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YEAR IN CARDIOLOGY SERIES

The Year in Cardiac Imaging

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This review is a sequel to our 8 previous reports summarizing the most important published research for single-photon emission computed tomography (SPECT), cardiac positron emission tomography (PET), cardiac computed tomography (CT), and cardiac magnetic resonance imaging (MRI). This report generally covers the English-language published data between July 1, 2011, and September 30, 2012.

We have again organized our summary around topical themes in the belief that an integrated, multi-modality imaging approach is ideal for the solution of most clinical problems.

Technical Developments

PET/CT. Plaque biology remains of great interest. Dweck et al. (1) reported the use of combined PET and CT to investigate uptake of fluorine-18-sodium fluoride (18F-NaF) as a marker of plaque calcification and fluorine-18-fluorodeoxyglucose (FDG) as a marker of plaque inflammation. They found that, in 119 volunteers, 18F-NaF uptake was higher in patients with coronary atherosclerosis and correlated ($r = 0.65$) with the calcium score, although 40% of patients with very high calcium scores (>1,000) had normal uptake. In contrast, FDG uptake in the coronary arteries was confounded by myocardial activity and not increased in patients with atherosclerosis.

In a second study on the same patients, Dweck et al. (2) reported the use of 18F-NaF and FDG to examine calcification and inflammation in aortic valve disease. Patients with aortic stenosis had higher activity of both tracers than control subjects. The 18F-NaF uptake increased with valve severity ($R^2 = 0.54$) and had a much closer relationship than FDG ($R^2 = 0.22$). Of patients with aortic stenosis, 91% had increased 18F-NaF uptake; only 35% had increased FDG uptake. As noted by Aikawa and Otto (3), many more studies are needed, but these early results suggest the possibility of PET valve imaging as a measurement tool in future drug trials.

Patient Safety

Cardiac CT radiation dose reduction. Efforts at balancing radiation dose and image quality in CT continue. Radiation dose varies exponentially with changes of the tube potential, but so does image noise. The decision to use tube voltage of 100 kVp versus 120 kVp is sometimes based on body mass index (BMI). However, BMI often reflects abdominal thickness more than chest thickness. In a series of 106 consecutive cardiac CT angiograms, acquired at 120 kVp ($n = 64$) or 100 kVp ($n = 42$), Ghafourian et al. (4) determined both subjective and objective measures of image quality and compared these measures with both BMI and scout view attenuation. Scout view attenuation was the best predictor of image noise and "low noise" images (area under the curve, 0.73). After adjustment for the scout view attenuation, BMI was not statistically significant. This suggests that the scout view can help decide which tube potential to use.

The findings of prospective, randomized studies of image quality and radiation exposure including more than 100 patients are summarized in Table 1 (5,6).

Diagnosis: Coronary Artery Disease

CT: coronary stenoses. With the maturation of technical aspects of coronary computed tomography angiography (CTA), the research focus is increasingly shifting toward identifying the patient groups in which coronary CTA provides the most value.

In a retrospective analysis of 14,048 patients enrolled in the CONFIRM (Coronary CT Angiography Evaluation for Clinical Outcomes: An International Multicenter Registry) (7), pre-test probability was estimated on the basis of sex, age, and chest pain. The observed prevalences for 50% and 70% diameter coronary stenoses on coronary CTA were substantially lower than those predicted by clinical parameters (18% vs. 51% for >50% stenoses, 10% vs. 42% for >70% stenoses; $p < 0.001$), particularly for patients with typical angina (19% vs. 71% for >70% stenosis) (Fig. 1). In an accompanying editorial, Diamond (8) attributed some of these differences to the use of self-administered questionnaires and verification bias.

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The high negative predictive value (NPV) of coronary CTA is important for its use to "rule out" coronary artery disease (CAD). Most of the studies showing this high NPV were performed in populations with low to intermediate pre-test probability. In a retrospective analysis of prospectively acquired data for the CORE-64 study (Coronary Artery Evaluation Using 64-Row Multi-Detector Computed Tomography Angiography), Arbab-Zadeh et al. (9) examined the impact of disease prevalence and coronary calcium on the diagnostic accuracy of coronary CTA. Although the areas under the curve for diagnostic accuracy were similar for patients with intermediate probability of CAD, high probability for CAD, and known CAD (0.93, 0.92, and 0.93, respectively), the NPVs varied substantially (0.90, 0.83, and 0.50, respectively [$p < 0.001$]) and decreased to 0.81 when the calcium score was $\geq$600. In patients with high calcium scores and high pre-test probability for obstructive CAD, the NPV of coronary CTA is lower than previously reported.

