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SHORT COMMUNICATION

Myocardial viability assessment during Impella support with 18-fluorodesoxyglucose PET imaging

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Abstract

Formal assessment of myocardial viability (MV) is challenging in acute myocardial infarction-related cardiogenic shock (AMI-CS) patients receiving Impella mechanical circulatory support, as the cardiac magnetic resonance gold standard technique is not feasible due to the metallic components of the device. 18-fluorodesoxyglucose metabolic myocardial positron emission tomography (^{18}FDG-PET) may represent a valid and feasible alternative to obtain semi-quantitative and objective evidence of MV during Impella support. We hereby report the first series of sequential AMI-CS patients who received ^{18}FDG-PET scanning to assess MV during Impella support to demonstrate the safety and feasibility of this approach. In this cohort no adverse events occurred during ^{18}FDG-PET scans, and all images were of excellent quality. This study provides a pragmatic guidance on how to perform this imaging modality during Impella support and finally confirms the safety and feasibility of this advanced imaging method also in this vulnerable cohort of patients.

Keywords Acute coronary syndrome; Acute myocardial infarction; Cardiogenic shock; Impella; Myocardial metabolic PET; Myocardial recovery; Myocardial viability; Positron emission tomography

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All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

Background

Myocardial recovery likelihood assessment is a prerequisite in the weaning process from temporary mechanical circulatory support (tMCS) in cardiogenic shock (CS) patients. Myocardial viability (MV) has been linked to LV systolic function improvement in coronary artery disease (CAD) patients and tested during durable MCS to assess the likelihood of myocardial recovery.[1,2] Formal assessment of MV during tMCS is challenging as the gold-standard cardiac magnetic resonance (CMR) is not feasible due to the metallic components of the mechanical devices. Metabolic myocardial imaging with 18-fluorodesoxyglucose (^{18}FDG) positron emission tomography (PET) may overcome these limitations and provide quantitative information on regional MV.

We aimed to assess the safety and feasibility of ^{18}FDG-PET for MV evaluation during tMCS with the micro axial-flow pump (mAFP) Impella (Abiomed, Danvers, USA) for acute myocardial infarction-related CS (AMI-CS).

Methods

We included patients who underwent myocardial ^{18}FDG-PET, as decided by the treating physician, while on Impella for AMI-CS at San Raffaele Hospital (Milan, Italy). In accordance with the American Society of Nuclear Cardiology and Society of Nuclear Medicine and Molecular Imaging guidelines,[3,4] all patients were fasting ≥6 h before the scans. Based on fasting

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serum glucose, appropriate oral glucose doses were given, with optional doses of insulin in case of hyperglycaemia. Steady insulin infusion was used for insulin-resistant or diabetic patients, as previous studies have shown excellent image quality even in this subset.[5] Approximately 60' after oral glucose administration, ^{18}FDG (370 MBq) was administered intravenously. Thorax cardiac PET scan was acquired using a Discovery STE PET/CT (General Electrics, USA) approximately 60' after ^{18}FDG injection.

For the assessment of regional ^{18}FDG uptake, summed ^{18}FDG-PET images were analysed using the CardIQ Physio software (General Electrics, USA). In a completely automated process, the software determined the region with the maximal uptake of ^{18}FDG within the LV, defined as the reference ROI and set as 100%. Regional viability was defined as segmental tracer uptake >50% of this maximum uptake, based on prior studies.[6–8] We also applied a visual method to assess viability: the LV was divided into 17 segments, each segment visually assigned a score from 0 to 4 based on relative tracer uptake (0, normal; 1, mildly reduced; 2, moderately reduced; 3, severely reduced; and 4, absent). Scar score was determined counting the segments graded 3 or 4. The total percentage of the myocardium scarring was computed by normalizing scar score with the maximum potential score [score/(17 × 4) × 100%]. Values are reported as medians (IQR) or proportion, as appropriate.

