Protective effect of Impella on left ventricular function after acute broad anterior wall ST elevation myocardial infarction with cardiogenic shock: cardiaovascular magnetic resonance imaging strain analysis

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Abstract

Background

The clinical efficacy of Impella for high-risk percutaneous coronary intervention and cardiogenic shock remains under debate. We thus sought to investigate the protective effects on the heart by the early use of Impella before percutaneous coronary intervention using cardiovascular magnetic resonance imaging (CMR).

Methods

We evaluated cardiac magnetic resonance imaging results in 22 broad anterior ST-elevation myocardial infarction cases between 2017 and 2019. A mechanical circulation system (Impella or intra-aortic balloon pump) was implanted before percutaneous coronary intervention if needed; all patients underwent cardiac magnetic resonance imaging 2 weeks later.

Results

There were 6 patients in the Impella group and 16 in the non-Impella group; no differences were found in the door-to-balloon time (60 ± 17 vs. 58 ± 25 min, P = 0.58), peak creatine kinase (7922 ± 4864 vs. 6950 ± 4801 IU/L, P = 0.74), and hospital admission days (28 ± 8 vs. 25 ± 7 days, P = 0.40) between the two groups; however, cardiac magnetic resonance imaging-derived left ventricular end-diastolic volume was significantly smaller in the Impella group (140.6 ± 28 vs. 182.5 ± 45 ml, P = 0.004). Overall diastolic strain rate (SR) at the non-infarcted area in the IMPELLA group was significantly higher as compared to non IMPELLA group (longitudinal diastolic SR: 1.1 ± 0.4 vs 0.7 ± 0.3 S^{-1}, P = 0.04, radial diastolic SR: -1.8 ± 0.4 vs -1.1 ± 0.4 S^{-1}, P = 0.004, circumferential diastolic SR: 1.0 ± 0.1vs 0.6 ± 0.2 S^{-1}, P = 0.001).

Conclusions

Early implantation of Impella before percutaneous coronary intervention for anterior ST-elevation myocardial infarction acutely prevented enlargement of left ventricular end-diastolic volume and worsening of diastolic SR in the remote myocardium. This study provides clinical insight into understanding the usefulness of Impella to prevent future heart failure.

Background

The survival rate of acute myocardial infarction (AMI) has generally improved due to technological advancement in Japan[1]; however, ST-elevation myocardial infarction (STEMI) with cardiogenic shock has a high mortality rate, even after shortening the door-to-balloon time (DTBT).[2] Additionally, heart failure

associated with STEMI tends to increase due to the development of left ventricular (LV) remodeling; thereafter, prognosis worsens.[3]

Previously, the main treatment strategy for cardiogenic shock in AMI was to maintain hemodynamics using the mechanical circulatory support of intra-aortic balloon pumping (IABP) and veno-arterial extracorporeal membrane oxygenation (VA-ECMO). Earlier studies demonstrated that IABP reduces afterload and improves coronary blood flow[4]; however, although IABP stabilizes hemodynamics, afterload reduction was ineffective. Thus, IABP does not improve 30-day survival in STEMI patients with cardiogenic shock.[5] While VA-ECMO is a powerful technique that assists with systemic circulation, it increases LV load and afterload.

