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EDITORIAL COMMENT

Dark-Blood Late-Enhancement Imaging Improves Detection of Myocardial Infarction*

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Late gadolinium enhancement (LGE) has become a gold standard in myocardial viability assessment (1,2), providing excellent depiction of myocardial infarction (MI). As the use of late-enhancement imaging has matured, and as the span of applications has widened, clinicians are examining LGE images for more subtle signs of fibrosis, and the demands on image quality have grown (3). A large fraction of infarctions caused by coronary artery disease are subendocardial and thus adjacent to the blood pool. Although LGE achieves excellent contrast between infarcted and normal myocardium, the contrast between the MI and the blood pool is frequently poor, making it difficult to delineate the border; in some cases, it leads to missing detection entirely. The contrast between the blood and MI in the inversion recovery (IR) image depends on variables such as contrast agent and dosage, time from administration of gadolinium, rate of clearance, and imaging parameters. These mechanisms are not fully characterized or controlled. Imaging at a later time may result in better blood-pool contrast for some subjects, but, in other instances, contrast may worsen, and it is frequently not practical to wait longer.

IR or phase-sensitive inversion recovery (PSIR) using electrocardiogram-gated, segmented FLASH readout—also referred to as spoiled gradient recalled echo (SPGR)—have become the most widely used sequences for LGE (4,5). A range of new techniques have emerged to improve the speed and quality of late-enhancement imaging. These include single-shot steady-state free precession (SSFP) imaging and motion-corrected averaging for acquisition during free breathing (6,7).

To address the issue of subendocardial MI with poor blood-pool contrast, a number of approaches have been proposed. Cine images may be used in conjunction with LGE (4) to delineate the subendocardial border. Cine images offer excellent resolution and contrast between blood and myocardium, and although this technique is often helpful, it is time consuming to interpret the results because of differences in spatial and temporal resolution and differences in respiratory position of separate breath-holds. Even small differences may complicate the interpretation or make it impossible to resolve. Alternatively, researchers have long sought to develop LGE imaging with blood suppression and have proposed a number of technical solutions. Similar approaches have been developed for vessel-wall imaging. Solutions to this problem range from the use of multiple separate contrasts, such as T1 and T2 (8,9), to blood-suppression techniques, either sensitized to blood flow or flow independent (10-17).

The blood signal based may be suppressed by adjusting the inversion time (18) or by using schemes with multiple inversions and carefully chosen inversion times (11,15,19) to null both the blood and the normal myocardium. Alternatively, LGE with flow-independent blood suppression may be achieved by combining a T2 preparation (10,12,14) with IR. The order of the T2 and IR preparations may be applied as T2-IR (14) or IR-T2 (10). T2-PSIR has also been used for black-blood vessel-wall imaging (17). A variation of the T2-PSIR method (17) presented in this issue combines a magnetization transfer (MT) preparation with IR (13). A hybrid preparation combining MT and T1 rho has also been proposed (16). In these schemes, the myocardial signal is reduced relative to the blood signal, thereby reducing the inversion times to null the myocardium. In this way, it is possible to null

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both the myocardium and the blood at the same time. Furthermore, by using a PSIR reconstruction (5), the blood signal may be made darker than the myocardium (i.e., negative signal values), thereby providing contrast between the blood and both the MI and remote myocardium (12,13).

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The study from Kim et al. (13), published in this issue of *iJACC*, validates that dark-blood (DB) LGE imaging more accurately delineates the subendocardial border by a comparison of the MT-PSIR and conventional segmented IR method with histological staining. The MI size for the proposed MT-PSIR scheme versus histological staining had no statistically significant bias and had improved limits of agreement versus the conventional protocol. Importantly, the extent of the MI for infarcts using the conventional protocol was significantly underestimated when compared with the proposed DB method—despite previous validation (2)—in agreement with our experience with PSIR-T2 DB LGE method in the study of 172 patients (20). Previous validation of MI size using the conventional protocol was based on ex-vivo imaging for which there was no adjacent blood (2). Kim et al. (13) also demonstrate the improvement in diagnostic performance (accuracy, sensitivity, and specificity) for detection of coronary artery disease in a limited study of 20 carefully selected patients with documented MI of varying age—including acute and chronic MI—against a conventional breath-held segmented magnitude IR protocol (4). The improvement in performance was even more dramatic when considering only subendocardial MI. Kim et al. (13) demonstrate the benefits of the proposed DB PSIR LGE image in patients for whom the conventional protocol produces "ambiguous" results (Figure 9). By comparison, the DB MT-PSIR images have exquisite quality in these instances.

DB LGE schemes provide contrast between the MI and the blood pool at the expense of signal-to-noise ratio (SNR). The authors compared the SNR between their MT-PSIR using a breath-held segmented SSFP protocol with their conventional magnitude IR, using a breath-held FLASH protocol, and found a minor loss of SNR of approximately 14%. Comparison against a PSIR SSFP was not performed in this study.

The benefits of DB PSIR LGE include a reduction in missed detections and a reduction in false detections due to either trapped blood in the subendocardial trabeculae or bright rims of blood pool, leading to an improvement in diagnostic confidence. Improved accuracy of MI size leads to better overall assessment. DB PSIR has the ability to see LGE clearly in papillary muscles. The authors recommend wider-scale evaluation of DB late enhancement (13).

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