Evaluating Acute Ischemic Myocardial Injury with Photon-counting Computed Tomography

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Myocardial injury characterization in acute coronary syndromes (ACS) is clinically important. While cardiovascular magnetic resonance (CMR) remains the reference standard, a single modality capable of high-resolution coronary assessment and simultaneous myocardial tissue characterization would offer significant clinical advantages, particularly in late-presenting ST-segment-elevation ACS (STEACS) and non-ST-segment-elevation ACS (NSTEACS). Photon-counting computed tomography (PCCT) combines ultra-high resolution with advanced spectral capabilities, enabling simultaneous coronary CT angiography (PCCTA) and myocardial evaluation through late iodine enhancement (LIE) in a single session.

We evaluated the ability of low-energy LIE using PCCT to quantify infarct size (IS) and microvascular obstruction (MVO) using CMR late gadolinium enhancement (LGE) as the reference standard in ACS.

Thirty consecutive STEACS patients were prospectively recruited for same-day research CMR-LGE (first) and PCCT-LIE protocol, within 7 days of admission (Figure 1A). Exclusion criteria have been previously described.[1,2]

PCCT imaging was performed using a first-generation NAEOTOM Alpha system (Siemens Healthineers, VA50 SP1):

1. Contrast-enhanced multi-energy CTCA (70 ml Omnipaque 350 at 4.5 ml/s followed by a 50ml saline chaser at 4.5 ml/s),
2. Following a 3-minute wait, contrast-enhanced ultrahigh-resolution (UHR) CTCA (80 ml Omnipaque 350 at 4.5 ml/s followed by a 50ml saline chaser at 4.5 ml/s)
3. Following a 5-minute wait, an unenhanced multi-energy LIE scan for myocardial evaluation.

Virtual monoenergetic images (VMI) at 55 keV (for optimum contrast-to-noise ratio for blood pool–myocardium differentiation, improving infarct visibility) and iodine images were reconstructed every 1.0mm (slice width 1.5mm) with a Qr40 kernel, quantum iterative reconstruction level 3.[3] CMR was performed earlier the same day using a 1.5T Siemens Avanto Fit *system* (VE11C).[2]

PCCT image analysis was conducted on syngo.via (VB80D, Siemens Healthineers) at the AMIIC core lab by two experienced readers in a blinded fashion using CAD-RADS2.0.

Culprit vessel identification combined clinical data and PCCTA findings. PCCT-LIE analysis was performed by the same investigators using the CT Cardiac Functional Analysis Research app (v3.0), with myocardial characterization based on iodine-derived extracellular volume (ECV):

$$ECV = (1 - hematocrit)\, x\, \frac{iodine\ density_{myo}}{iodine\ density_{blood\ pool}},$$

MVO was defined as hypodense regions within hyperdense infarcted zones on ECV maps. The quantitative approach adapted CMR-LGE methodology to the higher spatial resolution of PCCT, using voxel-wise co-registered images and CT ECV maps to precisely define the infarct border on areas of expanded ECV in the infarct territory (corresponding to yellow/orange), thereby overcoming the visual limitations of CT-based LIE. IS was expressed as a percentage of total LV volume based on voxel counts (Figure 1B). CMR-LGE analysis was performed blindly using cvi42 software (Circle Cardiovascular Imaging).[2] Transmural injury extent was graded in five categories across the 16-segment AHA model; segments with ≥50% infarct were deemed non-viable.

Myocardial injury metrics were compared between modalities using Spearman's rho, two-way random intraclass corelation coefficient (ICC) with 95% confidence intervals and Bland-Altman analyses. Inter-modality agreement on transmural injury extent and prognostically relevant injury identification was assessed with Cohen's κ and visualized using Sankey diagrams.