Under these circumstances, the Impella 2.5 or 5.0 (Abiomed, Danvers, MA, USA), a percutaneous LV assist device for drug-resistant cardiogenic shock, was used since 2017 in Japan; the Impella CP (Abiomed), designed to provide a higher level of support than the Impella 2.5, was available since 2019. By drawing arterial blood from the left ventricle to the aorta, it is possible to directly unload the left ventricle. Direct LV unload lowers LV end-diastolic pressure, improving blood gas oxygenation and systemic perfusion.[6] Several reports have reported that use of Impella in the acute phase increases cardiac output, improving coronary blood flow.[7,8] Unexpectedly, the IMPRESS in Severe Shock trial, the first randomized pilot trial to compare the efficacy and safety of the Impella CP versus IABP, did not show 3-day and 6-month mortality in the 48 patients (24 per group)[9]; this was possibly due to the fact that Impella increased bleeding events, worsening renal function and cerebral infarction, and causing death during coronary treatment.[10] A major concern was that the Impella was placed “after” revascularization in 80% of the study patients; an earlier study demonstrated improved survival in patients who received an Impella pre-, rather than post-percutaneous coronary intervention (PCI).[11] Further, over 90% of the patients in that trial had resuscitated cardiac arrest patients. Those conditions might have lessened the beneficial effects of IMPELLA. From the standpoint of this view, we hypothesized that IMPELLA would provide some beneficial effects of LV remodeling for the patients who did not experience cardiac arrest and did receive IMPELLA before PCI. For bridging the gap between the trial-based evidence and “real-world” practice, we retrospectively evaluated the detailed LV function including myocardial deformation by cardiovascular magnetic resonance imaging (CMR) in the patients with anterior STEMI in whom IMPELLA was placed just before percutaneous coronary intervention (PCI), and they were compared to those without IMPELLA.

Methods

Study population

In order to investigate the protective effects on the heart by the early use of Impella before percutaneous coronary intervention using cardiac magnetic resonance imaging, this study retrospectively enrolled 47 consecutive patients with broad anterior STEMI who were admitted to our hospital between January 2017 and June 2019. The inclusion criterion was having undergone PCI for the first anterior STEMI, followed by

CMRI before discharge; patients with claustrophobia, a history of old myocardial infarction, or renal failure including dialysis were excluded. Anterior AMI patients with cardiopulmonary arrest and impaired consciousness were also excluded. In all patients, the culprit lesion was the proximal left anterior descending (LAD) or left main trunk. STEMI is universally defined as myocardial infarction, where ST-elevation refers to two or more leads. In V2-3 leads, the ST-elevation was: ≥2.0 mm for men > 40 years, ≥ 2.5 mm for men < 40 years, and ≥ 1.5 mm for women regardless of age; the ST rise was ≥ 1.0 mm. Figure 1 shows the flowchart for the study participants. Among 47 broad anterior STEMI patients, CMRI was not performed in 25 patients, 5 died immediately after admission, 12 had chronic kidney disease or hemodialysis, and 8 were frail; the remaining 22 patients were the study participants. All patients had consented, by the opt-out method, to use their data for study purposes. The study protocol was reviewed and approved by the Ethics Committee of Nihon University Itabashi Hospital (RK-200714-10).

Data collection

Patient characteristics and follow-up data were retrospectively obtained from our hospital records. Patient background at the time of PCI for ACS was anonymized and extracted; information included age, sex, age, body mass index (BMI), smoking history, comorbidities (hypertension, diabetes, dyslipidemia, or prior coronary disease), hemodynamic variables (heart rate, systolic blood pressure, and diastolic blood pressure), laboratory tests (hemoglobin concentration, lactate, and estimated glomerular filtration rate [eGFR]), and transthoracic echocardiographic parameters (LV ejection fraction [LVEF], LV end-diastolic volume [LVEDV], and LV end-systolic volume [LVESV]) obtained at the time of the emergency CAG. N-terminal pro-brain natriuretic peptide (NT-proBNP) levels at discharge were used for analysis.

Implantation of mechanical circulatory support and post-MI medical treatments

Impella is generally used in cardiogenic shock cases for mechanical circulatory support during PCI of anterior STEMI; however, IABP may be used even in shock cases. The choice between Impella or IABP was made at the physicians' discretion; in all cases, both Impella and IABP were placed just before PCI. The Impella 2.5 or CP was used, as the 5.0 model required the use of artificial blood vessels. The patient entered the coronary care unit after PCI for intensive care. The IABP and Impella were removed after the stabilized conditions from heart failure after starting a β-blocker and renin-angiotensin system inhibitor. Thereafter, they were transferred to a general ward for undergoing cardiac rehabilitation; the amount of cardioprotective agents was carefully increased. CMRI was performed before discharge from the hospital after all pressor agents, such as DOB for infusion, were tapered. The Impella and non-Impella groups were thus retrospectively compared.

