MDCT for Cardiovascular Evaluation

Are There 2 “One-Stop Shops”?

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TWO “ONE-STOP SHOPS”

Since its introduction in 2005, multi-detector row computed tomography (MDCT) has emerged as a useful tool for the evaluation of patients with suspected coronary artery disease (CAD). Through an array of prospective multicenter studies, MDCT for CAD evaluation has been established as an imaging method with high diagnostic performance for the identification and exclusion of anatomically obstructive coronary stenosis (1). Although MDCT is commonly regarded as a modality useful only for the exclusion of anatomically obstructive coronary stenosis (i.e., high negative predictive value) these prospective studies established MDCT to exhibit positive predictive value that exceeds or at least is comparable with that of more conventional imaging methods, such as single-photon emission computed tomography and stress echocardiography.

Recent advances in computational fluid dynamics and machine learning applied to coronary MDCT have allowed the noninvasive calculation of fractional flow reserve from computed tomographic scanning for determination of the hemodynamic significance of an anatomic coronary lesion (1). This method has refined our understanding of coronary pathophysiology, reminding us that not all “high-grade” anatomic stenoses cause ischemia and, conversely, that not all “nonobstructive” lesions do not (2). Combined, MDCT and computed tomographic fractional flow reserve—2 separate tests nevertheless afforded by a single image acquisition—hold the promise of serving as the “one-stop shop” to not only accurately identify coronary stenoses but determine the ones that cause ischemia.

Yet these observations alone neglect the “other shop” that comprises essential data necessary for understanding noncoronary cardiac structure and function. These evaluations started nearly 40 years ago, using “ultrafast” CT scanners, or electron-beam computed tomographic scanners (3). With a fixed gantry, the temporal resolution of electron-beam computed tomographic scanners is about 30 to 50 ms, a speed comparable with that of cine angiography that effectively “freezes” the heart for motion-free imaging. In the past decade, electron-beam computed tomographic scanners have largely fallen out of favor in lieu of the more contemporary multi-detector row computed tomographic scanners, which, although slower than electron-beam computed tomographic scanners, provide significantly higher spatial resolution (~500 μm isotropic), enabling high-quality coronary artery imaging. As a useful comparison, electron-beam computed tomography allows spatial resolution that is similar to that of current-generation cardiac magnetic resonance (CMR), while MDCT possesses spatial resolution that is about 6 times greater.

Given that cardiac structure and function are often obtained as a by-product of imaging for CAD assessment, it remains highly germane whether the current technological limitations of MDCT allow accurate structural and functional assessment. MDCT evaluations include assessment of ventricular and atrial morphology and function, myocardial blood flow, myocardial perfusion, and tissue characterization. By summation of these metrics on MDCT, proponents have offered MDCT as another one-stop shop that permits noncoronary cardiac evaluation, which, when coupled with CAD evaluation, can...
determine the etiology of ischemic versus non-ischemic cardiomyopathies. The latter has been a focus of abundant discussion. Yet similar to all metrics that categorize disease states into binary terms, these classifications of cardiomyopathies are both arbitrary and entirely too simplistic. In this issue of *iJACC*, 2 studies aim to evaluate MDCT’s abilities, beyond these crude classifications, to better describe cardiac pathology and identify patients who may benefit from invasive or medical therapies (4,5).

**DELAYED ENHANCEMENT COMPUTED TOMOGRAPHY**

In the first of the 2 studies, Esposito et al. (4) evaluated the role of MDCT for delayed enhancement (DE) characterization of myocardial foci that housed a ventricular tachycardia (VT) substrate. In perhaps the most careful study to date, Esposito et al. (4) evaluated 42 consecutive patients referred for VT radiofrequency catheter ablation with DE imaging. On the basis of hyperattenuated (i.e., brighter) areas of myocardium on MDCT, these investigators identified high negative predictive value and positive predictive value for the exclusion and identification of VT substrates, respectively.

Important differences in DE evaluation between MDCT and CMR should be noted. In the study by Esposito et al. (4), 80-kV imaging 10 min after iodinated contrast injection was performed to obtain DE MDCT images. This contrasts with CMR, which uses an iterative approach to detect the optimal duration between contrast injection and peak myocardial enhancement. MDCT cannot be performed in this manner, given the need for additional image acquisitions and increased radiation dose. Iodinated contrast kinetics in MDCT are likely to differ among patients on the basis of underlying cardiac function, blood pressure, and volume state, and it remains probable that an arbitrary 10-min post-contrast MDCT scan will not allow high accuracy in every patient. Yet, as highlighted in this study, more than 80% of patients undergoing DE MDCT for VT ablation had implantable converter-defibrillators, which precluded their assessment by CMR, a modality considered the ground truth for this purpose.

