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ORIGINAL ARTICLE
Interventional cardiology and cardiac surgery

Baseline characteristics and 1-year outcome by left ventricular function in the CABG PREFERS

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Aims

The aim of this study is to describe patients undergoing elective coronary artery bypass grafting (CABG) surgery by left ventricular (LV) function at baseline and 1-year follow-up.

Methods and results

In the single-centre CABG PREFERS cohort prospective study, we classified patients planned for elective CABG by LV function assessed by echocardiography and N-terminal pro-B-type natriuretic peptide (NT-proBNP) into three phenotype groups: preserved ejection fraction (EF; pEF), reduced EF (rEF), and normal, irrespective of signs or symptoms of heart failure (HF). At baseline and 1-year follow-up, electrocardiogram, echocardiography, cardiac magnetic resonance imaging, laboratory tests, and quality of life were assessed. Sixty-one of a total of 136 patients (45%) had systolic and/or diastolic LV dysfunction (25% pEF, 20% rEF, and the rest 55% none: the normal group). Median EF was 59% (pEF), 40% (rEF), and 59% (normal). Most patients had multivessel coronary artery disease without left main stem stenosis (60%). At 1-year follow-up, some improvements in echo parameters were seen in pEF and rEF. But in the normal group compared to baseline, there were deteriorations in the following: E/é: 7.8–8.9, $P < 0.001$; NT-proBNP 150–182 ng/L, $P = 0.015$; and estimated glomerular filtration rate (eGFR) 82.5–78.9 mL/min/1.73 m^2, $P = 0.003$. During a median follow-up time of 2.9 years, eight patients (5.8%) died and eight (5.8%) were hospitalized for HF.

Conclusion

In patients undergoing elective CABG, signs of LV dysfunction were common and found in 45%. Patients with normal LV function showed signs of worsening systolic and diastolic LV function, eGFR, and NT-pro-BNP at 1-year follow-up.

Registration

Clinicaltrials.gov identifier: NCT03671122

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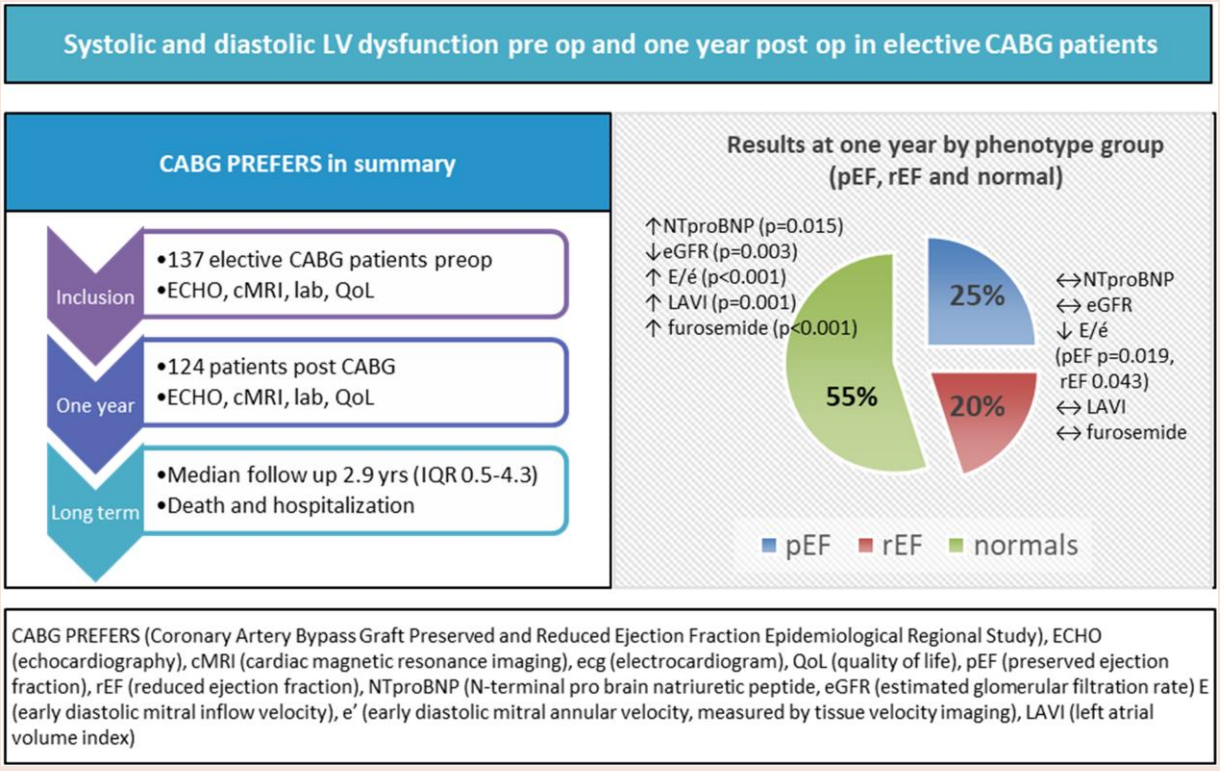
Graphical Abstract



CABG PREFERS (Coronary Artery Bypass Graft Preserved and Reduced Ejection Fraction Epidemiological Regional Study), ECHO (echocardiography), cMRI (cardiac magnetic resonance imaging), ecg (electrocardiogram), QoL (quality of life), pEF (preserved ejection fraction), rEF (reduced ejection fraction), NTproBNP (N-terminal pro brain natriuretic peptide, eGFR (estimated glomerular filtration rate) E (early diastolic mitral inflow velocity), e' (early diastolic mitral annular velocity, measured by tissue velocity imaging), LAVI (left atrial volume index)

Keywords Coronary artery disease • Coronary bypass surgery • Cardiac imaging • Bioinformatics • Heart failure

Introduction

Coronary artery bypass grafting (CABG) is an established revascularization therapy for ischaemic heart disease.[1] Percutaneous coronary intervention (PCI) is used whenever suitable both in the acute coronary syndrome and stable settings whereas elective CABG is mostly performed in stable patients, who are deemed unsuitable for PCI.

It has long been known that presence of heart failure (HF) with reduced ejection fraction (EF) (HFrEF) predicts short- and long-term prognosis post CABG and that the presence of HF is an important part of pre-operative evaluation.[2] Diastolic LV dysfunction is common and has also been associated with worse outcome.[3] Mortality after CABG is further influenced by comorbidities such as chronic kidney dysfunction.[4] Previous studies investigated the effect of CABG on short-term LV function,[5] but long-term effects in CABG patients have not been studied to the same extent and not in elective CABG patients. The aim of this study was to report imaging data and clinical characteristic of patients scheduled for elective CABG studied before surgery and at a 1-year follow-up visit and followed long term at a single centre.

Patients and methods

The CABG PREFERS study (2014–20) was part of the Preserved and Reduced Ejection Fraction Epidemiological Regional Study in Stockholm (PREFERS) studies.[6] The CABG PREFERS was a prospective, observational single-centre study enrolling patients with stable coronary artery disease (CAD) undergoing elective CABG evaluating baseline and 1-year clinical data, echocardiography, and cardiac magnetic resonance imaging (cMRI) together with long-term outcome assessment. Patients accepted for elective CABG at the Karolinska University Hospital were invited to participate. Inclusion and exclusion criteria have been described elsewhere.[6] In brief, patients were eligible if they did not require concomitant valvular surgery or had chronic kidney disease (CKD) > Stage 4 defined as eGFR < 30 mL/min/1.73 m^2. Consecutive patients were invited by letter followed by telephone call for willingness to participate. The study was conducted according to the Declaration of Helsinki and approved by the Regional Ethics Committee in Stockholm, Sweden (2013/1869-31/1). Oral and written informed consent was obtained from all study participants.