Cardiovascular Magnetic Resonance Imaging

All patients underwent CMRI within 21 days; images were acquired using a 1.5-T scanner (Ingenia; Philips Healthcare, Eindhoven, Netherlands) with retrospective electrocardiographic gating and dS Torso coil. The CMRI protocol comprised standard steady-state free precession (SSFP) cine and late gadolinium

enhancement (LGE) MRI. Standard SSFP cine images covered the entire LV using short-axis slices and 2-, 3-, and 4-chamber views with temporal resolution < 40 ms. Endo- and epicardial LV contours were manually drawn on short-axis cine images covering the mitral valve to the apex at end-diastole and end-systole to calculate end-diastolic and end-systolic volume, stroke volume, and ejection fraction. LV mass was calculated as the sum of myocardial volumes multiplied by the specific gravity (1.05 g/mL) of the myocardial tissue. Papillary muscles were excluded from the LV mass.

For LV strain analysis, endo- and epicardial borders were semi-automatically drawn at end-diastole in short- and long-axis cines (excluding papillary muscles from the endocardial contour) and automatically propagated to all slices throughout the cardiac cycle. Tracking was visually reviewed and manually corrected in case of inaccurate automated border tracking. Short-axis cines were tracked to derive radial and circumferential strain, while 2-, 3, and 4-chamber-view cines were tracked to derive longitudinal strain. Based on the 16-segment model, the software algorithm calculated 2D peak strains (longitudinal, radial, and circumferential) and subsequently, by averaging the according peak values of the segments. In all analyses, strain was defined as the average of peak of the global, infarcted, and non-infarcted strain curves and systolic strain rate (SR) was the average of peak of the global, infarcted, and non-infarcted SR curves in systole, and diastolic SR was the peak in diastole (Figs. 2 and 3). LGE imaging was acquired with a T1-weighted inversion recovery gradient-echo sequence 15 min after contrast administration (0.15 mmol/kg; Gd-BTDO3A; Gadovist, Bayer Japan, Tokyo, Japan) in three long-axis slices (2-, 3-, and 4-chamber) and a stack of short-axis slices completely encompassing the LV. The infarct size was quantified by the full-width at half-maximum method; this estimated an intensity threshold from the remote myocardium as the midway between the mean intensity within the remote region, and the maximal intensity within the affected tissue in short-axis. The LV myocardium was divided into infarcted and non-infarcted areas. The segmental coronary artery distribution model from the American Society of Echocardiography and the European Association of Cardiovascular Imaging guidelines[12] was used; the infarcted area was defined as the proximal LAD perfusion territory. This included segments 1–2, 7–8 and 13–16; the remaining LV myocardium was defined as the non-infarcted area.

Post-discharge follow-up

Each patient was followed up at our outpatient cardiology clinic around 3, 6, 9, and 12 months.

Study assessments

CMRI at the assessment endpoint included measurements of LVEF, LVEDV, LVESV, LV mass, and infarcted size. Strain analysis involved longitudinal, radial, and circumferential peak, systolic, and diastolic SRs in the global, infarcted, and non-infarcted areas. We also ascertained clinical events including hospitalization due to heart failure, all-cause death, non-fatal myocardial infarction (MI), stroke, stent thrombosis, and major bleeding via medical records.

Statistical analysis

Values are shown as mean ± SD, median and interquartile ranges, and number and percentages. Continuous variables between the groups were analyzed using the Student's t-test or Mann-Whitney U-test; differences in categorical variables were tested using the Fisher's exact or Chi-squared test. All analyses were performed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA); $P < 0.05$ was considered statistically significant.

