Myocardial blood flow assessment with SPECT systems: The renovation continues

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THE SCOPE

The incremental prognostic value of myocardial blood flow (MBF) and coronary flow reserve (CFR) by PET/CT has been well demonstrated in several studies.^{1,2} It was also shown that MBF can be obtained with CZT-based SPECT systems having dynamic imaging capability.^{3–10} Recently, several investigators demonstrated the feasibility of quantifying MBF with NaI-based dual-head SPECT systems equipped with rapid rotational gantry (RRG).¹¹ In this edition of the journal of nuclear cardiology, Rongzheng et al. from Fu Wai Hospital, China, performed a head to head comparison between resting MBF obtained by a conventional SPECT system with RRG and a CZT-SPECT system in 20 patients with congestive heart failure (CHF subgroup) and left ventricular systolic dysfunction (ejection fraction < 50% by echocardiography), and 20 non-CHF patient group with normal systolic function. The majority of the CHF patients (19 of 20) were diagnosed as suffering from ischemic heart disease. All patients (20 CHF and 20 non-CHF) were scanned on both dual-head NaI-based SPECT system and a CZT-SPECT system on two consecutive days. The results demonstrated good correlation between resting MBF by conventional and CZT-SPECT systems in CHF and non-CHF patients, with good repeatability. Moreover, resting

MBF was lower among CHF patients compared to non-CHF patients for both SPECT systems.

WHAT IS THE CLINICAL VALUE OF MBF?

It was well demonstrated that myocardial perfusion imaging (MPI) provides a valuable diagnostic and prognostic information. However, myocardial perfusion is displayed as a relative distribution of the radiotracer uptake in the myocardium where the highest count density voxel is presented with the brightest color in the selected color scheme. Therefore, the absolute tissue uptake remains unknown which may result in a normal distribution pattern despite a global reduction of the radiotracer uptake. MBF provides an absolute quantification of the myocardial tissue uptake by converting the count density values into absolute flow unit (mL/min/g). Therefore, a global reduction of radiotracer count density which may have a normal perfusion pattern will be reflected by low flow values. As demonstrated in several studies, the diagnostic power is increased when flow measurements are included^{1,2,12,13} which may also increase the adoption of stress-only protocols, lower radiation burden, and cost saving.

It should also be noted that SPECT and SPECT/CT systems are widely available globally therefore the infrastructure of adopting that technique is in place.

TECHNICAL REQUIREMENTS FOR MBF CALCULATION

In a nutshell, MBF calculation requires capturing the radiotracer transit through the left ventricle which is often referred as the arterial “input function” component of the kinetic model. This component is often obtained by a dynamic acquisition initiated prior to radiotracer injection and typically lasts for 8 to 10 minutes. The second component is the radiotracer

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perfusion uptake in the myocardium which is measured either by increasing the dynamic acquisition time duration or obtained as a separate perfusion acquisition.^{3,5,6} These two components are then used to assess the compartment modeling constants K1 and optionally k2 followed by conversion into flow units. High sensitivity systems are suited for blood flow quantification due to the fact that they allow reliable input function assessment. In addition, suitable kinetic modeling and radiotracers with high extraction characteristics shall be used to avoid underestimation at high flow rates.¹⁴ These requirements are in principle been addressed in PET imaging having high sensitivity systems and high extraction radiotracers such as ¹³N-ammonia and ¹⁵O-water.^{1,12,13} However, a delicate process is needed to obtain MBF in a robust manner and for the appropriate clinical indication.^{15,16} The later statement is obviously relevant for SPECT techniques which currently have lower system sensitivity and radiotracer kinetics (of ^{99m}Tc) as compared to PET. In recent years, revolutionized CZT-based cardiac-dedicated SPECT systems having 5- to 8-fold increase in system sensitivity while maintaining spatial resolution as compared to dual-head systems were introduced.^{17,18} These systems have a dynamic capability to capture the radiotracer transit through the left ventricle. Several studies have shown that MBF quantification can be obtained with these systems.^{3-9,19}

Along with the efforts to optimize the protocols and performance to calculate MBF using CZT-based systems, investigators are seeking for techniques to obtain MBF using conventional dual-head rotating SPECT and SPECT/CT systems.¹¹ The main challenge for these systems is to obtain the input function in a robust manner despite the inconsistency in the projection images due to the rotation of the system heads during the dynamic transit of the radiotracer through the left ventricle. The input function can be obtained using dynamic stationary planar image;²⁰ however, this technique is limited by the two-dimensional nature of the data and therefore was not widely adopted in clinical practice.

ARE WE READY FOR PRIME TIME?

The majority of nuclear cardiac studies are performed to date using SPECT systems, and most of these use a conventional rather than a CZT system. Several editorials outlined the potential of SPECT to follow PET and provide flow assessment in clinical routine.^{21,22} In this edition of the journal of nuclear cardiology, Rongzheng et al. compared the resting MBF of CHF and non-CHF patients using a cardiac stationary CZT system and a rotating dual-head NaI system. The system

heads of the dual-head rotating camera were rotated back-and-forth in order to obtain the arterial input function and radiotracer transition through the left ventricle at a maximal speed of 10 seconds per rotation. Angular inconsistencies were corrected by back-projection and forward projection technique of the empty angles. The authors also applied tissue attenuation, scatter, resolution recovery, spill over, and partial volume corrections during reconstruction prior to MBF quantification. High resting MBF correlation between the CZT and the dual-head system for both populations (CHF and non-CHF) was reported. As noted by the authors, a major limitation of the study is the fact that MBF was assessed in resting mode only. Additionally, no gold standard was available in this study. The primary technical ingredients required for myocardial blood flow assessment by SPECT are outlined which increase the importance of the manuscript as an educational resource for quantifying MBF using SPECT systems.

Additional test-retest studies are in the pipeline which will further explore the domain of MBF quantification with high sensitivity SPECT systems. It is expected that these studies will formalize the optimal protocols for MBF assessment with SPECT. However, to echo Juneau et al¹⁵ let us ensure we walk before we fly in SPECT as well as in PET.

Disclosure

Gil Kovalski is an employee of GE Healthcare. Tali Sharir has nothing to disclose.

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