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Stress hyperglycaemia is an independent predictor of left ventricular remodelling after first anterior myocardial infarction in non-diabetic patients

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Aims Stress hyperglycaemia (SH) is associated with adverse outcome in patients with acute myocardial infarction (MI) but the mechanisms underlying this association are unknown. Our hypothesis was that SH on admission for acute MI may be associated with left ventricular (LV) remodelling.
Methods and results We analysed LV remodelling in 162 non-diabetic patients with anterior MI. SH was defined as a glycaemia on admission $\geq$7 mmol/L. Systematic echocardiographic follow-up was performed at 3 months and 1 year after MI. The changes in end-diastolic volume (EDV) and end-systolic volume (ESV) from baseline to 1 year were 11.4 ± 16.5 and 6.4 ± 12.4 ml/m^2, respectively, in patients with SH vs. 1.9 ± 11.1 and 0.2 ± 8.5 ml/m^2, respectively, in patients without SH (both $P < 0.0001$). When LV remodelling was defined as a >20% increase in EDV, it was observed in 46% patients in the SH group vs. 19% patients in the no SH group ($P = 0.0008$). By multivariable analysis, baseline wall motion score index ($P = 0.001$) and SH ($P = 0.009$) were independently associated with changes in EDV. SH was an independent predictor of LV remodelling [adjusted OR: 3.22 (1.31–7.94)].
Conclusion SH is a major and independent predictor of LV remodelling after anterior MI in non-diabetic patients.

Introduction

Abnormally elevated blood glucose is a common finding in patients with acute myocardial infarction (MI) and has been referred to as stress hyperglycaemia (SH).[1–3] In a systematic overview and meta-analysis of the published literature, it has been reported that SH was associated with an increased risk of mortality; the association was observed irrespective of diabetic status but was stronger in non-diabetic patients.[4] Moreover, the risk of congestive heart failure was also increased in non-diabetic patients with SH on admission.[4] However, although there is strong evidence for the association between SH and prognosis, the mechanisms underlying this association are not well understood.

Among the pathophysiological mechanisms that may lead to an adverse prognosis after MI is left ventricular (LV) remodelling. LV remodelling is a dynamic and complex process that occurs in response to damage to the myocardium after MI.[5] Progressive LV dilation after MI has been recognized as a strong predictor of heart failure and cardiovascular death.[6,7] Several factors have been shown to influence LV remodelling; these include infarct size, anterior infarct location, or patency of the infarct-related artery.[8–11] Although there are data suggesting that patients with SH may have more extensive myocardial damage and impaired LV function,[12,13] the relationship between the occurrence of SH on admission and the risk of LV remodelling during follow-up has never been specifically examined.

We therefore designed the present study to test the hypothesis that non-diabetic patients with SH on admission for acute MI may be at greater risk for LV remodelling assessed by systematic echocardiographic follow-up at 3 months and 1 year after MI.

Methods

Study population

We included 220 patients who underwent reperfusion therapy for an acute anterior Q-wave MI; these patients from 13 centres in the region Nord Pas-de-Calais in France were included in a multicentre

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study on LV remodelling. Patients were considered eligible if the infarct zone comprised at least three LV segments (as defined subsequently) that were akinetic at predischarge echocardiography. Exclusion criteria were inadequate echographic image quality, age >85, life-limiting non-cardiac disease, significant valvular disease, or prior Q-wave MI; patients who had scheduled CABG were also excluded. The research protocol was approved by the Ethics Committee of the Centre Hospitalier et Universitaire de Lille, and written informed consent was obtained from each patient. The protocol required serial echographic studies at hospital discharge (day 5–day 15), at 3 months, and at 1 year after MI. For those patients who did not return at the designated times, information on clinical status was collected by telephone interview.

For the present analysis, all patients with glycaemia measured on admission, and who had no history of or treatment for diabetes mellitus at entry nor were diagnosed as diabetics during the hospital stay, were included. Diabetes mellitus was defined as an elevated (>7 mmol/L) fasting blood glucose on at least two separate occasions. Of the total population of 220 patients, 171 had no known or recognized diabetes mellitus. From this group, the level of admission glycaemia was recorded in 162 (95%), who form the study population.

