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EDITORIAL COMMENT

Cardiac Magnetic Resonance Imaging to Assess and Predict Improvement of Myocardial Function After Percutaneous Coronary Intervention

A New Standard?*

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Over the past 30 years, the technologic improvements in percutaneous coronary intervention (PCI) have been breathtaking. The incidence of coronary artery dissection, acute occlusion, emergency coronary artery bypass graft (CABG) surgery, and restenosis have all been significantly reduced by bare-metal and drug-eluting coronary stents. Technical problems such as tortuous vessels, calcification, diffuse disease, small vessels, distal lesions, and chronic total occlusions, have been addressed by a panorama of novel devices and equipment.

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Parallel with this technology has been the introduction of an impressive array of adjunctive pharmacologic agents. What was technically unapproachable in the past is now fair game. Multivessel and left main PCI is now within the purview of the interventional cardiologist as evidenced by the favorable results of PCI versus CABG in the recent SYNTAX (Synergy between Percutaneous Coronary Intervention with Taxus and Cardiac Surgery) study (1) and MAIN-COMPARE (Revascularization for Unprotected Left Main Coronary Artery Stenosis: Comparison of Percutaneous Coronary Angioplasty Versus Surgical Revascularization) registry (2) and other randomized and registry data. As a result, the interventional cardiologist is exposed to his or her own internal pressure—and the significant expectations from the referral base and patients—to perform PCI instead of CABG surgery in cases with multivessel coronary disease.

As Mark Twain once stated "To a man with a hammer, everything looks like a nail." (3) Along with the capabilities of performing PCI in complex multivessel disease, there is also the responsibility of assessing whether this will improve patient outcomes in the long term. Pre-revascularization risk assessment, evidence-based medicine, and the 2009 appropriateness criteria for coronary revascularization (4) are now standards of practice. The web-based SYNTAX score (5) provides an excellent anatomic tool to assess the suitability of multivessel revascularization by either CABG surgery or PCI. Coinciding with all these assessments are the findings of the New York State Registry (6) that the consequences of incomplete revascularization result in a significant increase in long-term mortality and morbidity. In addition to predicting the procedural and long-term success of revascularization alternatives, the need also arises for methods to properly evaluate the completeness of revascularization and to predict myocardial recoverability if PCI is undertaken for multivessel coronary disease in patients with impaired myocardial function.

Cardiac magnetic resonance imaging (MRI) offers some alluring possibilities for the evaluation of completeness of revascularization. In this issue of *JACC: Cardiovascular Interventions*, Kirschbaum et al. (7) provide important data regarding the use of cardiac MRI techniques to assess and predict improvement of left ventricular (LV) function in patients undergoing PCI for multivessel coronary artery disease. Their study was a prospective analysis of 71 patients to: 1) examine the effectiveness of complete, incomplete, and unsuccessful revascularization by PCI on myocardial function in patients with multivessel coronary artery disease and mildly impaired LV function; and 2) examine the diagnostic accuracy of 2 cardiac MRI techniques to predict functional myocardial recovery.

The 71 patients were divided into 3 groups: 34 patients who had successful complete revascularization, 22 patients who had incomplete revascularization, and 15 patients who had unsuccessful or no revascularization. Each of the groups underwent cardiac MRI at pre-PCI baseline and at post-PCI 6-month follow-up. Global and regional wall motion was assessed at baseline and at 6 months with a cine cardiac MRI steady-state free-precession technique. For viability assessment, 2 cardiac MRI techniques were used. Contractile reserve was quantified by dobutamine stress cardiac magnetic resonance imaging (DS-CMR) at rest and after 5 and 10 μg/kg/min infusion of dobutamine. In addition, the transmural extent of infarction (TEI) was assessed by delayed enhancement cardiac magnetic resonance imaging (DE-CMR).