Results

Six AMI-CS patients (57 [47, 68] years; 5 males) received Impella and underwent myocardial ^{18}FDG-PET during support. On admission, they had severe hypoperfusion [serum lactate: 9.0 (5.8–10.4) mmol/L], severe congestion [NT-proBNP: 18167 (11 462, 26 761) pg/L], and a LVEF of 17.5 (15.0–20.0)%. Five of the six patients presented with ST-elevation myocardial infarction (STEMI). Emergent coronary angiography was performed upon arrival in four STEMI patients, one late STEMI presenter underwent coronary angiography and PCI only after 24 h as arrhythmias and refractory angina symptoms ensued at that time. Coronary anatomy was assessed in all patients: 4 patients had three-vessel disease, and 2 had two-vessel disease. A proximal LAD plaque was the culprit lesion in five cases; in one patient a three-vessel disease without a clear culprit lesion was identified (*Table 1*).

Overall Impella duration was 23 (20, 23) days. Choice of Impella device was made by the treating physician. Four patients received Impella 5.0 to guarantee maximum LV unloading and prolonged circulatory support while allowing for patient mobilization. In patients #4 and #6, escalation from intra-aortic balloon pump (IABP) to Impella 5.0 was pursued, because of refractory CS; in patients #2 and #5, an

Table 1 Patient-level clinical characteristics

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
Age (years)	44	69	76	48	46	66
ACS presentation	NSTEMI	STEMI	STEMI	STEMI	STEMI	STEMI
LVEF (%)	15	15	20	15	20	25
Admission SCAI CS stage	E	E	D	D	E	D
NT-proBNP (pg/L)	9883	36 180	16 197	7495	28 969	20 137
Admission Lac (mmol/L)	10.5	5.0	20.0	10.0	1.3	8.3
Tn-T peak (ng/L)	32 777	22 512	11 061	5856	22 936	8836
Impella device at time of PET	CP	5.0	CP	5.0	5.0	5.0
Coronary diseased vessels	LAD, LCx, RCA	LAD, RI, LCx, RCA	LAD, LCx	LAD, LCx	LAD, LCx, RCA	LAD, LCx, RCA
Culprit vessel	LAD	No culprit	LAD	LAD	LAD	LAD
Time to PCI (hours)	27	-	0.6	1.0	0.5	0.3
Therapeutic decision informed by PET	Bridging to LVAD	Bridging to LVAD	Revascularization completion	Bridging to LVAD	Bridging to HTx	Impella weaning
LV necrotic area (%)	47%	41%	35%	53%	71%	29%
Impella to PET time (days)	22	7	22	11	15	4
Successful Impella weaning	Not weaned	Not weaned	Yes	Not weaned	Not weaned	Yes
Hospital outcome	LVAD	Death	Recovery	LVAD	Candidate to HTx and death	Death
Cause of death	-	Refractory CS	-	-	Refractory CS	COVID-19 severe pneumonia

ACS, acute coronary syndrome; CAD, coronary artery disease; CS, cardiogenic shock; HTx, heart transplant; Lac, serum lactate; LAD, left anterior descend artery; LCx, left circumflex artery; LV, left ventricle; LVAD, left ventricular assist device; MOF, multiorgan failure; RCA, right coronary artery; RI, ramus intermedius; SCAI, Society for Cardiovascular Angiography and Interventions; Tn-T, troponin T.