Results

Baseline characteristics between the Impella and non-Impella groups

Among the 22 patients with anterior STEMI, an Impella was used for mechanical support in 6 patients (2.5: 5 patients; CP: 1 patient); the remaining 16 patients (non-Impella group) received an IABP (11 patients) or no mechanical circulatory support (5 patients). There were no differences in age (68 ± 11 vs. 60 ± 12 years, P = 0.21), male sex (83 vs. 93%, P = 0.48), and BMI (21 ± 1.5 vs. 24 ± 3.3 kg/m^2, P = 0.06), nor in the coronary risk factors for hypertension, dyslipidemia, diabetes, and smoking between the two groups. One patient in each group received VA-ECMO.

On admission, no difference was observed in the lactic acid level (3.2 vs. 2.3 mmol/l, P = 0.15) and eGFR (63 vs. 72 ml/min, P = 0.32) between the two groups. No difference was found between TIMI 0 flow cases of LAD on angiography before PCI (67% vs. 75%, P = 0.67). The DTBT did not differ between the two groups (60 ± 17 vs. 58 ± 24 min, P = 0.58). There were no differences in transthoracic echocardiographic LVEF (48 ± 11 vs. 48 ± 7.1 %, P = 0.98), LVEDV on admission (107 ± 16 vs. 116 ± 33 ml, P = 0.38), and LVESV (52 ± 17 vs. 57 ± 18 ml, P = 0.60) between the two groups. The Impella was in place for 4 ± 1.7 days (Table 1).

Table 1
Baseline characteristics between patients with and without an Impella

	Impella (n = 6)	Non-Impella (n = 16)	P-Value
Age, years	68 ± 11	60 ± 13	0.21
Male gender	5 (83)	15 (93)	0.48
BMI (m^2/kg)	21 ± 1.6	24 ± 3.3	0.06
Hemodynamic variables on admission			
Heart rate (beats/min)	83 ± 19	86 ± 18	0.72
Systolic blood pressure (mmHg)	93 ± 25	133 ± 18	0.001
Diastolic blood pressure (mmHg)	76 ± 20	88 ± 18	0.18
Cardiogenic Shock	6 (100)	5 (31)	0.006
History or comorbidities			
Current smoking	1 (17)	8 (50)	0.18
Hypertension	5 (83)	11 (69)	0.46
Diabetes Mellitus	1 (17)	5 (31)	0.46
Dyslipidaemia	6 (100)	8 (50)	0.04
Prior coronary disease	0 (0)	0 (0)	
Blood values on admission			
Lactate (mmol/l)	3.2 ± 1.4	2.4 ± 1.0	0.15
Hb (mg/dl)	13 ± 1.7	14 ± 1.1	0.05
eGFR (mg/dl)	63 ± 17	72 ± 20	0.32
Blood values at discharge			
NT-proBNP at discharge (pg/ml)	937 (422,2093)	1662 (809,2776)	0.24
Support device			

Values are shown as the number (%), mean ± SD or median (interquartile ranges).

STEMI, ST-elevation myocardial infarction; BMI, body mass index; Hb, haemoglobin; eGFR, estimated glomerular filtration rate; DAPT, dual antiplatelet therapy; CPA, cardiopulmonary arrest; IABP, intra-aortic balloon pumping; VA ECMO, veno-arterial extracorporeal membrane oxygenation; LVEDV, left ventricular end-diastole volume; LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; NT-pro BNP, n-terminal pro brain natriuretic peptide; TIMI, thrombolysis in myocardial infarction; CK, creatinine kinase; DES, drug eluting stent; CMRI, cardiac magnetic resonance image; N.A., not applicable