The major findings were that complete revascularization resulted in a significant improvement in ejection fraction (EF) ($46 \pm 12\%$ to $51 \pm 13\%$, $p < 0.0001$) compared with no improvement in the incomplete or unsuccessful groups. Frankly, this would be expected and is no surprise. The more intriguing aspect of this article, however, was the capability of DS-CMR and DE-CMR to predict improvement in LV function. In the DS-CMR assessment, 3

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dysfunctional but viable segments/ventricle were required to achieve an improvement in EF >4%. In the DE-CMR evaluation, according to the linear regression line for TEI, 4% improvement in EF corresponded to 25% of the LV that was dysfunctional but viable, which was 4 segments before revascularization. Thus, LV function improved significantly in patients who underwent complete revascularization if the contractile reserve positive change in segmental thickening was >7% by DS-CMR or if TEI was <25% by DE-CMR. The DS-CMR, compared with DE-CMR, had a significantly higher sensitivity (100% vs. 70%, $p < 0.001$), but specificity was not different (75% vs. 77%, $p = 0.80$).

The strengths of Kirschbaum's study are that she and her colleagues present very accomplished use of cardiac MRI techniques and data to determine viability and predictive value for completeness of revascularization in multivessel PCI patients. Because multivessel coronary artery disease patients with LV dysfunction might be candidates for either CABG surgery or PCI, this study underscores the need for achieving complete revascularization if a PCI strategy is chosen. This report also highlights the importance of viability assessment in predicting the myocardial functional outcome after PCI and offers the alternative of cardiac MRI methods.

This study has a number of limitations. It was not designed as a randomized trial of pure viability assessment to guide revascularization decision-making. The numbers of patients were quite small, and EF was used as a surrogate. At best, improvement in EF was moderate (4%) in the complete revascularization group. There were few data regarding clinical outcomes. This study only focused on moderately reduced LV function—not severely reduced function. Patients with severely impaired myocardial function represent a major category of more complex decision processes to assess the suitability of revascularization modalities. Future studies of DS-CMR and DE-CMR techniques should be done in patients with severe myocardial dysfunction. In addition, it would be interesting to see a comparison of myocardial recovery with these cardiac MRI techniques in patients who undergo PCI versus those treated with CABG.

This paper makes a meaningful contribution to the field of interventional cardiology and the use of cardiac MRI techniques in patients who are being evaluated for multivessel PCI. It sets good measurements for the determination of viability of myocardium and offers the promise of perhaps improved methods to predict the potential recovery of LV function with complete revascularization without extensive radiation exposure to the patient. If proven so in more comparative studies with greater numbers, cardiac MRI could eventually replace other methods of viability determination, such as thallium-201 imaging, technetium-99m–labeled agents, positron emission tomography, and dobutamine echocardiography. However, the use of cardiac MRI will be limited in patients too obese for the scanner or those with claustrophobia—in addition to other issues, such as patients with implantable metal devices or those with significantly irregular rhythms. Of practical question in this era of health care reform and pre-approval of studies by third-party payers: What are the economics and cost of cardiac MRI studies?

To address the Mark Twain quote (3)—yes, we now have even better "hammers." But we are also developing better mechanisms of determining which "nails" need pounding and, if pounded, whether it makes a difference. This report opens the door for more use of cardiac MRI to evaluate the completeness of revascularization in multivessel coronary artery disease. Dobutamine stress cardiac MRI is a functional physiologic parameter of viability, whereas DE-CMR provides anatomic information. This dual assessment strategy is quite promising and offers the possibility that DS-CMR and DE-CMR techniques might be more precise predictors of recovery of the myocardium after revascularization. However, more work needs to be done and more data need to be acquired on cardiac MRI viability modalities—particularly in patients with severely impaired myocardium—before it replaces other methods of recovery assessment. Therefore, the cardiac MRI viability techniques reported in this article are not quite ready to be considered unequivocal gold standards of diagnostic assessment for impaired myocardial recoverability in patients with multivessel coronary artery disease. But, at present, they offer another good alternative to help determine the appropriateness of revascularization. The future use of expanded cardiac MRI techniques in this venue seems very promising.

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Key Words: cardiac magnetic resonance imaging ■ multivessel coronary artery disease ■ percutaneous coronary intervention.