Editorial

Insights into Myocardial Microstructure During Infarct Healing and Remodeling

Pathologists Need Not Apply

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Healing of acute myocardial infarction (MI) and subsequent increase in left ventricular (LV) cavity size or LV remodeling is a complex process. LV remodeling depends largely on infarct size and transmurality which in turn is determined by the status of the epicardial infarct artery and the microvasculature. Within a larger, near-transmural or transmural infarction, there is myocyte loss, in part because of apoptosis, and cellular slippage that leads to reduced tensile strength within the infarct zone and subsequent infarct expansion. Infarct expansion and wall thinning in the infarct zone then leads to regional cavity dilatation and increased wall stress throughout the LV. Elevated wall stress in turn activates the renin-angiotensin system and other autocrine-paracrine systems and cellular hypertrophy ensues. Cellular hypertrophy occurs primarily in noninfarcted regions adjacent to the infarcted segment and is eccentric due to the laying down of sarcomeres. Eccentric cellular hypertrophy in noninfarcted regions together with fibrosis contribute to mechanical dysfunction in adjacent noninfarcted regions that persists during remodeling. Remote noninfarcted regions are initially mildly dysfunctional in the first few days after large MI, but these recover over the next several weeks as global LV function improves. The sum total of these events is a deleterious increase in end-diastolic and -systolic cavity sizes. It is the latter that is the most important determinant of outcome after acute MI. Until very recently, studies of the structural events that occur during LV remodeling have required painstaking histopathology and have been performed primarily in animals. With the advent of advanced cardiac imaging techniques, similar observations can now be made in vivo. Diffusion tensor cardiac magnetic resonance imaging (DT-CMR) was developed more than a decade ago, but was initially applied in MI only in animal studies. Its first application in patients after MI was very recently and represents a technical tour-de-force. DT-CMR enables delineation of the microstructure of the heart based on the principle that diffusion of water within the myocardium parallels the orientation of cardiac microstructure. Thus, DT-CMR can yield information regarding not only the mean diffusivity of water molecules, but also fractional anisotropy or the variability of the direction of water mobility and helix fiber angle of the myofibrillar architecture. All these imaging parameters reflect myocardial structural alterations during infarct healing and LV remodeling. In their original application of DT-CMR to 37 post-MI patients, Wu et al. demonstrated increased water diffusivity reflecting increased extracellular space within the scar, and increased fractional anisotropy, a marker of myofibrillar disarray. In addition, they noted an increase in left-handed helical fibers representing an overrepresentation of the subepicardial fibers within the infarct because of loss of subendocardial myocytes, and this change in fiber orientation correlated with increased infarct size and reduced ejection fraction.

The article from this same group in this issue of Circulation: Cardiovascular Imaging is a follow-up study of their original study population. Twenty of the original 37 patients were imaged for this study, but only 17, less than half of the original and all male, had adequate data for analysis. The initial imaging was performed 3 weeks after the index MI and follow-up on average 7 months after MI. Five of the patients had received percutaneous coronary intervention before the initial CMR, whereas an additional 7 patients underwent percutaneous coronary intervention in the interval between imaging sessions. It would have been useful to know if the changes that occurred between the 2 imaging sessions were different in the 7 revascularized patients compared with the rest of the population as it may be difficult to tease out natural history from effects of revascularization. Presumably the patients were on state-of-the-art post-MI medical therapy during this period. Nine of the infarcts were in the LAD territory, 2 in the left circumflex, and 6 in the right coronary artery territory. Examining differences in the anterior infarct group would have been of interest as anterior infarcts are known to be prone to greater adverse LV remodeling. The relatively small size of the patient group may have precluded this type of substudy. Imaging was performed entirely in the midventricle with 3 slices representing this territory. On the basis of standard late gadolinium-enhanced CMR, the myocardium was divided into 2 territories; infarct-adjacent and remote. Infarct-adjacent segments were defined as those that contained infarcted tissue of any transmurality, and adjacent noninfarcted tissue was thus defined as midwall and subepicardial border zones. Unfortunately, no data are presented regarding extent of transmurality of infarction in these patients. This could

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certainly impact the findings because subsequent remodeling is distinctly different between subendocardial and transmural infarcts.

During the 6 months between DT-CMR studies, the infarct-adjacent region demonstrated wall thinning while the remote zone demonstrated hypertrophy and increased wall thickening relative to the infarcted segment. During infarct healing, the infarct-adjacent region demonstrated a decrease in mean diffusivity, toward normal, likely due to resolution of edema and further organization of scar. Similar findings were noted in remote. In addition, myofibrillar disarray as evidenced by fractional anisotropy tended to improve in the infarct zone and did improve in remote. The fiber angle became more right-handed helical with time in the infarct-adjacent region consistent with replacement with epicardial fibers whereas the remote region became more left-handed helical, likely due to relative hypertrophy of fibers with subendocardial orientation. Correlations were noted between mean diffusivity in the infarct-adjacent region and improved wall thickening. Similar correlations were noted in remote.

Despite all of these microstructural improvements, global ejection fraction did not improve over time in this patient population. This is a result of a relative decline in wall thickening in the infarct segment while remote regions improved. Wu et al did not include in their manuscript the changes in end-diastolic or -systolic volumes that may have occurred over time in this population of patients. Ejection fraction may not change, but if end-diastolic and -systolic volumes increase proportionally, this portends an adverse prognosis in the post-MI population.16

This study does not explain the wall thinning in the infarct zone as diffusivity and anisotropy improve. The wall thinning must still be in large part due to loss of myocytes and cell slippage. In addition, imaging doesn’t yet offer the kind of spatial resolution that can differentiate eccentric from concentric cellular hypertrophy. We must infer these changes from relationships between noninfarcted segment lengths, wall thickness, and cavity size. Despite these limitations, this study makes important contributions to our understanding of the process of scar healing and LV remodeling in vivo. Studies of this kind have previously not been possible in the living human heart. Wu et al should be congratulated for completing such technically challenging imaging as well as data analysis in this patient population. Only with similar studies in larger patient groups will investigators be able to tease out differences in infarct healing and LV remodeling based on infarct location, transmurality, and the presence or absence of microvascular obstruction in acute MI. As cardiovascular imagers become more proficient in such advanced techniques, the need for pathologists performing microstructural studies in small animals will dissipate.

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