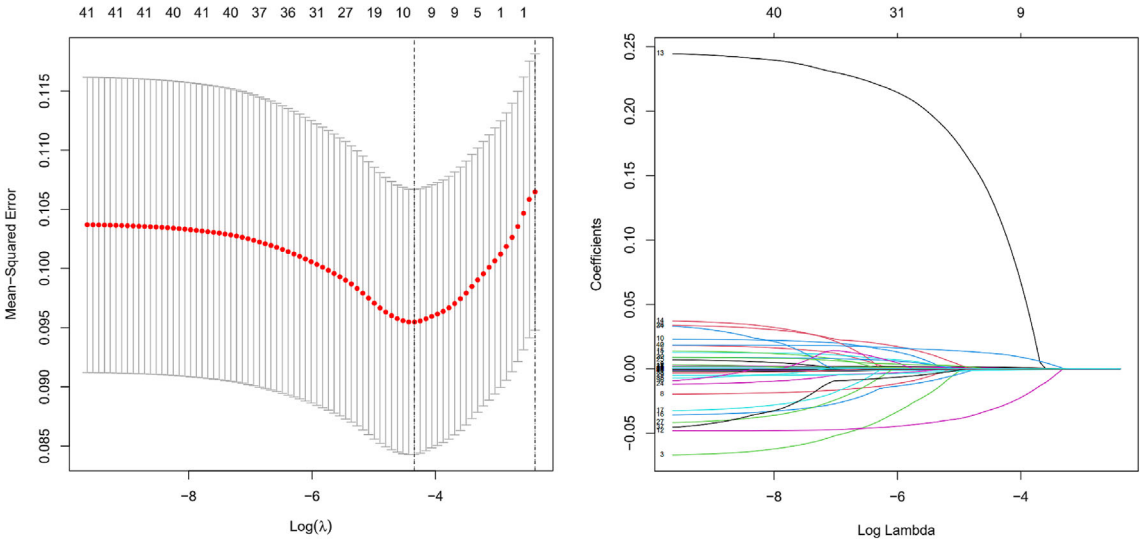


Table 2 Univariable and multivariable Cox regression analyses of the associations between different definitions of remodelling and adverse outcomes

	Unadjusted		Model 1		Model 2		Model 3	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
All-cause mortality, heart failure hospitalization								
Remodelling (LVEF)	4.49 (2.97–6.78)	<0.001	4.56 (3.01–6.91)	<0.001	5.69 (3.62–8.95)	<0.001	5.42 (3.42–8.58)	<0.001
Remodelling (LVEDV)	1.54 (1.00–2.35)	0.049	1.53 (0.99–2.34)	0.051	1.51 (1.97–2.35)	0.065	1.57 (1.00–2.44)	0.048
Remodelling (LVESV)	2.16 (1.44–3.24)	<0.001	2.39 (1.59–3.60)	<0.001	2.52 (1.66–3.84)	<0.001	2.51 (1.64–3.85)	<0.001
All-cause mortality								
Remodelling (LVEF)	2.91 (1.59–5.30)	0.001	2.84 (1.55–5.21)	0.001	2.94 (1.52–5.67)	0.001	2.78 (1.41–5.48)	0.003
Remodelling (LVEDV)	1.08 (0.57–2.05)	0.806	1.06 (0.56–2.00)	0.864	1.08 (0.56–2.08)	0.830	1.26 (0.65–2.45)	0.499
Remodelling (LVESV)	1.33 (0.73–2.40)	0.349	1.42 (0.78–2.58)	0.247	1.41 (0.76–1.62)	0.274	1.60 (0.86–3.01)	0.140

Model 1: Adjusted for age >75 years and gender. Model 2: Adjusted for variables from Model 1 plus diabetes mellitus, hypertension, current smoker, AMI type, previous infarct, anaemia and multivessel disease. Model 3: Adjusted for variables from Model 2 plus peak cTnI, NT-proBNP, LDL-C, glucose and eGFR.
CI, confidence interval; HR, hazard ratio; LVEDV, left ventricular end diastolic volume; LVEF, left ventricular ejection fraction; LVESV, left ventricular end systolic volume.

Figure 2 Clinical features were selected by the LASSO binary Logistic regression model. LASSO model used fivefold cross-validation. Optimal log(λ) resulted in features with nonzero coefficients. (A) LASSO cross-validation diagram. (B) LASSO coefficient profiles of the 41 features.