	Impella (n = 6)	Non-Impella (n = 16)	P-Value
Mechanical ventilation	2 (33)	3 (16)	0.47
IABP	0 (0)	11 (61)	0.006
VA ECMO	1 (17)	1 (6)	0.48
Anterior STEMI	6 (100)	16 (100)	
Infarct-related artery			
Left main stem	1 (17)	0 (0)	
Left anterior descending	5 (83)	16 (100)	
Multivessel disease	2 (33)	2 (13)	0.26
Stent placement			
Drug-eluting stent	6 (100)	16 (100)	
Number of DES stents	1.0 ± 0	1.1 ± 0.3	0.39
Initial TIMI flow 0	4 (67)	12 (75)	0.54
Final TIMI flow3	6 (100)	15 (94)	0.72
Max CK (IU/L)	7922 ± 4864	6950 ± 4801	0.68
Max CK MB (IU/L)	585 ± 351	561 ± 400	0.9
Door to balloon time (min)	60 ± 17	58 ± 24	0.58
Echo parameter on admission			
LVEF	48 ± 11	48 ± 7.1	0.98
LVEDV (ml)	107 ± 16	116 ± 33	0.38
LVESV (ml)	52 ± 17	57 ± 18	0.60
Duration of IMPELLA support (days)	4.0 ± 1.7		
Medications at discharge			

Values are shown as the number (%), mean ± SD or median (interquartile ranges).

STEMI, ST-elevation myocardial infarction; BMI, body mass index; Hb, haemoglobin; eGFR, estimated glomerular filtration rate; DAPT, dual antiplatelet therapy; CPA, cardiopulmonary arrest; IABP, intra-aortic balloon pumping; VA ECMO, veno-arterial extracorporeal membrane oxygenation; LVEDV, left ventricular end-diastole volume; LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; NT-pro BNP, n-terminal pro brain natriuretic peptide; TIMI, thrombolysis in myocardial infarction; CK, creatinine kinase; DES, drug eluting stent; CMRI, cardiac magnetic resonance image; N.A., not applicable

	Impella (n = 6)	Non-Impella (n = 16)	P-Value
DAPT	6 (100)	16 (100)	
RAS inhibitor	6 (100)	16 (100)	
Beta blocker	6 (100)	15 (94)	0.72
Statin	6 (100)	16 (100)	
Days of coronary care unit (days)	7.8 ± 3.9	6.0 ± 3.0	0.26
Days of hospital admission (days)	28 ± 8	25 ± 7	0.40
Days of CMRI after admission (days)	16 ± 7	19 ± 8	0.98
Values are shown as the number (%), mean ± SD or median (interquartile ranges).			
STEMI, ST-elevation myocardial infarction; BMI, body mass index; Hb, haemoglobin; eGFR, estimated glomerular filtration rate; DAPT, dual antiplatelet therapy; CPA, cardiopulmonary arrest; IABP, intra-aortic balloon pumping; VA ECMO, veno-arterial extracorporeal membrane oxygenation; LVEDV, left ventricular end-diastole volume; LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; NT-pro BNP, n-terminal pro brain natriuretic peptide; TIMI, thrombolysis in myocardial infarction; CK, creatinine kinase; DES, drug eluting stent; CMRI, cardiac magnetic resonance image; N.A., not applicable			

CMRI assessment between the Impella and non-Impella groups

CMRI was performed 19 ± 8 days after admission (Impella: 16 ± 7 days; non-Impella: 19 ± 8 days, P = 0.98). The LVESV (83 ± 27 vs. 119 ± 43 ml, P = 0.06) and LV mass tended to be smaller (80 ± 13 vs. 95 ± 23 g, P = 0.07), the LVEF higher (42 ± 9.6 vs. 34.9 ± 7.4%, P = 0.07), and the LVEDV significantly smaller in the Impella than non-Impella group (141 ± 28 vs. 183 ± 45 mL, P = 0.004); no difference was observed in the infarcted size of the LV myocardial mass (29 ± 15 vs. 30 ± 12%, P = 0.79; Fig. 3).