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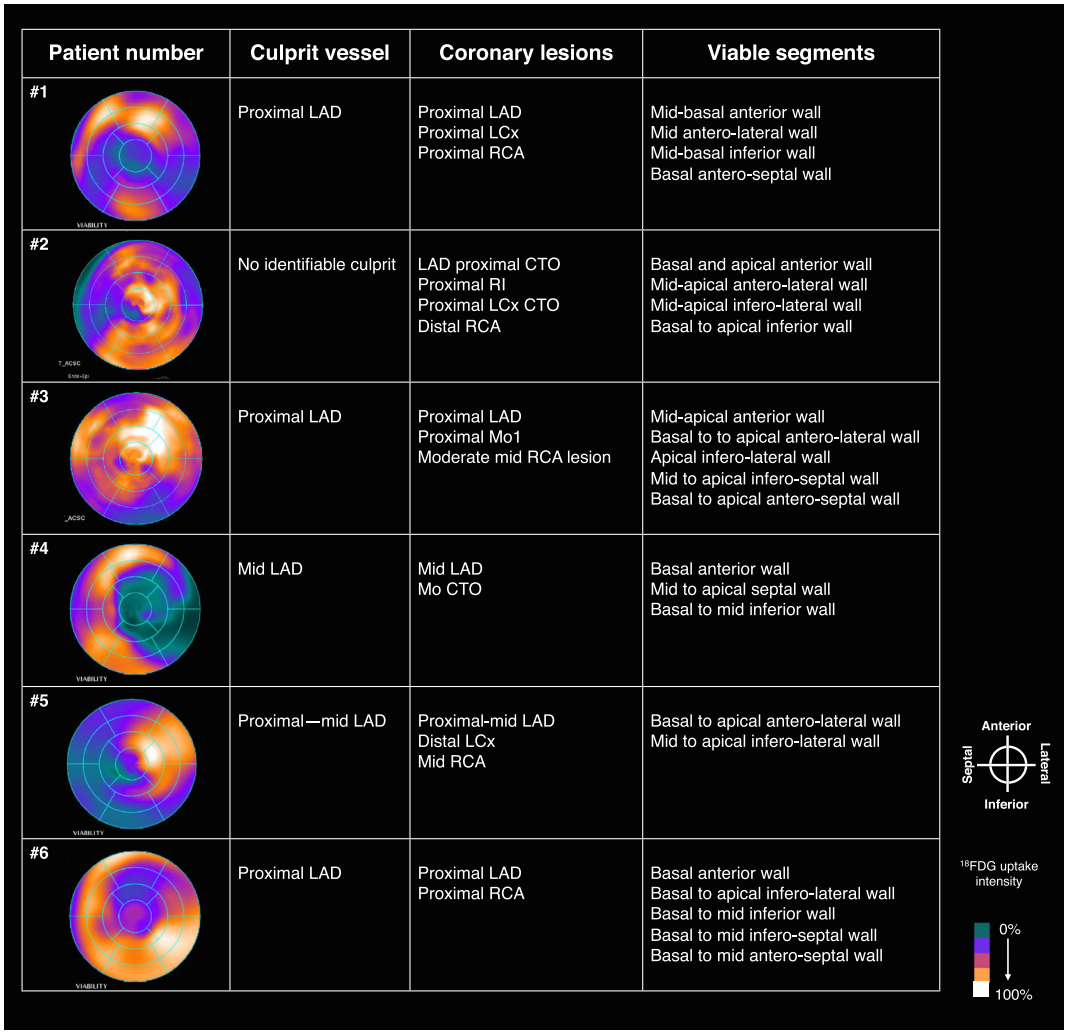
upgrade to Impella 5.0 from Impella CP was necessary due to CP device complications (pump failure and severe hemolysis, respectively). In remaining two cases, the Impella CP was used upfront.

PET scans were performed 13 (8–20) days after Impella pump insertion. At time of PET imaging all patients had a pulmonary artery catheter in place: pulmonary artery wedge pressure was 13 (9, 15) mmHg and mean pulmonary artery pressure 19 (17, 21) mmHg. Impella P-level was 6 (5, 8) with a median Impella flow of 3.7 (3.4, 4.0) L/min. Two patients were on inotropic treatment at time of PET scan; 5 patients received mechanical ventilation on admission, but all were spontaneously breathing at time of PET testing. No adverse event occurred while in the Nuclear Medicine department, and total time spent outside the CICU for the test was 2 (2, 3) hours. Despite the mildly elevated blood glucose (126 [88, 152] mg/dL) at time of scan and the suboptimal position with the arms along the flanks, PET image quality was excellent (*Figure 1*). Total amount of radiation exposure was 7.1 mSv per patient. PET discriminated vital from non-vital segments: only 9.0 (7.25, 10.75) segments/patient were viable; LV necrotic area/patient was 44.1 (36.8, 51.5)%. Median necrotic score was 39.7 (27.6, 49.6)%. PET also provided valuable information for subsequent management: in patient #3, it encouraged staged revascularization of residual coronary stenoses; in two (patients #4 and #5), it suggested that revascularization might had been futile due to extensive necrosis of non-culprit artery territories. In all other patients, PET provided objective evidence of either low likelihood of myocardial recovery thus prompting transitioning to advanced heart replacement therapies (HRT) or fair amount of viable myocardium thus encouraging weaning pursuit.