Predictive accuracy and net benefit of the prediction nomogram

According to *Figure 4A*, the AUC of training cohort was 0.766, and the calibration curve approached the ideal diagonal line (*Figure 5A*). DCA showed a significantly better net benefit in the predictive model (*Figure 6A*). Additionally, an external validation was conducted using 249 patients from the same hospital to assess the performance of the nomogram, resulting in an AUC of 0.774 (*Figure 4B*), reflecting good accuracy of the nomogram. Validation cohort calibration curves were also close to ideal diagonal lines (*Figure 5B*), indicating that the model had good consistency. DCA also showed that the predictive nomogram provided an important net benefit in the validation cohort (*Figure 6B*).

Discussion

To the best of our knowledge, our study is the first to compare and analyse LV remodelling-defining and its prognostic value in patients with AMI undergoing PCI, which provides the recommended definition to recognize high-risk patients. Our findings revealed that LV remodelling defined by the changes in three echocardiographic parameters was associated with composite endpoints, but only LV remodelling defined by LVEF was significantly associated with all-cause mortality. In addition, based on the preferred definition of LVEF in the present study, the nomogram and online calculator were established by machine learning, which provided an accurate and effective tool for the prediction of postinfarct remodelling.

Figure 3 Nomogram for the prediction of LV remodelling.

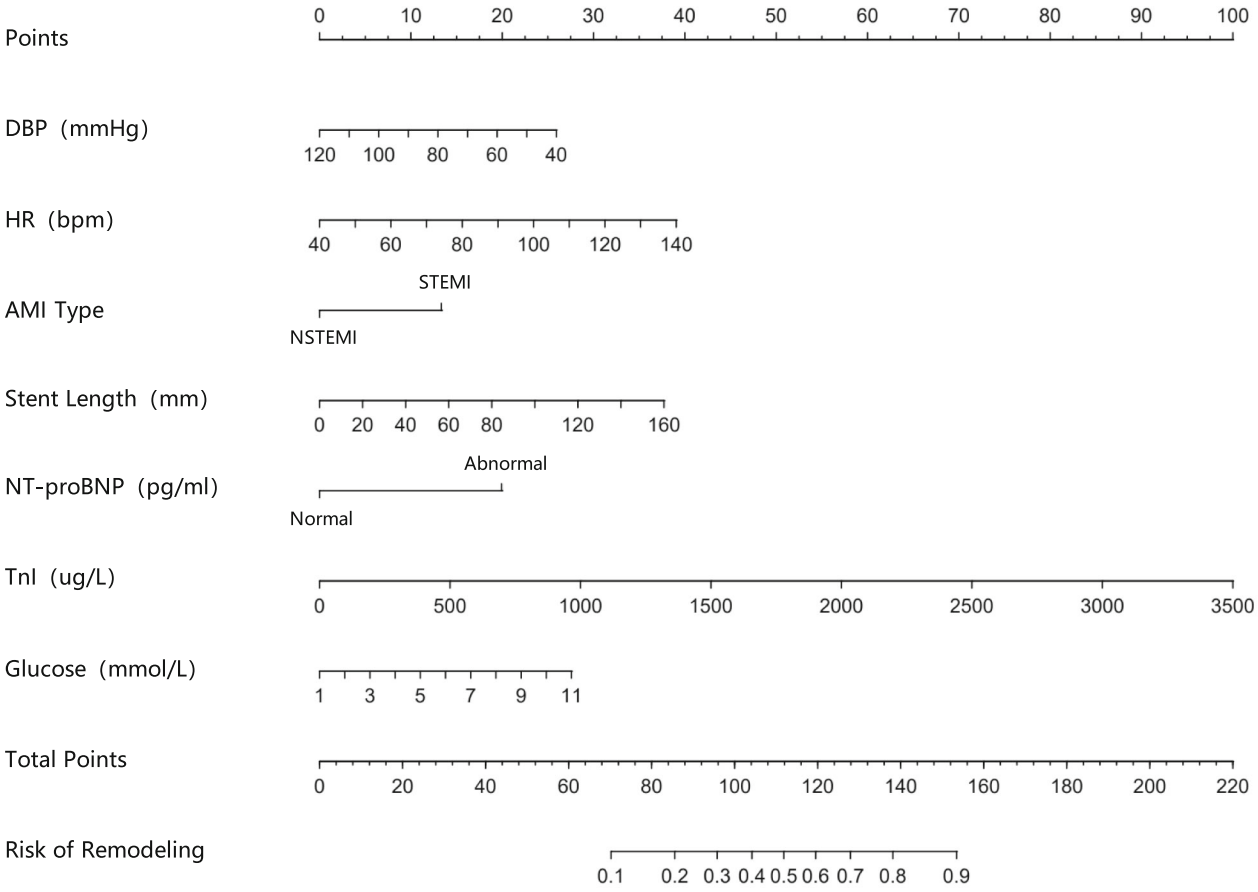


Figure 4 ROC curves. (A) Training cohort. (B) Validation cohort. ROC, receiver operating characteristic.