Echocardiographic study

Echographic data were obtained using commercially available second harmonic imaging systems. Echocardiograms were performed by experienced ultrasonographers and repeated by the same operator wherever possible. Images were recorded on optical disks. A standard imaging protocol was used based on apical four- and two-chamber views; 2D echocardiograms of the LV short axis were recorded at three levels: mitral valve, mid-papillary muscle level, and apex. All echocardiograms were analysed at the Lille Core Echo Laboratory, with each echographic variable analysed by one investigator. LV volumes and ejection fraction (EF) were calculated using a modified Simpson's rule. The mean value of three measurements of the technically best cardiac cycles was taken from each examination and LV volumes were corrected for body surface area. We randomly selected 30 echocardiograms to assess variability. The variables were measured by two independent observers and by one observer at two separate times (time elapsed between the two assessments: 4 weeks). Intra-observer variability (the mean of absolute differences between two measurements) in the evaluation of end-diastolic volume (EDV) and end-systolic volume (ESV) was $3.3 \pm 2.9\%$ and $3.2 \pm 2.7\%$, respectively; inter-observer variability was $3.7 \pm 2.9\%$ and $5.7 \pm 6.4\%$, respectively. To evaluate regional systolic function, the left ventricle was divided according to a 16-segment model as recommended by the American Society of Echocardiography.[14] For each segment, wall motion was scored from 1 (normal) to 4 (dyskinetic) and a global wall motion score index (WMSI) was calculated as the average over 16 segments. From mitral Doppler tracings, the following variables were measured: peak velocity of early rapid filling wave (*E*), peak flow velocity at atrial contraction (*A*), *E*/*A* ratio, and deceleration time of early filling.

Statistical analysis

Stata 9.0 software was used for statistical analysis. Continuous variables were described as mean ± standard or median with 25th and 75th percentiles; frequencies were expressed as percentages. Since there is no consensus, the median value of the admission glycaemia was used as the threshold value defining SH. Continuous variables were compared with the unpaired Student's *t*-test or with non-parametric tests, as appropriate. Discrete variables were compared using χ^2 analysis or Fisher's exact test as appropriate. Two-sided *P*-value <0.05 was considered statistically significant. *P*-values were not adjusted for multiple testing; the inflation of the experiment-wise Type I error was limited by having a pre-specified hypothesis and focusing on one primary endpoint, EDV. Independent correlates of change in EDV were identified by multiple linear regression. The variables entered in the multivariable model were SH, age, sex, peak creatine-kinase (CK), final TIMI flow grade, systolic blood pressure, and WMSI. Colinearity was excluded by means of a correlation matrix between candidate predictors. The linearity and continuity assumptions were assessed by plotting residuals against independent variables. To illustrate the increased risk associated with SH, LV remodelling was defined as a >20% increase in EDV between baseline and 1 year; this definition has been previously used to indicate severe remodelling.[15] Odds ratios adjusted for age, sex, peak creatine-kinase (CK), final TIMI flow grade, heart rate, systolic blood pressure, and WMSI were computed from a multivariable logistic regression model. The variables were included into the model without using a building procedure. Linearity assumption for continuous variables was assessed using the graphic method. The Hosmer–Lemeshow goodness-of-fit test was used to check that the model adequately fit the data. Sample size calculations were based on a two-sided alpha error of 0.05 and 80% power. On the basis of unpublished data from our echocardiographic laboratory showing an EDV of 68 ± 15 mL/m^2 after MI, we calculated that 150 patients would provide sufficient power to detect a 10% difference in EDV measured at 1 year between patients with SH and patients without SH.

Results

Most of the patients were male with a mean age of 56.2 ± 14.2. Initial reperfusion therapy was thrombolysis in 64% of the patients and primary angioplasty in 36%. During hospitalization, coronary angiography was performed in all patients and percutaneous coronary interventions (PCIs) in 93%; when PCI was performed, coronary stenting was almost systematic (99%).

Median glycaemia on admission was 7.0 (6.1–8.7) mmol/L. *Table 1* summarizes the baseline characteristics of the study population according to the presence or absence of SH defined as a glycaemia on admission ≥7.0 mmol/L. Patients with SH were older and more frequently female; peak CK and the proportion of patients with a final TIMI flow grade <3 were higher in patients with SH. Fasting glycaemia measured prior to hospital discharge was slightly higher in patients with SH on admission [5.2 (4.9–5.5) mmol/L vs. 5.0 (4.7–5.3) mmol/L; $P = 0.02$].