Figure 1 ^{18}FDG PET scans and myocardial viability assessment. LAD, left anterior descending coronary artery; LCx, left circumflex artery; Mo1, first marginal obtuse branch; RCA, right coronary artery; RI, ramus intermedius.



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ICU stay was 44 (35, 56) days. In-hospital deaths occurred in three patients (50%): two from refractory CS conditioning multiorgan failure and one from COVID-19 pneumonia; LVAD was pursued in 2 patients as bridge-to-transplant; one patient was candidate for heart transplant but died before transplantation; one patient experienced myocardial recovery and was discharged with native heart.

Discussion

MV is a key factor influencing the myocardial recovery process after CS, along with the aetiology of CS, the pre-existing degree of myocardial dysfunction and end-organ adaptation to the CS state.

In ischemic cardiomyopathy, systolic function recovery after revascularization may require several weeks and its amount is correlated to the extent of MV.[1,9] Interestingly, repeated assessment of MV with ^{99m}Tc-Sestamibi SPECT along with strain analysis has been reported as a potential marker to predict myocardial recovery during durable LVAD support.[2] In the AMI-CS setting, MV imaging may thus inform on the need of HRT. We hereby reported our experience with PET imaging in the context of ongoing Impella support. Despite logistical issues related to the presence of several indwelling catheters, the need to bring a fragile patient outside the ICU, and the relatively long time required to obtain images, our experience showed the feasibility and safety of PET imaging. No adverse events occurred in the Nuclear Imaging department, plus all images were of excellent quality (*Figure 1*). Of note, PET scans were obtained after several days of support: this ensured that the patient was stable enough to leave the CICU for the time required for PET scan; as such, the safety of this method may not extend to the very acute and early phase of CS. ^{18}FDG-PET identified patients who could benefit from staged revascularization, those for whom revascularization would likely be futile, and was helpful in providing objective evidence of low likelihood of myocardial recovery thus prompting transitioning to advanced HRT. MV evaluation is therefore useful in the multiparametric assessment (that includes clinical, laboratory, instrumental and imaging findings) for the decision-making between staged revascularization, bridging supports or definitive HRT. Unfortunately, given the small sample size of the study we could not provide reliable comparative data between patients who were successfully weaned and those experiencing an adverse outcome.

To our knowledge, this is the first study addressing use of advanced imaging modalities during Impella support. While other non-invasive metrics, like strain imaging, may be a simple first-level bed-side evaluation to predict systolic function recovery in ischemic cardiomyopathy,[10] factors related to decubitus and suboptimal acoustic windows may limit its application in the Impella population. We acknowledge, however, that ^{18}FDG-PET imaging is not widely available and has high associated costs; in future, the regional and quantitative information provided by PET imaging may be used to derive strain-imaging threshold for MV assessment during Impella, thus increasing the clinical outlook of this method. Finally, MV status may be incorporated in protocols and guide the decision to proceed to non-culprit coronary lesions revascularization in patients with AMI-CS supported by mAFP. While our study underscores the feasibility and safety of ^{18}FDG-PET during mAFP in this small cohort of patients, further research with larger patient cohorts is warranted to validate these findings and elucidate how the quantitative data from PET imaging can optimally inform therapeutic decision-making. Future studies should explore the cost-effectiveness and broader applicability of ^{18}FDG-PET in guiding management strategies for AMI-CS patients receiving tMCS, thereby enhancing the comprehensive approach to patient care in this challenging clinical scenario.

Conclusions

Our study demonstrates the safety and feasibility of ^{18}FDG-PET for myocardial viability assessment during Impella support for AMI-CS. No adverse events were observed during PET scans and image quality was excellent in all cases. ^{18}FDG-PET imaging provided valuable insights into myocardial viability, guiding clinical decisions in this critically ill cohort.

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Conflict of interest

Dr. Baldetti received speaker honoraria and travel grants from Abiomed. The rest of the authors declare no conflict of interest.

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