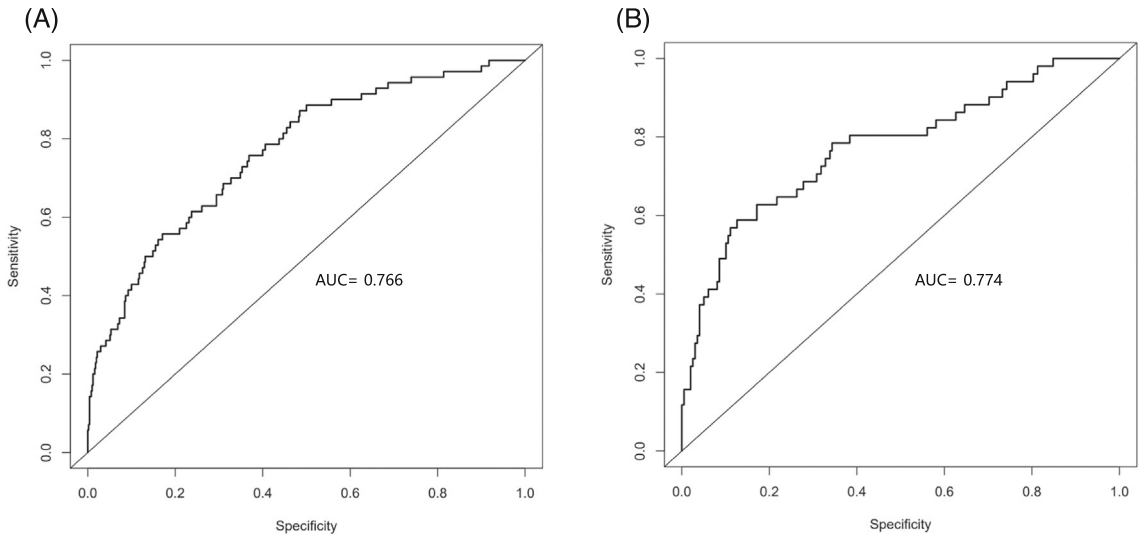


Figure 5 Calibration curve for predicting probability of remodelling. (A) Training cohort. (B) Validation cohort.

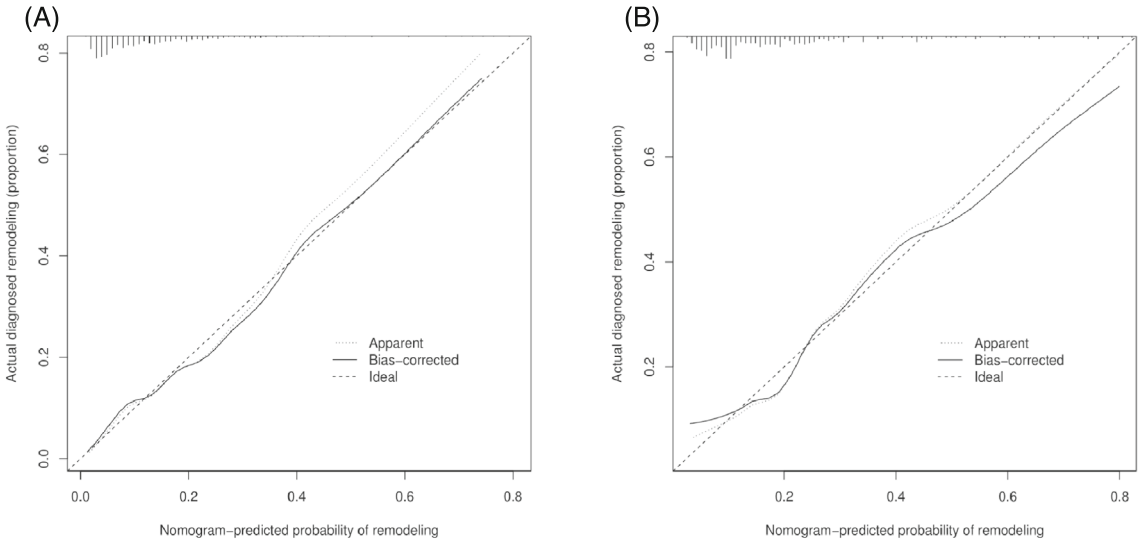
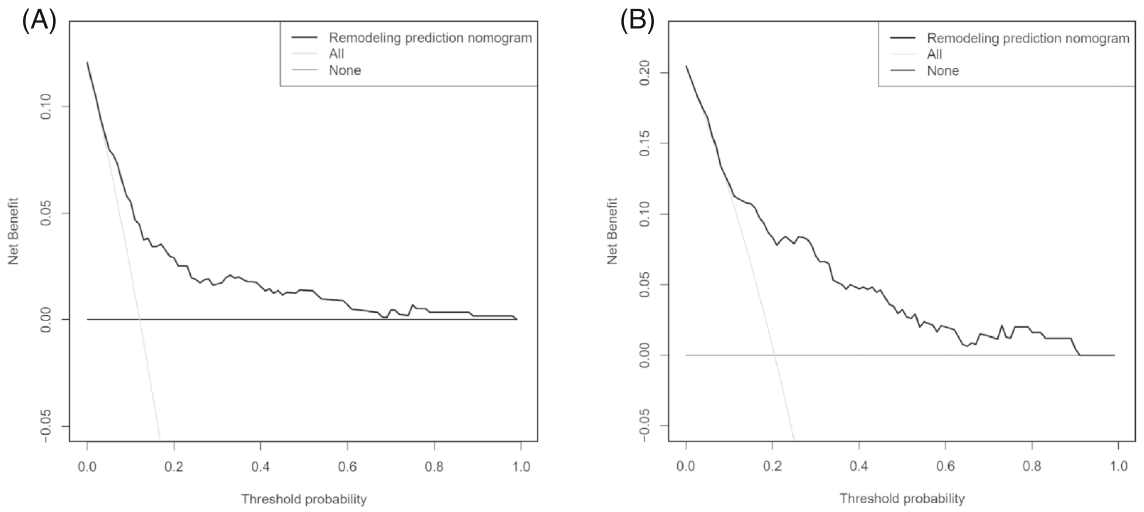