Study design

Patients were assessed by one of three cardiologists (U.L., H.P., and C.L.) and one study nurse (H.K.) before and 1 year after CABG. The pre-operative visit was for logistical reasons performed 4–8 weeks before CABG surgery. Assessments included 12-lead electrocardiogram (ECG), Doppler echocardiography, late gadolinium enhancement cMRI, and routine laboratory panel including N-terminal pro-B-type natriuretic peptide (NT-pro-BNP). Quality of life (QoL) was assessed at the same time intervals with EuroQoL 5 Dimensions (EQ5D) including the visual analogue scale (VAS) 0–100 mm for general health and Minnesota Living with Heart Failure Questionnaire (MLHFQ) for a HF-specific QoL. Medical history and physical examination were

documented in electronic health records in a standardized chart used for HF patients in the Stockholm area. Post CABG, no changes in medical treatment were made by study physicians and patients received standard clinical care including a visit to referring cardiologist within 4–6 weeks and follow-up at the cardiac surgery clinic. The CABG surgery was performed by one cardiac surgeon (M.C.) according to the standard procedure with opening of the pericardial sac.

Doppler echocardiography

Details of the Doppler echocardiography protocol have been previously described.[5] In brief, transthoracic echocardiography was performed with the Vivid 9 ultrasound system (Vingmed-General Electric, Horten, Norway) by two experienced sonographers and images were digitally stored. Data analysis and calculations according to recommendations[7] were performed on an EchoPAC workstation (version 203.82, General Electric, Norway) by two physicians experienced in cardiac imaging (M.E. and E.M.). The biplane method of disks (modified Simpson's rule) was used for EF and LAVI calculations.[8] Global longitudinal strain (GLS) was analysed by speckle-tracking. Ratio of mitral Doppler E wave velocity to mitral annular é wave velocity (E/é) was used for assessment of diastolic LV function and maximal velocity of tricuspid regurgitation (TR Vmax) as an indicator of systolic pulmonary arterial pressure. Relative wall thickness (RWT) was derived by equation RWT = 2 × posterior wall thickness/LV end-diastolic diameter. Right ventricular end-diastolic diameter (RVEDD) and tricuspid annular plane excursion (TAPSE) and right atrial (RA) were assessed. All variables were presented as a mean value of three cardiac cycles.

Cardiac magnetic resonance imaging

Patients underwent assessment with cMRI at baseline on the same day as echocardiography prior to and 1 year after surgery. Cardiac magnetic resonance imaging was performed with a 1.5 T scanner (Magnetom Aera, Siemens Healthcare, Erlangen, Germany) using a six-element phased-array body matrix coil. The state-of-the-art standard protocol included steady-state free precession of the LV in three long-axis images (four-, three-, and two-chamber views) as well as short-axis images which were adjusted to cover from base to apex, with identical positions for all relevant sequences. Late gadolinium enhancement for detection of myocardial scar was obtained 10 min after intravenous injection of 0.2 mmol/kg body weight gadoteric acid (Dotarem, Gothia Medical AB, Billdal, Sweden). Patients with claustrophobia or with eGFR < 30 mL/min did not undergo cMRI.

Definitions

We used ACC/AHA/HFSA criteria on stages on HF based on echocardiographic findings and NT-proBNP results which includes Stage B without current or previous symptoms of HF but with structural echocardiographic changes, signs of elevated filling pressures, and/or elevated NT-proBNP.[9] Patients were classified into three phenotype groups: pEF, rEF, and normal, in a stepwise manner using established criteria[7,8] and an established analysis method[10,11] without regards to signs or symptoms of HF. In *the pEF group*, EF ≥ 45% was required together with majority of the following criteria: septal é < 7 (cm/s) or lateral é < 10 (cm/s), the mean of septal and lateral é < 9 (cm/s), E/é ratio 8 ≥ 15, TR velocity ≥ 2.8 m/s, LA volume index > 34 mL/m^2, and NT-proBNP (pg/mL) ≥ 125 pg/mL. If one of the above-mentioned criteria was lacking to meet a majority, at least one of the additional following criteria was required: LV mass index female > 95 g/m^2 or male > 115 g/m^2, RWT ≥ 0.42, and decrease in E/A at the Valsalva manoeuvre by >50%. The *rEF group* was defined by EF < 45% and the *normal group* defined by EF ≥ 45% and absence of the above criteria for pEF. Atrial fibrillation (AF) was defined as prior diagnosis of any type of AF including paroxysmal, permanent, and persistent as mentioned in medical charts and/or AF on the enrolment ECG. Anaemia was defined as haemoglobin (Hb) < 130 g/L in men and <120 g/L in women.

Extent of coronary artery disease

Extent of CAD was based on pre-operative coronary angiography. Patients were categorized into groups according to the Swedish Coronary Angiography and Angioplasty Registry (SCAAR) registry [part of The Swedish Web-system for enhancement and development of evidence-based care in heart disease evaluated according to recommended therapies (SWEDEHEART)].[12] The five categories in SCAAR are as follows: no main stem stenosis together with one, two, or three vessels and main stem stenosis together with two or three vessel disease respectively (*Table 1*).

Outcomes

Peri-operative complications (<30 days post-operatively) were registered defined according to common practice after open heart surgery as new-onset AF, venous thrombosis, stroke or transient ischaemic attack, hospitalization for infection, and hospitalization for myocardial infarction (MI) or angina pectoris. Long-term outcomes were collected through medical records. Patients were followed until death or censored alive at last long-term follow-up 1 August 2020. All-cause and cardiovascular death, first HF hospitalization, and emergency department visit for HF were registered. Establishment of cardiovascular cause of death was done in agreement by two cardiologists (C.L. and H.P.).

Statistical methods

Data are presented as median and interquartile range (IQR) and number and percentages. For comparison testing between groups, Fishers exact test for categorical and Kruskal–Wallis for continuous variables were used. For changes over time (baseline to 1-year follow-up) within groups, Wilcoxon signed rank test for continuous variables and McNamar's test for categorical variables were used. Differences between the three groups are given in the tables and in the text and are described as *P*-value overall at baseline and at 1-year follow-up and Δ in each group. All analyses were performed by STATA 15.1, USA.

Results

Of the approximately 700 patients undergoing elective CABG at the Karolinska University Hospital during 2014–2019, 286 patients received an invitation letter with a follow-up telephone call. A total of 137 patients were included, and 136 patients (121 men and 15 women) with a median age of 69 years completed the baseline pre-operative visit prior to CABG. The median time from enrolment to surgery was 58 days, IQR (27–92). Of the patients, 124/136 completed the 1-year follow-up visit (*Figure 1*). All patients had stable CAD with or without a previous MI.

Clinical characteristics

Baseline and 1-year follow-up clinical characteristics are presented in *Table 1*. Of the 136 patients that completed the baseline visit, 61 (25%) were classified as pEF, 27 (20%) as rEF, and 75 (55%) as the normal group. None in the pEF group had a history of HF whereas 13 in the rEF (48%) and 4 (5%) in the normal group had a previous HF diagnosis ($P = 0.001$ Δ overall). Multivessel CAD without left main stem stenosis was present in the majority (60%) of patients and similar between groups. Nineteen per cent of the patients had a previous MI and 19% had undergone revascularization.