There was no difference in IS or MVO calculated using either CMR-LGE or PCCT-LIE (Figure 1A). PCCT-LIE strongly correlated with CMR-LGE for both IS and MVO (Figure 1B), with ICCs 0.96(95%CI:0.91–0.98) and 0.98(95%CI:0.96–0.99), respectively (p<0.001 for both). Bland-Altman analyses confirmed the precision of PCCT-LIE in characterizing myocardial injury relative to CMR-LGE. PCCT-LIE slightly overestimated IS and MVO by 1.02%(95%CI:-0.39%–2.43%)/LoA:7.39 and 0.18%(95%CI:-0.25%–0.61%)/LoA:2.27%, respectively, with no evidence of systematic bias. Interobserver agreement for IS and MVO quantification by PCCT-LIE was excellent, with ICCs of 0.99(95%CI:0.98–1.00) and 0.99(95%CI:0.97–1.00), respectively (p<0.001).

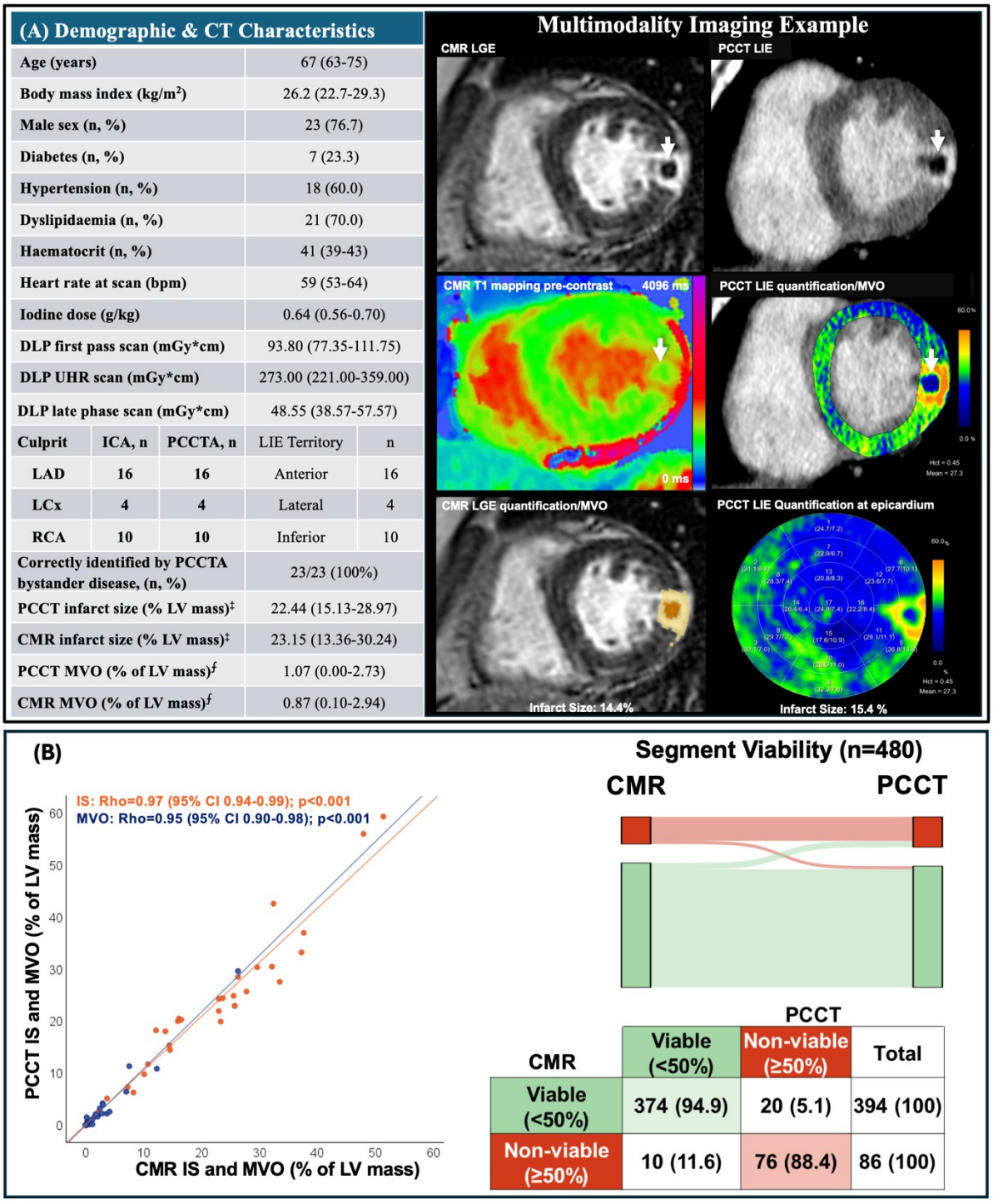
Transmural injury was evaluated in 480 segments, with CMR-LGE and PCCT-LIE identifying 17.9%(n=86) and 20%(n=96) non-viable segments, respectively (Figure 1B). Viability assessment showed excellent agreement (κ=0.80(95%CI:0.72–0.86),p<0.001), with