Figure 6 Decision curve analysis in prediction of remodelling. (A) Training cohort. (B) Validation cohort.



There is no current uniform definition of LV postinfarct remodelling, which makes it difficult for clinicians to accurately recognize remodellers so as to make timely adjustments to the treatment plan. Existing reports have indicated that the probability of LV remodelling after infarction fluctuates at 20%–48%.[1,14,15,21,22] As PCI has become increasingly accessible and pharmacotherapy for remodelling has evolved tremendously, a unified definition remains a challenge and plays a crucial role for patients with PCI and optimal medication treatment in current clinical practice. In addition, various definitions have different predictive values for prognosis. A cohort study of 1995 patients with STEMI revealed that remodelling based on LVEDV was not associated with mortality but with hospitalization for heart failure (hazard ratio = 2.66, 95% confidence interval 1.69–4.19, $P < 0.001$),[15,23] which was consistent with our findings. Another study indicated that LV remodelling related to LVEDV or LV myocardial mass was associated with major adverse cardiovascular events including all-cause death, reinfarction, stroke and new congestive heart failure 24 months following STEMI, whereas there was no significant correlation of LV remodelling related to LVESV or LVEF with major adverse cardiovascular events.[15,23] In contrast, Bolognese et al. found that LVEDV increase ≥12% at 6 months after reperfusion in STEMI population could not predict all-cause death and heart failure rehospitalization, but it was significantly associated with composite events

(log-rank $P = 0.03$) when combined with LVESV increase ≥12% at the same time.[23] In the present study, we found that the development of LV remodelling defined by LVEDV and LVESV was independently associated with all-cause death or hospitalization for heart failure. However, due to the limited predictive ability of these two definitions for long-term mortality, we considered that LV remodelling defined by LVEDV and LVESV may have a better predictive value for the occurrence and worsening of heart failure. This improved the performance to predict the primary endpoint events.

The present study demonstrated that LV remodelling defined by LVEF had a better performance for long-term mortality than LVEDV and LVESV. Previous studies have stated that LVEF is a strong predictor of LV remodelling and heart failure prognosis.[9] Decreased LVEF significantly increases the risk of poor prognosis, including death and hospitalization for heart failure.[7] First, compared with structural parameters such as LVESV and LVEDV, LVEF represents multidimensional cardiac function, and it includes stroke volume and end-diastolic volume. LVEF combines the characteristics of LVESV and LVEDV in measurement, which not only represents systolic function but is also a great indicator of cardiac eccentric hypertrophy remodelling.[24] Second, the measurement of absolute value depends on the accuracy of the instrument, and the measurement of ventricular volume is highly variable, while LVEF, as a unitless ratio, can avoid the corresponding measurement defects.[25] When cardiac pump function is impaired, LVEDV increases, and myocardial fibres elongate to maintain cardiac output because of a compensatory mechanism,[26] followed by eccentric hypertrophy. When LVEF decreases, the compensatory mechanism is impaired and the heart undergoes progressive adverse remodelling.[27] The Survival and Ventricular Enlargement (SAVE) Trial demonstrated that low LVEF was a risk factor for cardiovascular death and cardiac enlargement.[28] A recent meta-analysis of ventricular reverse remodelling showed that the prognostic value based on LVEF was better than that of LVESV, while changes in LVEDV did not independently predict cardiovascular death. In other words, LVEF was optimal because improvements in LVEF were more strongly associated with a lower risk of cardiovascular death.[29]