Representative CMR results of the two groups are shown in Fig. 2; there were no significant differences in the global peak strains (i.e., longitudinal, radial, and circumferential) and systolic SR in all LV areas (i.e., global, infarcted, and non-infarcted areas). Radial and circumferential diastolic SRs in the global and infarcted area were higher in the Impella group (global radial diastolic SR: -1.3 ± 0.5 vs. -0.7 ± 0.4 S^{-1}, P = 0.006; infarcted radial diastolic SR: -0.9 ± 0.6 vs. -0.4 ± 0.5 S^{-1}, P = 0.05; global circumferential diastolic SR: 0.8 ± 0.2 vs. 0.4 ± 0.2, P = 0.004; infarcted circumferential diastolic SR: 0.6 ± 0.3 vs. 0.2 ± 0.3 S^{-1}, P = 0.04). Additionally, all diastolic SRs in the non-infarcted area were significantly increased in the Impella group (longitudinal diastolic SR: 1.1 ± 0.4 vs. 0.7 ± 0.3 S^{-1}, P = 0.04; radial diastolic SR: -1.8 ± 0.4 vs. -1.1 ± 0.4 S^{-1}, P = 0.004; circumferential diastolic SR: 1.0 ± 0.1 vs. 0.6 ± 0.2 S^{-1}, P = 0.001; Table 2, Fig. 4).

Table 2
CMRI strain parameters between the patients with and without Impella

CMRI strain parameters	Impella (n = 6)	Non-Impella (n = 16)	P-Value
LV longitudinal			
Global			
Peak Strain (%)	-9.1 ± 2.1	-8.5 ± 2.4	0.60
Systolic strain rate (1/s)	-0.8 ± 0.2	-0.5 ± 0.4	0.12
Diastolic strain rate (1/s)	0.6 ± 0.2	0.5 ± 0.2	0.22
Infarcted area			
Peak Strain (%)	-6.3 ± 2.5	-6.2 ± 3.2	0.93
Systolic strain rate (1/s)	-0.5 ± 0.4	-0.3 ± 0.4	0.42
Diastolic strain rate (1/s)	0.2 ± 0.3	0.3 ± 0.3	0.68
Non-Infarcted area			
Peak Strain (%)	-13 ± 3.3	-12 ± 4.4	0.56
Systolic strain rate (1/s)	-1.1 ± 0.6	-0.7 ± 0.7	0.2
Diastolic strain rate (1/s)	1.1 ± 0.4	0.7 ± 0.3	0.04
LV radial			
Global			
Peak Strain (%)	20 ± 6.5	16 ± 5.6	0.18
Systolic strain rate (1/s)	1.1 ± 0.3	0.9 ± 0.3	0.15
Diastolic strain rate (1/s)	-1.3 ± 0.5	-0.7 ± 0.4	0.006
Infarcted area			
Peak Strain (%)	16 ± 7.3	13 ± 6.0	0.29
Systolic strain rate (1/s)	0.9 ± 0.4	0.7 ± 0.4	0.21
Diastolic strain rate (1/s)	-0.9 ± 0.6	-0.4 ± 0.5	0.05
Non-Infarcted area			
Peak Strain (%)	24 ± 5.6	19 ± 8.2	0.22

CMRI, cardiac magnetic resonance image; LV, left ventricular

CMRI strain parameters	Impella (n = 6)	Non-Impella (n = 16)	P-Value
Systolic strain rate (1/s)	1.4 ± 0.2	1.2 ± 0.4	0.28
Diastolic strain rate (1/s)	-1.8 ± 0.4	-1.1 ± 0.4	0.004
LV circumferential			
Global			
Peak Strain (%)	-12 ± 3.3	-9.9 ± 3.4	0.21
Systolic strain rate (1/s)	-0.7 ± 0.2	-0.6 ± 0.2	0.20
Diastolic strain rate (1/s)	0.8 ± 0.2	0.4 ± 0.2	0.004
Infarcted area			
Peak Strain (%)	-10 ± 4.3	-8.1 ± 4.3	0.40
Systolic strain rate (1/s)	-0.6 ± 0.2	-0.4 ± 0.3	0.26
Diastolic strain rate (1/s)	0.6 ± 0.3	0.2 ± 0.3	0.04
Non-Infarcted area			
Peak Strain (%)	-15 ± 2.2	-12 ± 4.0	0.17
Systolic strain rate (1/s)	-0.9 ± 0.1	-0.8 ± 0.3	0.36
Diastolic strain rate (1/s)	1.0 ± 0.1	0.6 ± 0.2	0.001
CMRI, cardiac magnetic resonance image; LV, left ventricular			