Population radiation exposure can be potentially reduced by prospectively identifying patients who are likely to have nondiagnostic image quality of coronary CTA. In a retrospective analysis of registry data, Vanhecke et al. (10) developed an "uninterpretable risk score" in 8,585 symptomatic patients and used it to predict uninterpretable studies in 915 subsequent symptomatic patients. For each 4-point increase of the score (maximum, 32 points), the rate of encountering at least 1 uninterpretable coronary segment increased approximately 1.5-fold. Increased heart rate and the coronary calcium score were most predictive of uninterpretable coronary CTA results. Patients with an uninterpretable study had an increased frequency of adverse outcomes over 3-month follow-up.

CT myocardial perfusion imaging. The technology and application of computed tomography myocardial perfusion imaging (CTMPI) continue to evolve.

Ko et al. (11) compared invasive fractional flow reserve (FFR) measurements and adenosine stress CTMPI in 86 coronary perfusion territories that were supplied by vessels with $\geq$50% diameter stenosis. Blinded qualitative assessment of segmental CTMPI after triphasic injection of contrast during adenosine infusion correctly identified 31 of 41 (76%) territories with FFR $\leq$0.8 (Fig. 2). The CTMPI was normal in 38 of 45 (84%) myocardial segments with preserved FFR. The combination of a defect on CTMPI and a $\geq$50% stenosis on coronary CTA (with 320 detector rows) was 98% specific for identifying abnormal FFR, and the combination of normal CTMPI and a stenosis <50% or less on coronary CTA was 100% specific for identifying preserved FFR (Fig. 2).

Computational fluid dynamics can be applied to estimate FFR from typical coronary CTA protocols, which currently requires proprietary software and approximately 5 h/exam. Koo et al. (12) compared FFR by CT with invasive FFR in 159 vessels of 103 patients (Fig. 3). The accuracy of abnormal FFR by CT to identify vessels with abnormal invasive FFR (0.8) was 84.3%. The FFR by CT correlated

Table 1 Effect of Cardiac CT Radiation Reduction Techniques on Image Quality

First Author (Ref. #)	Scan Techniques Investigated	n	Main Outcome Variable	Major Findings	Mean Effective Dose	Comments
Hausleiter (5)	Prospective ECG triggering (axial) vs. retrospective ECG gating (helical)	400	Image quality (ordinal, 1–4)	Image quality noninferior in axial vs. helical scanning (3.36 ± 0.59 vs. 3.37 ± 0.56)	3.5 ± 2.1 vs. 11.2 ± 5.9 mSv	Beta-blocker use 77% vs. 79% HR 54 ± 6.1 vs. 56 ± 5.5
Neefjes (6)	High-pitch scanning vs. prospective ECG triggering (narrow window) (HR <65 beats/min; n = 160) Prospective ECG Triggering (wide window) vs. retrospective ECG gating with ECTCM (HR ≥65 beats/min; n = 112)	272	Image quality (ordinal, 1–3)	Image quality scores: 2.67 ± 0.38 vs. 2.86 ± 0.21 ($p < 0.001$) 2.81 ± 0.28 vs. 2.80 ± 0.38 ($p = 0.54$)	High pitch vs. prospective triggering (narrow) 0.81 ± 0.03 vs. 2.74 ± 1.14 mSv (120 kVp) 1.65 ± 0.69 vs. 4.21 ± 1.2 mSv (100 kVp) Prospective triggering (wide) vs. retrospective gating 4.07 ± 1.07 vs. 5.54 ± 1.76 mSv (120 kVp) 7.50 ± 1.79 vs. 9.83 ± 3.49 mSv (100 kVp)	Metoprolol 100 mg PO 1 h before scan unless contraindicated

Studies >100 patients.
CT = computed tomography; ECG = electrocardiography; ECTCM = electrocardiography-correlated tube current modulation; ETT = exercise treadmill testing; FDG = fluorodeoxyglucose; HR = heart rate.