Table 1 **Baseline and 1-year follow-up patient characteristics**

	Baseline (BL)				One-year follow-up (FU)				Change BL-FU, *P*-values		
Baseline and 1-year follow-up characteristics	**pEF phenotype**	**rEF phenotype**	**Normal phenotype**	***P*-value overall**	**pEF phenotype**	**rEF phenotype**	**Normal phenotype**	***P*-value overall**	**HFpEF phenotype**	**HFrEF phenotype**	**Normal phenotype**
n	34 (25)	27 (20)	75 (55)		32	25	65				
Demographics											
Sex (females)	5 (15)	3 (11)	7 (9)	0.664							
Age (years)	73.0 (69.0, 77.0)	70.0 (65.0, 75.0)	68.5 (62.0, 74.0)	0.026							
Medical history											
Hypertension	29 (85)	24 (89)	52 (69)	0.060							
Hyperlipidaemia	9 (26)	9 (33)	33 (44)	0.200							
Atrial fibrillation[a]	12 (35)	14 (52)	17 (23)	0.019							
Chronic obstructive pulmonary disease	1 (3)	3 (11)	2 (3)	0.172							
Diabetes	6 (18)	13 (48)	22 (29)	0.104							
PAD	4 (12)	2 (7)	1 (1)	0.037							
Stroke/TIA	3 (9)	0	4 (5)	0.554							
Previous MI	4 (12)	3 (11)	13 (17)	0.679							
Previous PCI	8 (24)	2 (7)	11 (15)	0.246							
Previous CABG	3 (9)	0	2 (3)	0.194							
Previous HF	0	13 (48)	4 (5)	<0.001							
Coronary artery disease											
1 vessel, no main stem	0	1 (4)	2 (3)	0.567							
2 vessels, no main stem	4 (12)	3 (11)	13 (18)								
3 vessels, no main stem	23 (70)	16 (59)	42 (57)								
Main stem + 2 vessels	2 (6)	2 (7)	1 (1)								
Main stem + 3 vessels	4 (12)	5 (19)	16 (22)								
Clinical findings											
SBP (mmHg)	152 (139, 166)	143 (131, 159)	140 (124, 149)	0.002	149 (138, 175)	132 (116, 158)	132 (120, 148)	0.001	0.957	0.049	0.056
DBP (mmHg)	82 (75, 88)	83 (74, 90)	79 (70, 84)	0.138	78 (71, 84)	73 (66, 87)	76 (68, 80)	0.142	0.380	0.015	0.001
HR (b.p.m.)	57 (53, 62)	69 (55, 76)	65 (56, 70)	0.004	57 (52, 66)	65 (55, 76)	60 (55, 66)	0.118	0.776	0.757	<0.001
BMI (kg/m^2)	26.8 (23.4, 29.2)	27.1 (24.8, 33.8)	27.6 (24.4, 29.3)	0.190	27.3 (24.1, 29.1)	28.1 (23.8, 32.9)	25.6 (23.8, 28.4)	0.383	0.875	0.448	0.977
Pulmonary rales	2 (6)	0	0	0.007	0	0	0	1.000	n/a	n/a	n/a
Peripheral oedema	1 (3)	0	2 (3)	1.000	0	0	0	1.000	n/a	n/a	n/a
Quality of life											
EQ5D VAS score (0–100)	68 (50, 80)	60 (40, 85)	70 (50, 80)	0.752	80 (70, 88)	80 (70, 90)	80 (70, 90)	0.675	0.002	0.017	<0.001

Continued

Table 1 *Continued*

Baseline and 1-year follow-up characteristics	Baseline (BL)				One-year follow-up (FU)				Change BL-FU, *P*-values		
	pEF phenotype	rEF phenotype	Normal phenotype	*P*-value overall	pEF phenotype	rEF phenotype	Normal phenotype	*P*-value overall	HFpEF phenotype	HFrEF phenotype	Normal phenotype
MLHFQ (0–105)	31 (16, 43)	22 (11, 48)	20 (10, 34)	0.196	10 (5, 26)	13 (7, 26)	7 (2, 17)	0.091	<0.001	0.051	<0.001
Laboratory findings											
eGFR MDRD (mL/min/1.73 m^2)	79.4 (59.9, 91.2)	80.1 (59.2, 88.3)	82.5 (72.2, 92.6)	0.323	73.5 (57.8, 83.9)	69.8 (52.9, 85.3)	78.9 (69.3, 90.1)	0.063	0.074	0.233	0.003
eGFR MDRD < 60 (mL/min/1.73 m^2)	6 (18)	6 (22)	5 (7)	0.051	7 (21)	5 (19)	8 (11)	0.307	0.655	0.706	0.317
NT-proBNP (ng/L)	249 (172, 604)	881 (421, 1320)	150 (73, 242)	<0.001	386 (166, 555)	656 (372, 1220)	182 (101, 370)	<0.001	0.501	0.601	0.015
hsCRP (mg/L)	1.4 (0.6, 2.5)	1.4 (0.7, 2.1)	1.2 (0.5, 2.3)	0.820	1.1 (0.3, 2.0)	1.4 (0.5, 2.9)	1.0 (0.5, 2.0)	0.413	n/a	n/a	0.579
Anaemia[b]	10 (29)	9 (33)	12 (16)	0.216	9 (26)	7 (26)	10 (13)	0.393	0.782	0.480	0.564
Troponin T (ng/L)	10.5 (6.5, 15.5)	13.0 (10.0, 24.0)	11.0 (6.0, 15.0)	0.066	12.5 (8.0, 15.0)	18.0 (11.0, 26.0)	11.0 (8.0, 15.0)	0.018	0.085	0.767	0.049
Total cholesterol (mmol/L)	3.8 (3.5, 4.2)	3.6 (3.1, 4.2)	3.8 (3.4, 4.4)	0.540	3.7 (3.4, 5.0)	3.3 (3.0, 4.0)	3.5 (3.1, 4.2)	0.091	0.856	0.393	0.030
LDL (mmol/L)	2.0 (1.7, 2.9)	1.8 (1.5, 2.3)	1.8 (1.6, 2.5)	0.360	1.9 (1.5, 2.6)	1.8 (1.3, 2.3)	1.8 (1.3, 2.2)	0.387	0.320	0.861	0.110
HDL (mmol/L)	1.3 (1.2, 1.6)	1.1 (1.0, 1.4)	1.2 (0.9, 1.4)	0.237	1.4 (1.1, 1.7)	1.1 (0.9, 1.4)	1.2 (1.0, 1.3)	0.012	0.456	0.327	0.286
Triglycerides (mmol/L)	1.3 (0.8, 1.4)	1.2 (0.8, 1.9)	1.4 (1.1, 1.9)	0.128	1.1 (0.9, 1.6)	1.3 (1.0, 1.7)	1.6 (1.1, 2.0)	0.065	0.932	0.257	0.301
HbA1c (mmol/mol)	41.0 (37.0, 47.0)	43.0 (39.0, 51.0)	40.0 (36.0, 46.0)	0.308	39.0 (38.0, 45.0)	44.5 (41.0, 58.0)	40.0 (37.0, 48.5)	0.031	0.962	0.287	0.229
U-Albumin/creatinine ratio	2.4 (0.8, 6.3)	3.7 (1.1, 7.5)	1.5 (0.7, 3.6)	0.202	2.5 (1.0, 5.7)	2.8 (1.1, 8.7)	1.6 (0.7, 3.9)	0.153	n/a	n/a	0.157
Medical treatment											
Antiplatelet therapy	24 (71)	18 (67)	62 (83)	0.131	21 (62)	13 (48)	51 (68)	0.144	0.439	0.132	0.028
OAC	3 (9)	7 (26)	2 (3)	0.002	3 (9)	7 (26)	3 (4)	0.006	1.000	1.000	0.317
Nitrates longstanding	12 (35)	10 (37)	35 (48)	0.421	0	0	5 (7)	0.242	<0.001	<0.001	<0.001
Beta-blocker	24 (71)	23 (85)	42 (57)	0.022	25 (74)	21 (78)	52 (69)	0.955	0.739	0.317	0.050
ACE inhibitor	8 (24)	11 (41)	16 (22)	0.180	9 (26)	10 (37)	19 (25)	0.505	0.655	0.564	0.317
ARB	8 (24)	10 (37)	18 (24)	0.422	22 (65)	15 (56)	56 (75)	0.241	0.257	0.414	1.000
Statin	26 (76)	26 (96)	60 (80)	0.075	27 (79)	23 (85)	62 (83)	0.686	0.739	0.083	0.617
Ezetimibe	3 (9)	0	4 (5)	0.388	6 (18)	1 (4)	8 (11)	0.387	0.180	<0.001	0.157
Hydrochlorothiazide	1 (3)	0	4 (5)	0.711	1 (3)	0	6 (8)	0.532	1.000	1.000	0.317
Furosemide	4 (12)	3 (11)	0	0.004	5 (15)	9 (33)	2 (3)	<0.001	0.706	0.083	<0.001
MRA	2 (6)	3 (11)	0	0.014	2 (6)	7 (26)	3 (4)	0.004	1.000	0.103	<0.001
Calcium antagonist	12 (35)	8 (30)	24 (32)	0.909	15 (44)	5 (19)	26 (35)	0.143	0.366	0.180	0.670