During the 1-year follow-up period, seven patients died (six patients in the SH group and one patient in the no SH group; $P = 0.12$); one patient was lost to follow-up. The use of major medications at hospital discharge and during follow-up is shown in *Table 2*. Most patients in both groups received at least one antiplatelet drug, a beta-blocker, an angiotensin-converting enzyme (ACE)-inhibitor or an angiotensin II receptor blocker (ARB), and a statin throughout the 1-year follow-up period. The proportion of patients receiving diuretics was higher in patients with SH. No patient received insulin at hospital discharge or during follow-up; a single patient in the SH group received an oral hypoglycaemiant at 1-year follow-up.

Echocardiographic follow-up was performed in 137 of 154 eligible patients (89%; 87% in the SH group, and 91% in the no SH group). The major characteristics of the 137 patients who underwent echocardiographic follow-up did not differ from those of the 17 patients without echographic follow-up (data not shown). Echocardiographic data at baseline and during follow-up are summarized in *Table 3*. At baseline, EDV, ESV, *E*/*A* ratio, and early mitral deceleration time did

Table 1 Baseline characteristics of the study population ($n = 162$) according to absence/presence of stress hyperglycaemia on admission

	Glycaemia <7 mmol/L ($n = 78$)	Glycaemia ≥ 7.0 mmol/L ($n = 84$)	*P*-value
Age, years	52.1 ± 14.0	60.1 ± 13.4	0.0003
Female gender, *n* (%)	12 (15)	25 (30)	0.03
Body mass index, kg/m^2	26.7 ± 5.3	26.8 ± 4.1	0.96
Hypercholesterolaemia, *n* (%)	34 (44)	38 (45)	0.83
Hypertension, *n* (%)	27 (35)	35 (42)	0.36
Prior angina, *n* (%)	9 (12)	5 (6)	0.21
Prior PCI, *n* (%)	3 (4)	4 (5)	0.77
Initial reperfusion therapy			
Thrombolysis, *n* (%)	51 (65)	52 (62)	0.66
Primary PCI, *n* (%)	27 (35)	32 (38)	
Time from symptom onset to reperfusion, hours	4 (2–7)	4 (2–7)	0.97
Peak total CK	2131 (1104–4297)	3072 (1769–4656)	0.02
Coronary angiography during hospitalization, *n* (%)	78 (100)	84 (100)	–
Multivessel CAD, *n* (%)	27 (35)	27 (32)	0.41
PCI during hospitalization, *n* (%)	71 (91)	80 (95)	0.29
Stent implantation, *n* (%)	71 (91)	78 (93)	0.67
Final TIMI flow in culprit vessel grade <3, *n* (%)	5 (6)	15 (18)	0.03
Fasting glycaemia pre-discharge, mmol/L	5.0 (4.7–5.3)	5.2 (4.9–5.5)	0.02
Serum creatinine predischarge, mg/dL	0.96 ± 0.24	1.00 ± 0.24	0.24
Heart rate, b.p.m.	67 ± 10	66 ± 11	0.84
Systolic blood pressure, mmHg	114 ± 18	109 ± 18	0.06
Diastolic blood pressure, mmHg	67 ± 14	64 ± 10	0.12

Table 2 Major medications at hospital discharge and during follow-up according to absence/presence of stress hyperglycaemia on admission

	Glycaemia <7 mmol/L	Glycaemia ≥ 7 mmol/L
Aspirin (Hospital discharge/3-month/1-year), %	97/92/86	98/94/79
Clopidogrel (Hospital discharge/3-month/1-year), %	98/76/58	93/73/52
Beta-blockers (Hospital discharge/3-month/1-year), %	94/90/88	99/97/93
ACE-inhibitors or ARB (Hospital discharge/3-month/1-year), %	99/96/95	97/95/94
Spironolactone (Hospital discharge/3-month/1-year), %	10/10/8	13/16/14
Diuretics (Hospital discharge/3-month/1-year), %	13/9/12	30[a]/25[a]/26[b]
Statins (Hospital discharge/3-month/1-year), %	99/96/96	98/93/92
Insulin (Hospital discharge/3-month/1-year), %	0/0/0	0/0/0
Oral hypoglycaemiant agents (Hospital discharge/3-month/1-year), %	0/0/0	0/0/1

