Is SPECT LVEF assessment more accurate than CT at higher heart rates? More evidence for complementary information in multimodality imaging

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Measurement of left ventricular ejection fraction (LVEF) is critical for management and risk stratification in many cardiovascular disorders. LVEF can be accurately and automatically assessed with single photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI)¹ and has independent prognostic value.² Cardiac computed tomographic angiography (CCTA) also has high accuracy and precision for left ventricular end-diastolic volume (LVEDV) and LVEF compared to cardiovascular magnetic resonance (CMR).³ Given a large number of studies with discrepant findings, physicians and scientists are frequently left wondering which modality has the highest accuracy and under what conditions.

In this issue of *Journal of Nuclear Cardiology*, Chen et al. present the results of a dynamic cardiac phantom study, comparing the assessment of ejection fraction (EF) between (CCTA) and SPECT MPI.⁴ The authors demonstrate that SPECT MPI calculations of EF were accurate within 2% of actual values, regardless of heart rate. The CCTA calculations of EF demonstrated similar accuracy for heart rates between 40 and 60 beats·min⁻¹, with increasing error as the heart rate increased. However, volume estimates were more accurate with CCTA compared to SPECT MPI. The authors conclude that SPECT MPI provides more accurate EF calculation at higher heart rates. This is a well-designed study, highlighting the differences in technical specifications between CCTA and SPECT MPI and how those differences impact performance.

The results are intuitive, given the higher spatial resolution and the lower temporal resolution of CCTA compared to SPECT MPI. The spatial resolution of CCTA is determined by the detector size and reconstruction algorithms but is typically 0.5 mm for current CT scanners.⁵ The spatial resolution of SPECT, on the other hand, is determined by the collimator and geometric design of the camera system, reconstruction algorithms, and detector properties.^{6,7} The central spatial resolution of solid-state camera systems (Discovery NM 530c ~ 6.7 mm and DSPECT ~ 8.6 mm) is higher compared to conventional SPECT camera systems (~ 15 mm),⁷ like the one employed by Chen et al. The temporal resolution of CCTA is limited by the time it takes to provide full heart coverage and is influenced by the number of detectors and gantry rotation speed,⁵ with current generation dual-source scanners achieving temporal resolution ~ 75 ms.⁵ The temporal resolution of the CT scanner used by Chen et al. was 175 ms. In contrast, the temporal resolution of SPECT MPI is determined by the number of gates and heart rate and is ~ 38 ms at a heart rate of 100 using 16 bins. However, this could be decreased further if more gates were used at the expense of longer acquisition time to ensure an adequate number of counts per bin.

The study by Chen et al., nevertheless, has a few important limitations. The study only included two potential cardiac states, a normal heart model, and an ischemic cardiomyopathy model. Comparing the accuracy of SPECT and CCTA LVEF measurement across a range of end-diastolic volumes may identify important differences in the accuracy. SPECT MPI tends to overestimate LVEF in the setting of low end-systolic volume. However, newer reconstruction algorithms may help overcome this “small heart effect”.⁸ The authors used an outdated reconstruction method (filtered back-

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projection). Most clinical systems use iterative methods for SPECT reconstruction, which often include resolution recovery and could obtain more accurate results.

Additionally, the experiment did not include the simulation of heart rate variability. Increased heart rate variability, which can occur at high or low heart rates, negatively impacts CCTA image quality.⁹ In an analysis of the German Cardiac Computed Tomography Registry, patients with atrial fibrillation were more likely to have non-diagnostic coronary segments and had significantly higher radiation exposure compared to those without.¹⁰ While the use of systolic imaging may preserve CCTA accuracy at higher heart rates, this comes at the expense of higher radiation exposure.¹¹ In contrast, the diagnostic accuracy of SPECT MPI is similar in patients with atrial fibrillation compared to sinus rhythm when pharmacologic stress is used.¹² Overall, these results suggest that the real-world performance of CCTA LVEF measurements may demonstrate even lower accuracy due to heart rate variability compared to that shown by Chen et al. Lastly, the authors did not use the most recent generation of dual-source CT scanners which offer higher temporal resolution. However, the technology used in the study is representative of the hybrid SPECT/CT scanners used by many nuclear cardiology labs.

This study has clear implications for other laboratories performing similar cardiac phantom studies, with results conclusively demonstrating that CT should not be considered the gold standard at higher heart rates. The authors' findings raise fundamental and still unanswered questions about how to establish a gold standard for assessment of EF measurements for clinical or research purposes.¹³ CMR is typically believed to be the clinical gold-standard for LVEF assessment due to its high precision,¹⁴ but accuracy has always been compared relative to another imaging modality. The CT imaging protocol used by Chen et al. is not fully described, but presumably, it was a full-dose retrospectively gated study. Clinical CCTA for LVEF assessment would typically be performed with prospective gating and automated tube voltage modification to reduce radiation exposure at the expense of image quality.¹⁵ However, even with these modifications, the radiation exposure is higher compared to a single-phase CCTA acquisition.

CCTA LVEF is typically assessed in conjunction with the coronary arteries, and physicians are more likely to use echocardiography or CMR to assess LVEF if a second modality is deemed necessary. In patients undergoing SPECT MPI it is unlikely that nuclear cardiology labs would incorporate CT measurements of LVEF, which would increase radiation exposure compared to the acquisitions typically used for CT

attenuation correction. Based on the results of Chen et al., nuclear cardiology labs can be reassured that SPECT MPI accurately assesses LVEF, but not end-diastolic or end-systolic volumes, regardless of heart rate at the time of imaging. Therefore, clinicians may feel more comfortable incorporating post-stress LVEF as a prognostic marker. However, methods to incorporate the multitude of prognostic markers remain poorly implemented in clinical practice.¹⁶

Overall, this study supports the conclusion that there is no single best imaging modality. The cardiovascular imaging modalities all have specific strengths and weaknesses, which can help facilitate patient-specific decisions for test selection. Despite the evidence for decreased rates of death or non-fatal myocardial infarction with the use of CCTA in addition to functional imaging in patients with chest pain syndromes,¹⁷ many patients may be best served with MPI. In addition to those patients with significant renal dysfunction, known contrast allergies or known coronary artery disease, this study contributes to existing literature suggesting that patients with a history of arrhythmia or high resting heart rates may benefit from the investigation with SPECT MPI instead of CCTA. Using complementary information from CT and SPECT will likely lead to the highest diagnostic and prognostic accuracy. Coronary artery calcium information improves SPECT MPI diagnostic certainty¹⁸ and provides additive prognostic value to SPECT MPI results.^{19,20} Similarly, MPI with SPECT or positron emission tomography can help clarify the significance of equivocal lesions on CCTA.

Disclosures

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