Continued

Table 1 *Continued*

Baseline and 1-year follow-up characteristics	Baseline (BL)				One-year follow-up (FU)				Change BL-FU, *P*-values		
	pEF phenotype	rEF phenotype	Normal phenotype	*P*-value overall	pEF phenotype	rEF phenotype	Normal phenotype	*P*-value overall	HFpEF phenotype	HFrEF phenotype	Normal phenotype
Glucose lowering therapy	6 (18)	10 (37)	12 (16)	0.076	6 (18)	9 (33)	16 (21)	0.557	1.000	0.317	0.157
Whereof insulin	1 (3)	3 (11)	6 (8)	0.451	1 (3)	4 (15)	5 (7)	0.265	1.000	0.317	0.317

Data are *n* (%) or median (IQR).
PAD, peripheral artery disease; TIA, transient ischaemic attack; MI, myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; HF, heart failure; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; b.p.m., beats per minute; MLHFQ, Minnesota Living with Heart Failure Questionnaire; eGFR, estimated glomerular filtration rate; MDRD, modification of diet in renal disease; NT-proBNP, N-terminal pro brain natriuretic peptide; hsCRP, high-sensitivity C-reactive protein; LDL, low-density lipoprotein; HDL, high-density lipoprotein; OAC, oral anticoagulants; ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blockers; MRA, mineralocorticoid receptor antagonists.
[a]Atrial fibrillation (AF) = history of and/or AF at ECG.
[b]Anaemia = Hb < 130 g/L men, <120 g/L women.

Figure 1 Consort diagram.

Hypertension was the most frequent comorbidity overall (77%) with a trend to be more common in the rEF and pEF groups compared to normal ($P = 0.060$ overall). Diabetes was present in one-third of patients, most common in rEF (48%). Atrial fibrillation according to our definitions was found in 52%, more often in the rEF group vs. pEF and normal ($P = 0.019$ Δ overall). Median age was highest in pEF (73.0) and lowest in the normal group (68.5 years; $P = 0.026$ Δ overall). Systolic blood pressure was higher ($P = 0.002$) and heart rate lower ($P = 0.04$) in pEF compared to rEF and normal groups. Only patients in the pEF group had rales on physical examination. Overall, conduction disturbances such as right or left bundle branch block were rare with left bundle branch block only found in rEF. As regards NT-proBNP, pEF (249 ng/L) and rEF (881 ng/L) had higher concentrations than the normal group (150 ng/L). Renal function was worse in the pEF and rEF groups compared to normal with greater proportion of patients with eGFR < 60 mL/kg/min. Beta-blockers were prescribed in 71% of the pEF group compared to 85% of rEF and 57% of patients in the normal group ($P = 0.022$ Δ overall). Antiplatelet or OAC and lipid-lowering therapy were used in most patients.

At 1-year follow-up visit, systolic blood pressure was higher in the pEF group ($P = 0.001$ Δ overall). The NT-proBNP was persistently higher in the rEF group compared to the other groups ($P < 0.001$ Δ overall), while in the normal group, a slight increase in NT-proBNP from 150 to 182 ng/L ($P = 0.015$) and worsening of eGFR from 82.5 to 78.9 mL/min/1.73 m^2 ($P = 0.003$) were noted.

An increment of ≥25% in NT-proBNP concentration compared to baseline was found in 41% in pEF, 22% in rEF, and 43% in normal group, respectively (NS).

Overall, significantly less nitrates were prescribed after 1 year and more patients received ACEi/ARB compared to baseline (*Table 1*). Most patients continued on lipid-lowering therapy.

Echocardiography

Baseline and 1-year follow-up echocardiographic results are presented in *Table 2* and *Figure 2*. Information about missing data is provided as *Supplementary material online, Table S2*. At baseline, median EF for the pEF, rEF, and normal groups was 59%, 40%, and 59%, respectively. Global longitudinal strain was −17.0% in the pEF group, −12.0% in the rEF group, and −18.5% in the normal group. At baseline, LVEDD was largest in the rEF group (54 mm, $P < 0.001$ Δ overall), and this group also had the largest LV mass index (126 g/m^2, $P < 0.001$Δ overall). The E/é ratio was 10.7 in the pEF group, 9.5 in the rEF group, and 7.8 in the normal group. The largest LAVI (41.8 mL/m^2) was seen in the pEF group ($P < 0.001$ Δ overall). The lowest TAPSE was seen in the rEF group (17.2 mm) compared to 21 mm in the other two groups ($P < 0.001$ Δ overall).

One year after CABG, EF declined ≥10% from baseline in eight patients whereof seven (26%) in the rEF group and one (1%) in the normal group. Overall, in the rEF group, LV volumes decreased and EF increased significantly. The E/é increased from 7.8 to 8.9 ($P < 0.001$) and LAVI from 31.5 to 33.0 mL/m^2 ($P < 0.001$). At least ≥2 units increase in E/é ratio or increase of E/é ratio to >14 was found in 44% of normal, 37% of rEF, and 12% of the pEF patients ($P < 0.003$ Δ overall).

In the normal group, right ventricular end-diastolic diameter (RVEDD) increased compared to baseline (35.0 to 37.0 mm, $P = 0.013$) as did right atrial area (15.0 to 17.0 cm^2; $P = 0.002$). Tricuspid annular plane excursion deteriorated in all groups until the 1-year follow-up and below normal reference. The E/é ratio decreased (*Figure 2*) in the rEF and pEF groups (10.7 to 9.9, $P = 0.019$ and 9.5 to 8.6, $P = 0.043$, respectively). Right atrial area increased in the pEF (17.4 to 19.0 cm^2, $P = 0.003$).