Data expressed as percentages/162 patients at hospital discharge, 159 patients at 3 months, 153 patients at 1 year.
[a]$P = 0.009$ vs. glycaemia <7 mmol/L.
[b]$P = 0.03$ vs. glycaemia <7 mmol/L.

not differ between the two groups while patients with SH had slightly higher WMSI and had a trend for a lower EF. We observed a significant LV remodelling in patients with SH as demonstrated by an increase in EDV and ESV throughout follow-up while no change was observed in patients without SH (*Figure 1*). The change in EDV from baseline to 1 year was 11.4 ± 16.5 mL/m^2 in patients with SH vs. 1.9 ± 11.1 mL/m^2 in patients without SH ($P < 0.0001$). The change in ESV from baseline to 1 year was 6.4 ± 12.4 mL/m^2 in patients with SH vs. 0.2 ± 8.5 mL/m^2 in patients without SH ($P < 0.0001$). Consequently, EDV and ESV at 1 year differed significantly between the two groups ($P = 0.0002$). The changes in EF, WMSI, *E*/*A* ratio, and early mitral deceleration time did not differ significantly between the two groups. When glycaemia on admission was assessed as a continuous variable, it was significantly associated with the change in EDV from baseline to 1 year ($P = 0.0003$) and with the change in ESV from baseline to 1 year ($P = 0.003$).

To provide information on LV remodelling in patients with the higher levels of glycaemia on admission, patients in the SH group were separated in two subgroups: 7–10 mmol/L ($n = 48$) and >10 mmol/L ($n = 20$). LV remodelling did not differ significantly between the two groups. The change in EDV from baseline to 1 year was 10.4 ± 14.4 mL/m^2 in the 7–10 mmol/L group vs. 13.8 ± 21.1 mL/m^2 in the >10 mmol/L group ($P = 0.46$). The change in ESV from baseline to 1 year was 6.0 ± 11.7 mL/m^2 in the 7–10 mmol/L group vs. 7.5 ± 14.2 mL/m^2 in the >10 mmol/L group ($P = 0.64$).

When LV remodelling was defined as a >20% increase in EDV between baseline and 1 year, it was observed in

Table 3 Echocardiographic follow-up according to absence/presence of stress hyperglycaemia on admission ($n = 137$ patients)

	Glycaemia <7 mmol/L ($n = 69$)	Glycaemia ≥ 7.0 mmol/L ($n = 68$)	*P*-value
End-diastolic volume, mL/m^2			
Baseline	55.7 ± 14.8	57.3 ± 13.8	0.52
3 months	58.3 ± 14.7	61.8 ± 15.6	0.21
1 year	57.6 ± 14.2	68.7 ± 19.6	0.0002
Changes from baseline to 1 year	1.9 ± 11.1	11.4 ± 16.5	<0.0001
End-systolic volume, mL/m^2			
Baseline	27.1 ± 8.2	29.5 ± 9.7	0.12
3 months	27.7 ± 8.2	31.7 ± 12.8	0.04
1 year	27.4 ± 9.2	36.0 ± 15.9	0.0002
Changes from baseline to 1 year	0.2 ± 8.5	6.4 ± 12.4	<0.0001
EF, %			
Baseline	51.2 ± 8.7	48.7 ± 9.3	0.10
3 months	52.3 ± 8.7	49.6 ± 9.0	0.09
1 year	52.7 ± 9.2	49.4 ± 9.9	0.05
Changes from baseline to 1 year	1.5 ± 9.0	0.7 ± 9.9	0.63
WMSI			
Baseline	1.83 ± 0.17	1.88 ± 0.14	0.03
3 months	1.71 ± 0.20	1.81 ± 0.17	0.006
1 year	1.66 ± 0.20	1.75 ± 0.21	0.02
Changes from baseline to 1 year	−0.16 ± 0.13	−0.13 ± 0.16	0.31
E/A			
Baseline	1.42 ± 0.67	1.48 ± 0.60	0.60
3 months	1.27 ± 0.57	1.44 ± 0.65	0.17
1 year	1.15 ± 0.59	1.35 ± 0.77	0.11
Changes from baseline to 1 year	−0.26 ± 0.49	−0.13 ± 0.84	0.27
Early mitral deceleration time, ms			
Baseline	190 ± 57	171 ± 53	0.06
3 months	203 ± 53	197 ± 70	0.61
1 year	209 ± 54	208 ± 68	0.98
Changes from baseline to 1 year	19 ± 68	37 ± 76	0.15