minimal reclassification. MVO detection also demonstrated excellent agreement (κ=0.81, 95%CI:0.53–1.00,*p*<0.001) and was perfect for prognostically relevant MVO (>1.55%LV mass;κ=1.00,*p*<0.001).

This is the first direct comparison of PCCT and CMR for assessing myocardial injury in STEACS. Same-day combined coronary/myocardial imaging with PCCT was feasible. IS and MVO measured by PCCT-LIE closely correlated with CMR-LGE, showing strong agreement across territories and viability thresholds, with no systematic bias. PCCT accurately identified prognostically relevant MVO and showed excellent segment-level agreement for viability.

PCCT's enhanced temporal, spatial and spectral resolution improves contrast-to-noise performance, addressing limitations of conventional energy integrating detector (EID) CT, such as overlapping spectra and beam hardening artefacts. Unlike dual energy EID CT, which suffers from misalignment and slow gantry speeds, PCCT offers spectral accuracy and anatomical fidelity, crucial for precise cardiac imaging. Our tailored quantitative approach enabled precise IS and MVO quantification, closely replicating CMR-LGE results. The method yielded robust, reproducible results with strong correlation to CMR-LGE, highlighting PCCT's potential in myocardial tissue characterization. Combined, these technical capabilities and analysis strategies enable comprehensive, same-scan evaluation of both coronary anatomy and myocardial injury, presenting an opportunity for PCCT to serve as a non-invasive alternative to invasive coronary angiography (ICA) and CMR. This is particularly relevant as current guidelines recommend viability assessment prior to revascularization in late-presenting STEACS.[2]

Study limitations include the single-centre design and use of CMR rather than histology as the reference and the small study population (30 STEACS, 4 circumflex territory infarcts). Future multicentre studies with broader patient inclusion, refined protocols and contrast dosing, and longitudinal follow-up, including validation of CT for predicting functional recovery after revascularisation, are needed. Nonetheless, these findings highlight PCCT's strong potential for integrated myocardial/coronary assessment, with promise as a non-invasive tool for guiding diagnosis and treatment in ACS patients.



CMR: cardiovascular magnetic resonance; DLP: dose length product; ECV: extracellular volume; IS: infarct size; LAD: left anterior descending; LCx: left circumflex artery; LGE: late gadolinium enhancement; LIE: late iodine enhancement; LV: left ventricular; MVO: microvascular obstruction; PCCT: photon-counting cardiac computed tomography; RCA: right coronary artery; UHR: Ultra-high resolution.‡,ƒ denote no statistically significant difference.

Figure 1 - Comparative myocardial injury evaluation by PCCT relative to CMR.

(A) Summary of patient demographics. Images showing myocardial infarction and MVO (white arrows) in PCCT vs CMR. (B) Correlation plots of IS and MVO between PCCT and

CMR, and segment-level viability classifications and reclassifications as visualized in a Sankey diagram.

Disclosures

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