Cardiac magnetic resonance imaging

Ninety-five patients underwent cMRI at baseline and 76 at the 1-year follow-up (*Table 2*). At baseline, 61/95 patients (64%) had signs of smaller ischaemic scarring without diagnosis of an acute coronary syndrome. Of the 17/20 patients with a baseline history of MI, 14 patients (82%) had visible smaller ischaemic scarring, 3 pEF (17%), 2 rEF (12%), and 9 normal (53%) (*Table 2*). At the 1-year follow-up cMRI, new smaller ischaemic scarring was noted in five patients whereof one (4%) in the pEF group and four (9%) in the normal group.

Quality of life

Overall, QoL improved from baseline to 1-year follow-up in all groups and by all QOL methods. The Minnesota score at baseline indicated moderate symptoms in all groups ranging from 31, 22, and 20 in the pEF, rEF, and normal groups, respectively. It improved significantly in the pEF and normal groups from baseline to 1-year follow-up ($P < 0.001$), with borderline significance in the rEF group ($P = 0.051$). In parallel, the EQ5D VAS score indicated moderate symptoms at baseline with significant 1-year improvements.

Table 2 cMRI, ECHO, and ECG

cMRI, ECHO, and ECG	Baseline (BL)				Follow-up 12 m (FU)				Change BL-FU, *P*-values		
	pEF	rEF	Normal	*P*-value	pEF	rEF	Normal	*P*-value	pEF	rEF	Normal
Cardiac magnetic resonance imaging	*n* = 29	*n* = 13	*n* = 53		*n* = 25	*n* = 9	*n* = 42				
Infarction scar (*n*, %)	17 (59)	11 (85)	33 (62)	0.247	16 (64)	8 (89)	28 (67)	0.407	0.317	n/a	0.046
New infarction scar at FU (*n*, %)					1 (4)	0 (0)	4 (9)	0.816			
Echocardiography	*n* = 34	*n* = 27	*n* = 75		*n* = 31	*n* = 25	*n* = 67				
LVEDD (mm)	46.5 (43.0, 51.0)	54.0 (51.0, 59.0)	47.0 (44.0, 50.0)	<0.001	48.0 (42.0, 52.0)	54.0 (50.0, 58.0)	47.0 (45.0, 50.0)	<0.001	0.515	0.569	0.718
IVS thickness (mm)	13.0 (11.0, 14.0)	14.0 (11.0, 14.0)	12.0 (11.0, 13.0)	0.024	12.0 (11.0, 13.0)	12.0 (11.0, 13.0)	11.0 (10.0, 13.0)	0.150	0.400	0.053	0.208
PW thickness (mm)	10.0 (9.0, 11.0)	10.0 (9.0, 10.0)	9.0 (8.0, 10.0)	0.001	10.0 (9.0, 10.0)	10.0 (9.0, 10.0)	9.0 (8.0, 10.0)	0.100	0.405	0.530	0.521
LV mass (g)	197.5 (166.9, 230.1)	251.6 (209.7, 295.0)	178.0 (143.8, 205.0)	<0.001	185.0 (154.0, 238.0)	223.0 (198.0, 270.0)	173.0 (141.0, 205.0)	<0.001	0.337	0.098	0.854
LV mass index (g/m^2)	98.8 (85.9, 114.8)	125.8 (107.1, 139.9)	90.0 (74.9, 103.8)	<0.001	95.0 (83.0, 118.0)	107.0 (97.0, 126.0)	89.0 (75.0, 103.0)	<0.001	0.411	0.093	0.583
RWT (2PW/LVDD)	0.4 (0.4, 0.5)	0.4 (0.3, 0.4)	0.4 (0.3, 0.4)	0.012	0.4 (0.4, 0.5)	0.4 (0.3, 0.4)	0.4 (0.3, 0.4)	0.062	0.244	0.788	0.486

Continued

Table 2 *Continued*

	Baseline (BL)				Follow-up 12 m (FU)				Change BL-FU, *P*-values		
cMRI, ECHO, and ECG	**pEF**	**rEF**	**Normal**	***P*-value**	**pEF**	**rEF**	**Normal**	***P*-value**	**pEF**	**rEF**	**Normal**
LVEDV (mL)	130.0 (113.0, 152.8)	162.0 (131.0, 193.8)	112.9 (97.0, 126.0)	<0.001	117.0 (105.0, 137.0)	157.0 (128.0, 181.0)	102.0 (93.0, 129.0)	<0.001	0.002	0.026	0.480
LVEDVI (mL/m^2)	66.8 (57.0, 74.5)	75.0 (65.2, 99.5)	57.0 (48.0, 65.0)	<0.001	60.0 (55.0, 70.0)	78.0 (60.0, 91.0)	53.5 (46.0, 66.0)	<0.001	0.015	0.044	0.589
LVESV (mL)	52.6 (42.3, 65.1)	93.0 (77.0, 132.0)	43.3 (37.8, 55.0)	<0.001	47.0 (41.0, 59.0)	88.0 (65.0, 101.0)	45.0 (37.0, 54.0)	<0.001	0.018	0.005	0.660
LVESVI (mL/m^2)	27.7 (22.0, 32.0)	45.0 (37.0, 60.0)	23.0 (19.0, 27.0)	<0.001	25.0 (21.0, 31.0)	41.0 (32.0, 52.0)	22.0 (18.0, 26.0)	<0.001	0.101	0.006	0.808
EF (%)	59.0 (56.0, 63.0)	40.0 (37.0, 44.0)	59.0 (57.0, 63.0)	<0.001	59.0 (56.0, 64.0)	43.0 (42.0, 51.0)	59.0 (56.0, 61.0)	<0.001	0.274	0.011	0.240
LVGLS (%)	−17.0 (−19.3, −15.8)	−12.0 (−13.7, −10.3)	−18.5 (−20.1, −17.3)	<0.001	−18.1 (−19.4, −17.2)	−12.6 (−15.0, −11.9)	−18.0 (−19.6, −17.1)	<0.001	0.510	0.389	0.102
E wave velocity (m/s)	0.8 (0.6, 0.9)	0.7 (0.6, 0.9)	0.7 (0.5, 0.8)	0.017	0.8 (0.6, 0.9)	0.7 (0.6, 0.9)	0.8 (0.7, 0.9)	0.730	0.695	0.757	<0.001
E/A ratio	1.1 (0.8, 1.3)	0.9 (0.7, 1.0)	0.9 (0.8, 1.1)	0.24	1.1 (0.9, 1.3)	0.8 (0.7, 1.1)	1.2 (0.9, 1.5)	0.005	0.080	0.795	<0.001
E wave deceleration time (ms)	209.0 (180.0, 258.0)	201.0 (172.0, 246.0)	226.0 (201.0, 261.0)	0.15	210.0 (189.0, 266.0)	184.0 (163.0, 220.0)	200.0 (183.0, 236.0)	0.170	0.433	0.308	0.001
E/e′ ratio	10.7 (9.1, 12.3)	9.5 (8.0, 13.6)	7.8 (7.0, 9.3)	<0.001	9.9 (8.1, 11.7)	8.6 (7.0, 10.8)	8.9 (7.7, 11.3)	0.800	0.019	0.043	<0.001
e′ septal (m/s)	0.062 (0.05, 0.075)	0.06 (0.04, 0.07)	0.0700 (0.060, 0.084)	0.002	0.060 (0.050, 0.080)	0.060 (0.050, 0.070)	0.070 (0.057, 0.080)	0.190	0.937	0.240	0.366
e′ lateral (m/s)	0.083 (0.070, 0.100)	0.090 (0.060, 0.110)	0.091 (0.080, 0.110)	0.034	0.100 (0.090, 0.110)	0.100 (0.075, 0.120)	0.100 (0.090, 0.120)	0.960	<0.001	0.002	0.033
e′ mean (m/s)	0.074 (0.063, 0.085)	0.0750 (0.050, 0.090)	0.0835 (0.070, 0.098)	0.009	0.085 (0.070, 0.092)	0.080 (0.065, 0.095)	0.085 (0.075, 0.097)	0.500	0.001	0.011	0.384
RVEDD (mm)	36.0 (34.0, 40.0)	38.0 (35.0, 40.0)	35.0 (33.0, 38.0)	0.007	38.0 (33.0, 42.0)	38.0 (35.0, 42.0)	37.0 (33.0, 40.0)	0.340	0.280	0.517	0.013
TAPSE (mm)	21.1 (18.1, 24.0)	17.2 (14.3, 21.0)	21.0 (17.7, 23.5)	<0.001	14.7 (12.5, 16.6)	13.8 (12.4, 15.1)	14.0 (12.0, 16.6)	0.440	<0.001	<0.001	<0.001
TR peak velocity (m/s)	2.7 (2.4, 2.8)	2.7 (2.5, 3.0)	2.4 (2.3, 2.5)	<0.001	2.6 (2.4, 2.8)	2.7 (2.5, 3.0)	2.5 (2.3, 2.7)	0.008	0.673	0.909	0.036
LAVI (mL/m^2)	41.8 (37.7, 50.0)	40.1 (35.1, 51.6)	31.5 (27.9, 33.1)	<0.001	40.0 (35.0, 52.0)	41.0 (35.0, 49.0)	33.0 (28.0, 39.0)	<0.001	0.953	0.374	0.001
RA area (cm^2)	17.4 (15.0, 20.2)	18.0 (15.5, 23.3)	15.0 (13.9, 17.6)	0.001	19.0 (16.0, 25.0)	17.0 (15.0, 24.0)	17.0 (15.0, 19.0)	0.039	0.003	0.080	0.002
SV (mL)	88.8 (79.6, 96.3)	72.1 (62.0, 82.4)	82.0 (72.0, 95.0)	0.005	86.0 (77.0, 97.0)	67.0 (64.0, 80.0)	81.0 (73.0, 90.0)	0.006	0.710	0.840	0.839
Electrocardiogram											
QRS duration (ms)	95.0 (88.0, 100.0)	108.0 (98.0, 128.0)	98.0 (88.0, 104.0)	<0.001	100.0 (92.0, 108.0)	106.0 (100.0, 136.0)	98.0 (84.0, 104.0)	0.003	0.018	0.968	0.249
PQ interval (ms)	174.0 (154.0, 194.0)	182.0 (164.0, 204.0)	164.0 (150.0, 182.0)	0.13	172.0 (158.0, 200.0)	170.0 (160.0, 190.0)	162.0 (154.0, 184.0)	0.082	0.078	0.943	0.271
Pathological Q-waves (*n*, %)	4 (12)	8 (30)	14 (19)	0.25	4 (13)	11 (46)	12 (20)	0.015	0.655	0.103	0.414
QTc interval (ms)	418 (405, 439)	442 (433, 454)	421 (413, 435)	<0.001	433 (411, 442)	449 (433, 466)	426 (414, 441)	<0.001	0.015	0.264	0.040