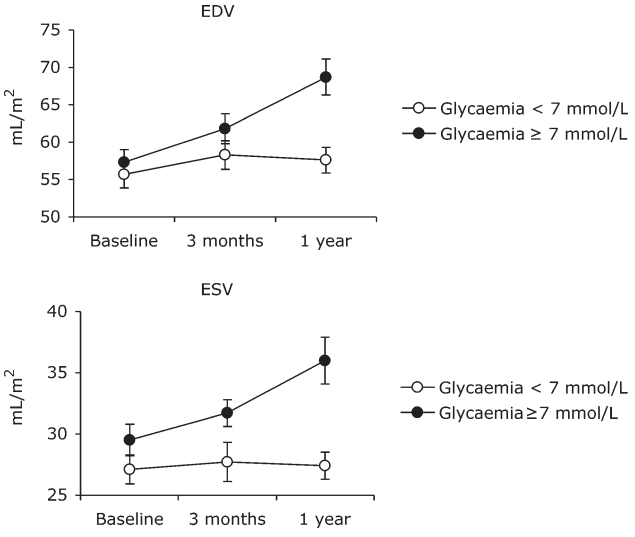

Figure 1 Changes in end-diastolic and end-systolic volumes (mean ± SEM) throughout 1-year follow-up according to glycaemia on admission.

31 (46%) patients in the SH group vs. 13 (19%) patients in the no SH group ($P = 0.0008$); glycaemia on admission was 7.7 (6.6–9.9) mmol/L in patients with LV remodelling vs. 6.6 (6.0–8.2) mmol/L in patients without ($P = 0.004$).

Multivariable analyses were performed to determine independent predictors of LV remodelling. As shown in *Table 4*, two variables were independently associated with change in EDV: the baseline WMSI and SH; similar results were found when glycaemia on admission was entered into the model as a continuous variable. Finally, by logistic regression, SH was an independent predictor of LV remodelling [adjusted OR: 3.22 (1.31–7.94); $P = 0.01$]. *Figure 2* illustrates the potential interest of combining WMSI with SH to provide an estimate of the risk of LV remodelling; the incidence of LV remodelling in patients who had both SH on admission and a WMSI >1.88 (median value) was 76%.

Discussion

Previous studies have demonstrated that patients with SH on admission for acute MI are at increased risk of mortality and congestive heart failure.[1–3] Moreover, it has been suggested that SH-associated risk may be greater in patients with MI who do not have antecedent diabetes than in those with diabetes. In a systematic overview of the literature, SH was associated with a highly significant increase in risk of in-hospital death in non-diabetic patients, whereas in diabetic patients the risk of death was only moderately increased.[4] More recently, a study performed in a very large sample of elderly patients demonstrated that the association between admission glucose and mortality was not limited to the early in-hospital phase but extended up to 1-year follow-up.[12] In this study, the relationship

Table 4 Multivariable linear models of change in end-diastolic volume from baseline to 1 year follow-up

Variables	Multivariable beta coefficient	*P*-value
Model 1		
Baseline WMSI	0.288	0.001
Glycaemia on admisssion ≥7 mmol/L	0.218	0.009
Final TIMI flow grade <3	0.145	0.07
Female gender	0.121	0.12
Systolic blood pressure	−0.109	0.16
Peak total CK	0.099	0.21
Heart rate	0.051	0.55
Age	−0.012	0.89
Model 2		
Baseline WMSI	0.284	0.001
Glycaemia on admisssion (continuous)	0.173	0.03
Final TIMI flow grade <3	0.141	0.08
Female gender	0.132	0.09
Systolic blood pressure	−0.120	0.13
Peak total CK	0.100	0.21
Heart rate	0.052	0.54
Age	0.029	0.71

In model 1, glycaemia on admission was entered as a qualitative variable (< or ≥7 mmol/L). In model 2, glycaemia on admission was entered as a continuous variable.