Clinical outcomes

No difference was found in the extent of infarction as evidenced by maximum creatine kinase (7922 ± 4864 vs. 6950 ± 4801 IU/L, P = 0.74) and creatine kinase-MB (585 ± 351 vs. 561 ± 400 IU/L, P = 0.93) between the two groups, nor in the length of hospital admission (28 ± 8 vs. 25 ± 7 days, P = 0.40) and NT-proBNP level at discharge (937 [422, 2093] vs. 1662 [809, 2776], P = 0.24; Table 1). In both groups, all patients were discharged on foot. During the median follow-up period of 434 ± 302 days, 1 (17%) patient in the Impella group experienced a major bleeding event (gastrointestinal bleeding) 450 days after discharge; 3 (19%) non-Impella patients were hospitalized due to heart failure.

Discussion

This study has two major findings: 1) with similar baseline patient characteristics on admission, LVEDV identified on CMRI 2 weeks later was significantly smaller, while diastolic SR in the non-infarcted (rather than infarcted) area was significantly greater in the Impella group than in the non-Impella group, despite

no difference in the infarct size; and 2) there was no difference in the length of hospital stay between the two groups. All patients were discharged on foot; 3 patients in the non-Impella group required re-admission due to heart failure, while no patients experienced heart failure in the Impella group.

Effect of Impella on the prevention of LV remodeling

It was widely known that shortening the DTBT enables reduction of infarct size; however, use of an Impella has not yet been demonstrated to reduce infarct size in humans.[13] When assessed via CMRI, our study showed no reduction in infarct size in the Impella group when compared with the non-Impella group. Despite the similar transthoracic echocardiographic LVEF, LVEDV, and LVESV on admission between the two groups, CMRI 2 weeks later revealed that LVEDV was predominantly reduced, while LVESV and LV mass tended to be smaller (despite no statistical significance) by LV unloading in the Impella group. This study also details LV function by systolic and diastolic SRs, segmented by global LV, infarcted, and non-infarcted areas. Myocardial strain (defined as the change in length of an object relative to its original length) is a sensitive measure of contractility, which can be calculated in a variety of coordinate systems at both the segmental and global level; it is typically determined in the three axes of myocardial contraction (circumferential, longitudinal, and radial).[14]

SR measures the change in strain for a given vector as a function of time. Global myocardial circumferential systolic strain and diastolic SR were reported to be objective, sensitive markers of myocardial systolic and diastolic function.[15] Another report demonstrated that both longitudinal and circumferential systolic SR were independent predictors of outcomes after MI, whereas only circumferential systolic SR was predictive of remodeling. The data suggested that preserved circumferential function might serve to restrain ventricular enlargement after MI.[16] Despite no difference in systolic SR during the acute phase, our data showed that magnitudes of diastolic SR in overall areas were significantly greater in the Impella group, and pronounced in the non-infarcted areas in particular. Our findings, together with recent reports, suggest that Impella reduced diastolic dysfunction in the non-infarcted, rather than infarcted area by unloading the entire LV. Bulluck et al. demonstrated increased extracellular volume fraction of the remote myocardium acutely and at 5 ± 2 months after STEMI in patients who developed adverse LV remodeling (defined as ≥ 20% increase in LV end diastolic volume).[17] Moreover, remote zone non-contrast T1-mapping provided independent and incremental prognostic information above the clinical risk factors and traditional CMRI outcome markers in STEMI patients treated by primary PCI.[18] The mechanism for improving the non-infarct area by Impella is incompletely unknown; however, recent findings indicate that post-MI LV remodeling is a multifactorial process that may involve excessive inflammation and/or fibrosis of the remote (non-infarct) myocardium; progression may be protected by the Impella.