Continues variables are presented as median and interquartile range (IQR).

cMRI, cardiac magnetic resonance imaging; LV, left ventricular; EDD, end-diastolic diameter; IVS, interventricular septum; PW, posterior wall; RWT, relative wall thickness; EDV, end-diastolic volume; EDVI, end-diastolic volume index; EDVS, end-systolic volume; EDSVI, end-systolic volume index; EF, ejection fraction; GLS, global systolic strain; E, early diastolic mitral inflow velocity; A, late diastolic mitral inflow velocity; e′, early diastolic mitral annular velocity measured by tissue velocity imaging; RV, right ventricular; TAPSE, tricuspid annular plane excursion; TR, tricuspid regurgitation; LAVI, left atrial volume index; RA, right atrial; SV, stroke volume.

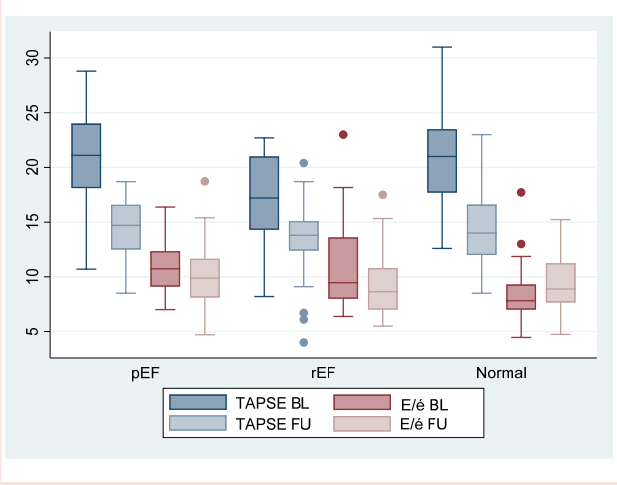


Figure 2 Echocardiography parameters tricuspid annular plane excursion (mm) and diastolic parameter E/é at baseline and 12 months follow-up. Significance for Δ tricuspid annular plane excursion $P < 0.001$ in all groups and for Δ E/é $P = 0.019$, $P = 0.043$, and $P < 0.001$ in the preserved ejection fraction, reduced ejection fraction, and normal group respectively.

Outcomes

Peri-operative outcomes

Peri-operative outcomes included new-onset AF in 17 patients (2, 9, and 6 patients in the pEF, rEF, and normal group, respectively) and TIA/stroke in 3 patients (2 in the pEF and 1 in the normal group). But no venous thromboses and hospitalizations for infection or MI/angina pectoris were registered.

Long-term outcome

The median long-term follow-up time was 2.9 (IQR 0.5–4.3) years. Eight patients died (5.8%): one (2.9%) in the pEF, four (15%) in the rEF, and three (4%) patients in the normal group. There were no cardiovascular deaths. Eight patients (three in the pEF, four in the rEF, and one in the normal group) were hospitalized or sought the emergency department for HF symptoms at least once. Three patients were both hospitalized and died.

Discussion

In this study, we present a thorough clinical characterization and cardiac imaging data at baseline and 1-year follow-up as well as long-term outcome in patients with stable, multivessel CAD undergoing elective CABG. Irrespective of HF symptoms, three phenotypes rEF, pEF, and normal cardiac structure and function could be recognized using echocardiography and NT-proBNP. Disturbed systolic and/or diastolic LV function was common and found in 45% of patients pre-operatively. We found small deteriorations in TAPSE reflecting right ventricular function at the 1-year follow-up irrespective of baseline EF. In patients with normal LV function, there were also signs of increased echocardiographic indices of filling pressures at 1 year. It is reasonable to believe that they might be attributable to the CABG procedure, and of note, the magnitude of changes is probably not clinically significant. Overall mortality at mean 2.9-year follow-up was low in the whole study population. Nonetheless, our findings may suggest a need for further long-term echocardiographic assessment and understand implications for long-term follow-up of CABG patients.

Patient material

Most CABG interventions are done sub-acutely and in the setting of acute coronary syndrome. We selected patients with stable multivessel CAD accepted for elective CABG to enable our research protocol of extensive echocardiography and cMRI not easily performed in a sub-acute setting. Our proportion of patients with LV dysfunction is defined according to ACC/AHA/HFSA criteria on stages on HF[9] and agrees with the findings from elective CABG in SWEDEHEART registry.[5] Regarding patient characteristics, the pEF phenotype group resembles patients with HFpEF even though signs and symptoms of HF were rarely present. In general, the rEF group had the most comorbidities such as diabetes and AF and most often a history of HF.