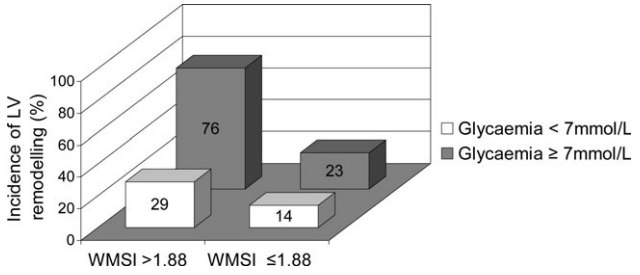

Figure 2 Incidence of LV remodelling during 1-year follow-up according to glycaemia on admission and WMSI at discharge. Glycaemia on admission improved risk-prediction model based on WMSI alone.

between admission glucose greatly differed according to diabetic status: admission glucose was associated with a step linear increase in mortality in non-diabetic patients, whereas in diabetic patients elevated glucose levels on admission were not associated with an increased risk of mortality, except at severe levels of hyperglycaemia. Recent data from non-diabetic patients included in the USIC registry have also shown an association of SH with 1-year mortality.[16] Moreover, in addition to its impact on mortality, SH has also been associated with an increased risk of congestive heart failure; again, the association was observed in non-diabetic patients but not in diabetic patients.[4]

Although there is a large consensus regarding the prognostic impact of SH both short- and mid-term after MI in non-diabetic patients, the exact mechanisms underlying this association remain poorly understood. Several studies have suggested that admission glucose may be associated with larger infarct size and worse LV function, but this remains controversial.[12,13,17] In the present study, peak CK was significantly higher in patients with SH. SH was also associated with more systolic abnormalities at predischarge echocardiography as judged by the WMSI; however, there was only a non-significant trend for a lower EF in patients with SH. Although parameters measured at hospital admission or discharge are helpful to predict mid- and long-term clinical outcome after MI, they may not be the most accurate prognostic indicators. Indeed, follow-up studies have documented progressive changes in the LV chamber size, shape, muscle mass, and function during the early months or years following MI, a process known as LV remodelling.[5] LV remodelling has been recognized as a major predictor of heart failure and cardiovascular death after MI.[6,7] We therefore designed the present study to analyse the impact of SH not only on predischarge LV function but also on LV remodelling assessed by echocardiography throughout a 1-year follow-up.

The main finding of our study is that patients with SH had a higher degree of LV remodelling during follow-up. Importantly, SH remained a major predictor of LV remodelling (with odds ratio >3) when the analyses were adjusted for measurements of infarct size. At least two possible explanations may account for this observation. SH on admission can either be an indicator of concomitant metabolic abnormalities which may themselves play a role in the remodelling process (higher free fatty acid concentrations, insulin resistance, and impaired myocardial glucose use), or, alternatively, can simply be a marker of more extensive myocardial damage that would not be entirely taken into account by relatively crude measurements of infarct size (peak CK, predischarge EF, or WMSI), but would, nevertheless, lead to an increased remodelling. Previous studies have suggested that SH could reduce collateral flow to the risk area,[18] could abolish the effect of preconditioning,[19] or may be associated with the no-reflow phenomenon.[20]

A precise answer to these physiopathological questions is of course largely beyond the scope of the present clinical study. However, several points may warrant consideration. First, we excluded all patients who had new diagnosis of diabetes mellitus during hospitalization. Moreover, we showed that the incidence of diabetes mellitus requiring medical treatment during the 1-year follow-up period was very low (a single occurrence in the group of patients with SH). Therefore, the classic interpretation that many patients with SH have in fact previously undiagnosed diabetes mellitus cannot apply to our results. We also observed that body mass index and frequency of hypertension were similar in patients with or without SH. Thus, there does not appear to be major metabolic differences between the two groups. Slight differences may, however, exist as suggested by the significantly higher fasting glycaemia at discharge in patients with SH on admission. Although the clinical significance of the observed 0.2 mmol/L difference may be questioned, we cannot exclude that this may reflect more subtle metabolic changes that would be associated with the remodelling process.

Clinical implications

Identifying patients prone to LV dilation who are at risk for sustaining adverse cardiovascular events is an integral part of management after MI. High-risk patients could indeed

be stratified for more aggressive therapy and/or for pronounced follow-up.