The study by Esposito et al. (4) and other similar studies open the door to an array of future evaluations that may enhance the use of MDCT in patients with suspected VT amenable to RFCA. Although not specifically reported in the study by Esposito et al. (4), information obtained on DE MDCT can be coupled with other potentially important foci of VT etiology and location, including areas of impaired myocardial perfusion on first-pass contrast-enhanced MDCT, global and regional ventricular function, wall thinning, and stress-strain relationships for the characterization of ventricular compliance. Given the widespread availability of cardiac MDCT, which can be easily performed with 1- to 5-s breath-holds that enable its performance in virtually all patients, the integrated measure of these findings may improve overall outcomes of VT RFCA. Furthermore, early pilot studies have demonstrated the feasibility of coregistration techniques to enable simultaneous dual-modality coregistration of electric and anatomic maps in VT. Such techniques, more widely used for pulmonary vein isolation in patients with atrial fibrillation, have demonstrated their utility in other structural heart disease interventions, such as in the transcatheter valve space. Future studies evaluating the therapeutic efficacy of VT RFCA with DE MDCT and their coregistration with x-ray and electric maps now appear warranted.

**MYOCARDIAL FIBROSIS IMAGING BY COMPUTED TOMOGRAPHY**

Compared with a CMR reference standard for tissue characterization, current-generation single-energy MDCT fares generally poorly. The signal-to-noise ratio for CMR is far superior to that of single-energy MDCT, stemming from excessively high electric noise rather than intrinsically lower signal. Efforts to improve tissue characterization for MDCT have resulted in the introduction of dual-energy computed tomography (DECT). Each MDCT vendor has released its own version of DECT, but the principles underlying their technologies are generally similar (6). By either simultaneous or near-simultaneous imaging with 2 polychromatic energy spectra, DECT enables the separation of tissue features on the basis of actual material densities rather than the generally crude Hounsfield unit (HU) method, whereby materials are classified on a simple, relative gradient, gray scale around a standard water value of zero. By achieving material density determination, materials (such as myocardium or iodinated contrast) can be described by their actual atomic numbers and, in this regard, might offer better tissue characterization.

In this issue of *iJACC*, Hong et al. (5) report on their evaluation of DECT to identify myocardial changes in a pre-clinical model of doxorubicin-induced dilated cardiomyopathy. This study has high potential import, given the increased recognition of anthracycline-induced cardiomyopathies and the pressing need to identify patients in the pre-clinical state, before left ventricular ejection fraction (LVEF)
decrease, and in whom drug-induced cardiomyopathy may be prevented.

In prior studies of patients undergoing chemotherapy with anthracyclines, LVEF has been the primary metric of focus, serving as a surrogate measure of cardiac output. Yet many other metrics that preclude impairment in LVEF may provide earlier, clinically valuable information that can be acted upon before phenotypic reduction in ventricular function becomes manifest. Regional wall motion and ventricular compliance described by the laws of Laplace and Young’s modulus of elasticity to quantify stress-strain relationships have also been proposed for use. Between these 2 measures likely lies the damage to myocardium before manifest left ventricular (LV) dysfunction occurs. As identified and established by CMR, this step of myocardial fibrosis may serve as a precursor harbinger for future LV dysfunction. Contemporary T1 mapping techniques characterizing myocardial tissue allow the measurement of extracellular volume (ECV) as a surrogate measure of myocardial fibrosis (7). ECV is generally defined as: (HUmyocardium/HULV blood pool) × (1 – hematocrit).

Using proprietary software for computed tomographic ECV mapping, Hong et al. (5) evaluated a longitudinal model of rabbits receiving twice-weekly doxorubicin treatments. By comparison with both CMR and pathology, computed tomography demonstrated high correlation for measures of myocardial fibrosis as suggested by ECV. Yet the investigators note that cardiac motion artifacts were prevalent, and the image quality of iodine maps afforded by DECT is in need of improvement. Furthermore, given the coincidence of ECV abnormalities on DECT and pathologic fibrosis, it remains questionable whether there is much clinical import to this technique if “the damage has already been done.” Future studies will determine whether ECV measurement by DECT is useful for the identification of at-risk patients in whom LV dysfunction will subsequently occur, but it will still be necessary to determine whether this is early enough in the anthracycline-induced cardiomyopathy cascade to intervene in a manner that improves patient outcomes.

Future MDCT technologies hold the promise to improve upon the current limitations of DECT. In particular, energy-resolved photon-counting detectors are being developed to enable true subvoxel multispectral computed tomographic imaging (8). Photon-counting detectors enable consideration of individual photons even within a single detector element and can be binned according to specific monochromatic energy with a resolution within a few kiloelectron volts. In this manner, electronic noise can be effectively rejected with minimal spectral overlap. Of equal importance, this multispectral information is acquired simultaneously across the entire gamut of different energies within a single scan, thus obviating the need for additional radiation or misregistration, as can be observed when using nonsimultaneous dual-energy image acquisition.

In sum, the reports in this issue of JACC remind us that there is indeed another shop. Although current-generation MDCT likely falls short of CMR for myocardial characterization, given its poorer signal-to-noise ratio and lower temporal resolution, there are many patients, including those undergoing VT RFCA and with suspected cardiomyopathy, who often have intracardiac devices that preclude CMR investigation. Although interesting, these present studies should be considered only as proof-of-principle investigations. Prospective evaluation in a multicenter fashion for health outcome endpoints will be necessary to establish the utility of MDCT for routine clinical use in evaluation of the measures of cardiac structure and function.

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