Although outcome was not the purpose of this paper, we noted low rates of mortality and HF hospitalizations and emergency visits during the median follow-up time of 2.9 years, reflecting the stable disease condition of the included patients. Although relative mortality was highest in rEF group, the difference between the groups did not reach statistical significance. Peri-operative complications were also few.

Changes in echocardiographic findings at baseline compared to 1-year follow-up

Small but significant improvements in EF and LV volumes were seen in the rEF group at 1-year follow-up. At baseline, LV mass index was increased in the rEF group as was intraventricular septal thickness (IVS) and LAVI in both rEF and pEF groups. At the 1-year follow-up, LV mass index decreased numerically in the rEF group together with significant decrease in E/é in pEF and rEF groups. Overall reflecting a trend towards improved systolic and diastolic function in both pEF and rEF groups. These observations agree with previous studies. In a cohort study of patients LVEF < 35% undergoing CABG, 51% had an improvement in EF after CABG.[13] In contrast, patients in the normal group had measures of slight deteriorations such as LAVI and E/é indicative of increased filling pressures after 1 year also accompanied by increase in NT-proBNP.

In our study, all patients were subject to pericardiotomy as part of CABG. The right ventricular function assessed as TAPSE decreased to a similar subnormal level following CABG in all groups. In the normal group, there were even slight signs of worsening over time in right ventricular function beyond TAPSE, such as increment of RVEDD and RA area. Tricuspid annular plane excursion is known to deteriorate in conjunction with surgical opening of the pericardium,[14,15] but effects on long-term global right ventricular function are less well explored. Steffen *et al.* described reduction of TAPSE and tricuspid annular systolic velocity including global RV function both longitudinal and transversal in a small study of patients 1 week after CABG. The authors attributed their results to the lack of support of pericardial layers to maintain RV function. In addition, in one short-term (40 day) study of patients undergoing standard or minimal invasive aortic valve replacement, both interventions deteriorated TAPSE, but the minimal invasive method did not result in a decline in right ventricular contractility,[16] reflecting the short-term effects of pericardial opening. In a study of 57 patients undergoing CABG, changes in RV shape and function persisted 8–10 months post-operatively,[17] which is in line with our findings at 1-year follow-up. It is worth pointing out that opening of pericardium during surgery alters constrain and pressure relationship, leading to increase in radial diameter, decrease in TAPSE, and more spherical shape of RV.

In general, long-term follow-up studies with echocardiographic data and comprehensive clinical evaluation after CABG are limited and seldom exclusively in elective CABG patients with different phenotypes (pEF, rEF, and normal). The STICH trial randomized patients with ischaemic heart disease and rEF to medical therapy or CABG to compare outcome and LV function recovery. Pre-operatively, RV dysfunction

was found in 13.7% and least moderate RV dysfunction in 13.6%.[18] In their 9.8-year follow-up sub-study, pre-operative RV dysfunction was associated with worse long-term outcome after CABG compared to patients with baseline normal RV function. Similar worse outcome was found in those with persistent RV dysfunction and new-onset RV dysfunction observed in 16.7%. In their study, RV function was measured at baseline and after 4 months and with another definition of RV dysfunction than in our study. Additionally, contrary to our study, STICH only included patients with LVEF < 35% at baseline whereas most of our patients had normal EF. Nonetheless, these and our results stress the importance of careful assessment of RV function before and after CABG.

Our observations also suggest small increments in right ventricular and LV filling pressures as indicated by LAVI, RA area, and E/é in patients with initially normal values and over one year. Still, it is not self-evident that this reflects only pericardial opening since the pericardium may heal late after surgery. Whatever the reason, our results indicate some residual potentially adverse effect. The implications of these findings need further studying and longer-term follow-up and in a larger number of patients to clarify if these slight changes are transient or progressive.

The prognostic implications of *pre-operative* systolic and diastolic dysfunction and RV function in CABG have been reported.[3,4] Mertus reported that the presence of diastolic dysfunction in 42% of patients undergoing CABG or aortic valve replacement and that diastolic dysfunction influenced short-term outcome. In a Swedish Registry study, 27 165 of a total of 41 906 undergoing CABG had pEF and 10 069 had rEF without HF. Heart failure history was found in an additional 4672. In this study, EF was more important for determining short-term outcome whereas patients with a history of HF had worse short-term and long-term outcomes regardless of pre-operative EF.[5] In another study, baseline LAVI was predictive of long-term outcome after cardiac surgery including CABG.[19] Right ventricular dysfunction is also of prognostic importance associated with a worse prognosis post CABG. In 142 patients with moderate to severe right ventricular dysfunction in the Surgical Treatment of Ischaemic Heart Failure trial (STICH), CABG did not provide additional survival benefits beyond medical therapy. In our study, we cannot relate the presence of pEF or rEF or LAVI (increased in pEF and rEF) or RV function to outcome either short or long-term in view of our limited number of patients. But the overall prognosis was favourable in our stable CABG patients.

Finally, although most of our patients with pEF and rEF were in ACC/AHA/HFSA Stage B, a recent follow-up has shown that the prevalence of Stage B has increased and that such patients are at high risk for progression to symptomatic HF.[9]

In addition, most patients undergoing CABG are not subject to cMRI as part of the standard clinical care. In our highly selected low risk elective CABG population, few patients had a history of previous MI but cMRI revealed additional signs of scarring three times more often. Moreover, additional small scars were noted in five patients at the 12-month cMRI. The clinical significance of these, often small, ischaemic scars is unclear.

Limitations

There are several limitations of the study. In our cohort study, all patients had stable angina pectoris with multivessel disease without significant left main stenosis. We did not include signs and symptoms of HF for our definitions of the groups since it may be challenging to distinguish HF symptoms from those of angina and since signs of HF such as ankle oedema may be unspecific. Indeed, few patients had a history of HF, and equally few had signs and clear symptoms of HF at the baseline evaluation and were in ACC/AHA/HFSA criteria on Stage B.[9] Moreover, our definition of pEF with EF > 45% reflects the definitions used at time of study design.[6] The modern HF definitions including HFmrEF did not exist at that the time of study planning. Our group definition of pEF, rEF, and normal was based on established Doppler echocardiographic criteria[7,8] and NT-proBNP. The division into groups was performed in a structured mannered as previously used by us in the CHARM preserved sub-study.[11] We captured 137 (20%) of the approximately 700 elective CABG patients. The bulk of surgery was for acute coronary syndrome and performed within a week, and such patients were not eligible by protocol. Our findings primarily apply to stable CAD patients undergoing elective CABG but may have implications for other patient populations, which would require further validation. The enrolment to the study was temporarily affected by organizational changes and the move to the new hospital building.

Conclusion

In patients with stable multivessel CAD undergoing elective CABG, LV dysfunction classified as rEF or pEF phenotype was found in 45% pre-operatively and slightly improved in these groups after 1 year. Right ventricular function parameters deteriorated below normal values in all patients at the 1-year follow-up irrespective of baseline LV function. Patients classified as normal phenotype with normal LV function showed signs of slight worsening of both systolic and diastolic LV function, eGFR, and NT-proBNP at 1-year follow-up. To clarify if these slight changes are transient or progressive, further long-term studies are needed.