Although various predictive factors of LV remodelling have been suggested by prior studies,[8,11,15,21,22] there is still a need for non-invasive, widely available, and relatively inexpensive methods to estimate the risk of LV dilation after MI in routine clinical practice. At present, risk stratification is largely based on the results of predischarge echocardiography. If confirmed in independent studies, our finding that SH is a strong independent predictor of LV remodelling, even when predischarge echocardiographic variables are taken into account, may have important clinical implications.

Study limitations

First, our results were obtained in selected patients with first anterior MI and substantial residual akinesia ($\geq$3 segments) at predischarge echocardiography; they may not apply to all post-MI patients. On the other hand, our results were obtained in patients with a very contemporary treatment of MI including a large use of coronary revascularization, ACE-inhibitors, and beta-blockers.

Secondly, we did not perform systematic angiographic follow-up to document the long-term patency of the infarct-related artery (IRA). However, the high rate of coronary stenting in the present study would be expected to result in a high rate of IRA patency. Indeed, although late re-occlusion of the IRA has been shown to occur in 15–30% of cases after thrombolysis[23] or balloon angioplasty,[24] coronary stenting of the IRA has been documented to result in extremely high long-term patency rates.[25]

Finally, several parameters that have been recently shown to influence the degree of LV remodelling, such as markers of neurohormonal activation[26] were not determined in this study. Adjusting for these variables may have modified the impact of SH on LV remodelling. However, our choice was rather to determine predictors that could be easily used in routine clinical practice in most centres.

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Conflict of interest: None declared.

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Clinical vignette

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Two great cardiac veins: demonstration by computed tomography, conventional coronary angiography, and during surgery

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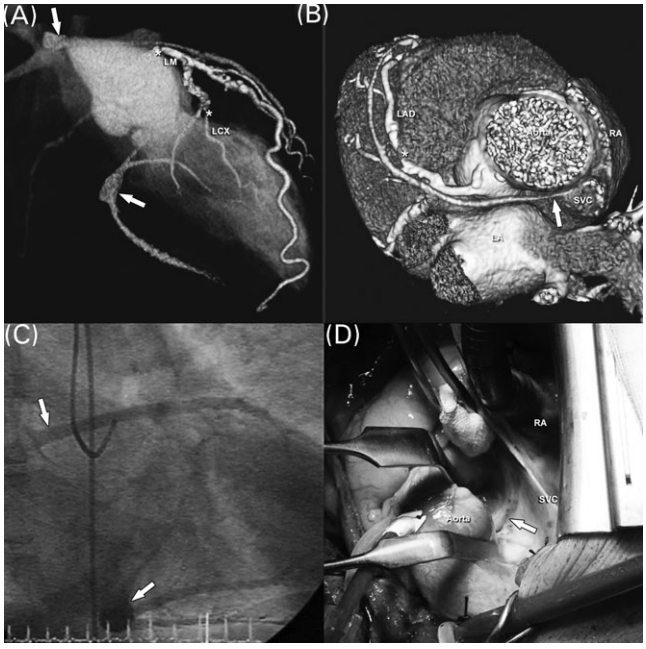

A 62-year-old man with typical angina pectoris was referred for imaging of the coronary arteries to detect stenoses. Multislice computed tomography (CT) demonstrated significant coronary three-vessel disease. CT also depicted an anterior interventricular cardiac vein that did not follow the normal course of this vein parallel to the left circumflex coronary artery (LCX), but ran between the aorta and the left atrium parallel to the left main (LM) coronary artery and became a tributary of the superior vena cava (SVC) (upper arrow in Panel A, coronary arteries are bright and veins are red). There was a second great cardiac vein with a normal opening into the coronary sinus (lower arrow in Panel A). On a view from above the orifice of the abnormal coronary vein into the SVC could be well seen (arrow in Panel B, left and right atrium, LA, and RA). Because of the stenoses in the LM coronary artery, left anterior descending (LAD), and LCX (asterisks in Panels A and B), the patient subsequently underwent conventional coronary angiography that confirmed the coronary stenoses and the existence of two great cardiac veins (arrows in Panel C). This hitherto unknown coronary venous anomaly was confirmed during subsequent surgery necessary for coronary artery bypass grafting (view from above in Panel D). Anomalies of the coronary veins and their non-invasive visualization are increasingly important because they can serve as conduits for bypass surgery and for left ventricular epicardial lead placement to achieve biventricular pacing.