Subsequently, we developed a remodelling prediction model with the lowest AIC, including seven variables based on the machine learning method that were readily available and/or already routinely measured. The prediction model and online risk calculator achieved good accuracy and consistency for the prediction of 6 month LV post-infarct remodelling, enabling the early detection of patients at risk of LV remodelling. We found that our model selected known predictors of pathologic LV remodelling such as STEMI and TnI, which are associated with severe myocardial injury and large infarct size. An increased heart rate results in proportionate increases in myocardial oxygen consumption.[30,31] Subsequently, diastolic duration is overproportionately reduced.[32] The decreased diastolic duration now even reduces coronary blood flow.[33] This is consistent with lower diastolic blood pressure aggravating the severity of myocardial injury and infarction.[34] However, the heart rate and diastolic blood pressure at admission could not reflect the average status. The relationship between the mean and remodelling needs further research. Interestingly, stent length is also among our selected predictors. Revascularization plays an important role in improving the prognosis of patients with myocardial infarction. Stent length partly reflects the affected lesion of coronary artery stenosis. Coronary stenosis in multilesion areas has been shown to be associated with postinfarction ventricular remodelling.[35] The level of NT-proBNP is considered to be the most valuable biomarker for diagnosing cardiac systolic dysfunction and heart failure.[36] It is well known that myocardial ischaemia or infarction is associated with elevation of NT-proBNP levels, reflecting the severity of LV dysfunction.[37] Furthermore, basal glucose levels and poor glycaemic control, consistent with previous reports, are predictors of adverse LV remodelling and cardiovascular events.[38]

There is no denying that our study has some limitations. First, this is a single-centre observational cohort study, and it is necessary to further verify and promote the results through multicentre studies. Second, we aim to compare the more commonly used three definitions of LV remodelling, but there are other new indicators that have not been included in our analysis. Cardiac magnetic resonance is the gold standard for the evaluation of cardiac remodelling, which may promote the accuracy of measurement. However, echocardiography has a wide range of applications in clinical practice, low economic cost, and is more universal and practical. Third, there was also a lack of data on some potentially significant predictors for LV remodelling, including anterior myocardial infarction and chronic total occlusion. In a further study, we will assess more potential indicators combined with clinical characteristics to build a more accurate prediction model for LV remodelling, with the aim of reducing mortality and heart failure hospitalization. Fourth, the samples from the training and validation cohorts may only be representative of the population of Southeast China.

Conclusions

Over three-quarters (37%) of patients treated with PCI and optimal pharmacotherapy showed LV remodelling within 6 months of infarction. In addition, postinfarct LV remodelling was independently associated with heart failure hospitalization and mortality. However, only remodelling defined by LVEF was suitable for predicting all-cause death. Based on the machine learning method, we built a prediction nomogram and online calculator for LV remodelling, providing clinicians with a simple and intuitive tool for the early detection and identification of LV remodelling.

Author contributions

S.C.Z., Z.Z., and M.Q.L. contributed equally to this work and acquired the data, drafted and revised the manuscript. L.C.C., C.H., Z.B.Y., H.M.H., M.Q.L. and L.W.Z. assisted to acquire and interpret the data. Y.S.G. and K.Y.L. designed the study, provided supervision and carefully revised the manuscript. All authors approve the final version of the manuscript and agree to be accountable for all aspects of the study.

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Conflict of interest

The authors declare that they have no competing interests.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Baseline clinical characteristics of non-remodelers and remodelers defined by LVEDV. LVEDV = left ventricular end diastolic volume.
Table S2. Baseline clinical characteristics of non-remodelers and remodelers defined by LVESV. LVESV = left ventricular end systolic volume.
Table S3. Baseline characteristics of all patients in the training cohort and validation cohort.
Table S4. Prediction factors for remodelling defined by LVEF. LVEF = left ventricular ejection fraction.
Figure S1. Forest plot of the subgroup analyses for association between the remodelling defined by LVEF and long-term mortality. LVEF = left ventricular ejection fraction.

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