Lead author biography

Dr Ulrika Löfström is a consultant cardiologist currently working at Capio St Görans hospital in Stockholm, Sweden. She completed her medical training at Karolinska Institutet and her residency in internal medicine and cardiology at Södersjukhuset in Stockholm, during which she began to focus on heart failure. She has since then been part of working groups both locally and nationwide aiming at improving heart failure care and is a PhD student at Karolinska Institutet.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

Supplementary material

Supplementary material is available at *European Heart Journal Open* online.

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References

1. Bakaeen FG, Blackstone EH, Pettersson GB, Gillinov AM, Svensson LG. The father of coronary artery bypass grafting: René Favaloro and the 50th anniversary of coronary artery bypass grafting. *J Thorac Cardiovasc Surg* 2018;**155**:2324–2328.
2. Wrobel K, Stevens SR, Jones RH, Selzman CH, Lamy A, Beaver TM, Djokovic LT, Wang N, Velazquez EJ, Sopko G, Kron IL, DiMaio JM, Michler RE, Lee KL, Yii M, Leng CY, Zembala M, Rouleau JL, Daly RC, Al-Khalidi HR. Influence of baseline characteristics, operative conduct, and postoperative course on 30-day outcomes of coronary artery bypass grafting among patients with left ventricular dysfunction: results from the surgical treatment for ischemic heart failure (STICH) trial. *Circulation* 2015;**132**:720–730.
3. Metkus TS, Suarez-Pierre A, Crawford TC, Lawton JS, Goeddel L, Dodd-O J, Mukherjee M, Abraham TP, Whitman GJ. Diastolic dysfunction is common and predicts outcome after cardiac surgery. *J Cardiothorac Surg* 2018;**13**:67.
4. Fallahzadeh A, Sheikhy A, Ajam A, Sadeghian S, Pashang M, Shirzad M, Bagheri J, Mansourian S, Momtahen S, Hosseini K. Significance of preoperative left ventricular ejection fraction in 5-year outcome after isolated CABG. *J Cardiothorac Surg* 2021;**16**:353.
5. Dalén M, Lund LH, Ivert T, Holzmann MJ, Sartipy U. Survival after coronary artery bypass grafting in patients with preoperative heart failure and preserved vs reduced ejection fraction. *JAMA Cardiol* 2016;**1**:530–538.
6. Linde C, Eriksson MJ, Hage C, Wallén H, Persson B, Corbascio M, Lundeberg J, Maret E, Ugander M, Persson H; Stockholm County/Karolinska Institutet 4D heart failure investigators. Rationale and design of the PREFERS (Preserved and Reduced Ejection Fraction Epidemiological Regional Study) Stockholm heart failure study: an epidemiological regional study in Stockholm county of 2.1 million inhabitants. *Eur J Heart Fail* 2016;**18**:1287–1297.
7. Nagueh SF, Smiseth OA, Appleton CP, Byrd BF, 3rd, Dokainish H, Edvardsen T, Flachskampf FA, Gillebert TC, Klein AL, Lancellotti P, Marino P, Oh JK, Popescu BA, Waggoner AD. Recommendations for the evaluation of left ventricular diastolic function by echocardiography: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr* 2016;**29**:277–314.
8. Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, Flachskampf FA, Foster E, Goldstein SA, Kuznetsova T, Lancellotti P, Muraru D, Picard MH, Rietzschel ER, Rudski L, Spencer KT, Tsang W, Voigt JU. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr* 2015;**28**:1–39.e14.
9. Mohebi R, Wang D, Lau ES, Parekh JK, Allen N, Psaty BM, Benjamin EJ, Levy D, Wang TJ, Shah SJ, Gottdiener JS, Januzzi JL, Jr, Ho JE. Effect of 2022 ACC/AHA/HFSA criteria on stages of heart failure in a pooled community cohort. *J Am Coll Cardiol* 2023;**81**:2231–2242.
10. Paulus WJ, Tschöpe C, Sanderson JE, Rusconi C, Flachskampf FA, Rademakers FE, Marino P, Smiseth OA, De Keulenaer G, Leite-Moreira AF, Borbély A, Edes I, Handoko ML, Heymans S, Pezzali N, Pieske B, Dickstein K, Fraser AG, Brutsaert DL. How to diagnose diastolic heart failure: a consensus statement on the diagnosis of heart failure with normal left ventricular ejection fraction by the Heart Failure and Echocardiography Associations of the European Society of Cardiology. *Eur Heart J* 2007;**28**:2539–2550.
11. Persson H, Lonn E, Edner M, Baruch L, Lang CC, Morton JJ, Ostergren J, McKelvie RS; Investigators of the CHARM Echocardiographic Substudy-CHARMES. Diastolic dysfunction in heart failure with preserved systolic function: need for objective evidence:results from the CHARM Echocardiographic Substudy-CHARMES. *J Am Coll Cardiol* 2007;**49**:687–694.
12. Jernberg T, Attebring MF, Hambraeus K, Ivert T, James S, Jeppsson A, Lagerqvist B, Lindahl B, Stenestrand U, Wallentin L. The Swedish web-system for enhancement and development of evidence-based care in heart disease evaluated according to recommended therapies (SWEDEHEART). *Heart* 2010;**96**:1617–1621.
13. Vakil K, Florea V, Koene R, Kealhofer JV, Anand I, Adabag S. Effect of coronary artery bypass grafting on left ventricular ejection fraction in men eligible for implantable cardioverter-defibrillator. *Am J Cardiol* 2016;**117**:957–960.
14. Unsworth B, Casula RP, Kyriacou AA, Yadav H, Chukwuemeka A, Cherian A, Stanbridge RdeL, Athanasiou T, Mayet J, Francis DP. The right ventricular annular velocity reduction caused by coronary artery bypass graft surgery occurs at the moment of pericardial incision. *Am Heart J* 2010;**159**:314–322.
15. Steffen HJ, Kalverkamp S, Zayat R, Kalverkamp S, Zayat R, Autschbach R, Spillner JW, Hagendorff A, Hatam N. Is systolic right ventricular function reduced after thoracic noncardiac surgery? A propensity matched echocardiographic analysis. *Ann Thorac Cardiovasc Surg* 2018;**24**:238–246.
16. Nashmil H, Jonas J, Brodin LÅ, Gomes-Bernardes A, Sartipy U, Svenarud P, Dalén M, Bäck M, Alam M, Winter R. Right ventricular mechanics and contractility after aortic valve replacement surgery: a randomised study comparing minimally invasive versus conventional approach. *Open Heart* 2018;**5**:e000842.
17. Rösner A, Avenarius D, Malm S, Iqbal A, Schirmer H, Bijnens B, Myrmel T. Changes in right ventricular shape and deformation following coronary artery bypass surgery-insights from echocardiography with strain rate and magnetic resonance imaging. *Echocardiography* 2015;**32**:1809–1820.
18. Zhou Z, Jian B, Fu G, Liu H, Huang Y, Feng Z, Huang S, Li H, Liang M, Wu Z. Evolution, coronary artery bypass surgery and outcomes of right ventricular dysfunction in ischaemic cardiomyopathy. *Eur J Cardiothorac Surg* 2023;**63**:ezad136.
19. Lazzeroni D, Gaibazzi N, Bini M, Bussolati G, Camaiora U, Cassi R, Geroldi S, Ugolotti PT, Brambilla L, Brambilla V, Castiglioni P, Coruzzi P. Prognostic value of new left atrial volume index severity partition cutoffs after cardiac rehabilitation program in patients undergoing cardiac surgery. *Cardiovasc Ultrasound* 2016;**14**:35.