Outcomes after Impella placement

Diastolic SR in all LV sites improved, and LV chamber size reduced after using Impella, despite no difference in NT-proBNP, LGE, and length of hospital stay at discharge between the patients with and

without Impella. While it is known that an increase in LVEDV is an important risk for heart failure,[17,18] End-systolic volume and LV mass are also been reportedly predictive factors for heart accidents.[19,20] Ersboll et al. showed that diastolic SR was a sensitive marker of diastolic dysfunction that might occur early in STEMI, independent of systolic dysfunction (strongly associated with adverse outcomes).[21] Our results, therefore, imply that Impella may provide favorable effects for the prevention of future heart failure.

Recent randomized control trials or observation studies have been shown controversial results regarding the prognostic effect of Impella. The small IMPRESS in Severe SHOCK trial (n = 48) did not show any beneficial effects of the Impella CP, compared with IABP.[9] A recent matched-pair analysis (237 matched pairs) comparing Impella- and IABP-treated CS patients showed similar 30-day mortality in both groups.[22] The lactate level was lower and baseline LVEF assessed by transthoracic echocardiography was higher in our Impella patients than in previous reports, suggesting a better condition in our study patients, possibly due to the early DTBT time in this study. Furthermore, Impella was placed before PCI in all study patients. Early unloading of Impella in our patients may provide protective effects on cardiac dysfunction, leading to subsequent clinical outcomes. This is implied by our results; 3 patients (19%) in the non-Impella group suffered rehospitalization due to heart failure, while none in the Impella group suffered any heart failure events. The STEMI-DTU Trial (NCT03947619) is currently ongoing in the United States; the purpose of this study is to evaluate whether using the Impella CP System for 30 minutes prior to catheterization can reduce damage to the heart caused by heart attack, compared with the current standard of care. This trial would answer our questions whether early unloading of Impella improve clinical outcomes in MI with cardiogenic shock.

Study limitations

First, our study is limited by the retrospective design of our analysis. Additionally, our data is the result of a single-center registry providing a limited number of patients with anterior STEMI. Despite the similar patient characteristics, IABP is generally placed in MI patients without severe risks; healthier bias in the non-Impella group might persist. Nonetheless, LV diastolic function and smaller LV chambers were observed in the Impella group. However, LV ejection fraction assessed by transthoracic echocardiography was lower at baseline; improvement of LV function might have been reasonable. The follow-up period was too short to obtain a statistical difference in clinical outcomes between the Impella and non-Impella groups. Further larger studies in a long period are required to identify the prognostic effect of Impella.

Conclusions

Early implantation of the Impella before PCI reduced enlargement of LVEDV and improved diastolic function (diastolic SR) assessed by CMRI. This study provides clinical insight into understanding the usefulness of the Impella for the cardioprotective effects preventing LV remodeling.

Abbreviations

AMI, acute myocardial infarction; BMI, body mass index; CMRI, cardiac magnetic resonance image; DTBT, door-to-balloon time; eGFR, estimated glomerular filtration rate; IABP, intra-aortic balloon pumping; LAD, left anterior descending; LGE, late gadolinium enhancement; LV, left ventricular; LVEDV, left ventricular end-diastole volume; LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; MI, myocardial infarction; SSFP, standard steady-state free precession; NT-proBNP, N-terminal pro-brain natriuretic peptide; CI, percutaneous coronary intervention; SR, systolic strain rate; STEMI, ST-elevation myocardial infarction; VA-ECMO, veno-arterial extracorporeal membrane oxygenation

Declarations

Ethics approval and consent to participate: All procedures were performed according to the ethical standards of the institutional research committee, as well as the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study and its protocols were approved by the Institutional Review Board of Nihon University Itabashi Hospital (RK-200714-10)..

Consent for publication: Not applicable..

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Authors' contributions: AY and HF had analyzed CMR data. All authors read and approved the final manuscript.

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