Published in final edited form as:
JACC Cardiovasc Imaging. 2012 February ; 5(2): 211–213. doi:10.1016/j.jcmg.2011.09.021.

Integration of CMR Scar Imaging and Electroanatomic Mapping:

The Future of VT Ablation?*

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Keywords

cardiac magnetic resonance; catheter ablation; ventricular tachycardia

In this issue of *iJACC*, Gupta et al. (1) present their single-center experience with intraprocedural 3-dimensional registration of cardiac magnetic resonance (CMR) scar mapping with voltage maps created at the time of ablation of ventricular tachycardia (VT) or premature ventricular contractions (PVCs) in 23 post-infarction patients. The methodology involves using 3 standard landmarks—the aortic root, mitral annulus plane, and left ventricular apex—to integrate voltage and scar maps, which allows more focused mapping of VT in areas with scar. Although there is previous experience with post hoc integration of CMR scar and voltage maps (2–5), the novel feature of this contribution is the use of this methodology to guide the VT ablation procedure. At the same time, the study raises several questions. First, is this methodology likely to improve the efficiency and success rates of VT ablation in the future? Second, does this methodology have the potential to be applied broadly to most patients undergoing VT ablation? Third, are there other imaging techniques likely to be more effective or more broadly applicable for patients undergoing VT ablation?

The rationale for the use of CMR for VT ablation in post-infarction patients is based on the relationship between scar and ventricular arrhythmia. VT often occurs in patients with healed myocardial infarctions because slow conduction through surviving myocytes in and around the infarction facilitates reentry, the usual mechanism of sustained post-infarction VT. The exit site for these reentrant VTs is usually located along the border zone of the scar (6). Nonsustained VT and PVCs also occur and may come from the infarct zone, although multiple mechanisms are possible for isolated PVCs, including enhanced automaticity, triggered activity, and localized reentry.

The distribution of myocardial scar is of interest during the ablation procedure because post-infarction VT usually arises from myocardial scar. Infarction appears bright on CMR late gadolinium–enhanced imaging, giving a clear delineation of the infarct size, borders, and transmurality. Although CMR assesses the full extent of scar, endocardial electroanatomic mapping (EAM) may be less sensitive to scar involving the midwall or subepicardium only. For example, a significant difference in bipolar voltage between endocardial versus intramural and epicardial scar (0.94 ± 1.07 mV vs. 1.52 ± 1.41 mV; $p < 0.01$) has been described (2). Fortunately, because post-infarction scars usually involve the

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Dr. Bilchick has reported that he has no relationships relevant to the contents of this paper to disclose.

subendocardium, endocardial EAM should effectively identify areas with myocardial infarction. In fact, pathological studies have shown that infarct size from bipolar EAM voltages of ≤1.0 mV highly correlate with infarct size on the basis of pathology ($r = 0.98$; $p = 0.0001$) (7).

In this way, the rationale for the use of CMR in the context of EAM for VT ablation is that more accurate identification of scar and thus critical ablation sites can be achieved more efficiently. Unfortunately, no conclusions can be made from Gupta et al. (1) with respect to relative efficacy due to the absence of a control group; however, the study did find that 92% of low-voltage points were within 5 mm of scar. Also, all critical sites identified during ablation (defined as sites resulting in elimination of PVCs or termination of VT) projected onto scar, which is consistent with the findings of a previous series of patients evaluated by this group (5). From a clinical standpoint, the patients did very well after the procedure, with an overall reduction in PVC burden of 96% and no recurrent VT in 9 of 10 patients. Whether similar efficacy rates would have been achieved using a standard approach is unknown on the basis of the results of this study.

The next question is whether the methodology has the potential to have a broad impact on the care of post-infarction patients with VT and PVCs. The answer requires consideration of the role of VT ablation in post-infarction patients and other characteristics of patients undergoing the procedure. In addition to catheter ablation, strategies to treat VT in post-infarction patients include implantable cardioverter-defibrillators (ICDs) (8) and pharmacologic therapy, with the specific strategy tailored to the individual patient. In patients with ICDs, catheter ablation is typically performed for sustained ventricular arrhythmia, often after drug failure. Alternatively, prophylactic substrate-based ablation may be performed in post-infarction patients before ICD implantation (9). PVCs may be targeted for ablation in patients who already have ICDs implanted for primary prevention of sudden cardiac death or in others with less severe left ventricular systolic dysfunction.

The presence of an ICD is an impediment at this time to the routine use of CMR in these patients (10). Even if performed as part of a research protocol (11), artifact from the ICD may obscure the characterization of myocardial scar, particularly in patients with anterior infarcts or not much separation between the ICD and cardiac silhouette on chest radiography. For this reason, patients who have not already received an ICD for primary prevention of sudden cardiac death or those undergoing VT ablation before ICD implantation may be the best candidates for intraprocedural CMR scar registration. The methodology could also be applied to prophylactic substrate-based ablation in post-infarction patients before ICD implantation. Of note, the utility of CMR for endocardial ablation in nonischemic cardiomyopathy may be diminished if scar has a predominant intramural or epicardial distribution.

The last question is whether CMR is indeed the best adjunctive imaging modality to identify scar in these patients. Particularly in patients with ICDs, cardiac computed tomography with or without positron emission tomography is another important methodology to identify myocardial scar in 3 dimensions (12), although the quality of scar imaging obtained in this way does not equal that of CMR. In addition, intracardiac echocardiography has been used to identify scar during VT ablation (13). In this study of 18 patients, thinned, akinetic areas by intracardiac echocardiography had an accuracy of 87% in identifying scar on the basis of voltage criteria in the post-infarction patients. Although echocardiography is not as specific for scar as CMR, it would have broader applicability in patients with ICDs and offers accurate real-time left ventricular contours.

In conclusion, Gupta et al. (1) present a descriptive account of real-time registration of 3-dimensional scar maps from CMR images with the voltage map obtained using EAM during VT ablation. Their results extend their previously published association between critical ablation sites and areas of scar on the basis of CMR to the real-time setting, indicating that this technique may facilitate more efficient mapping of scar-associated VT and isolated PVCs in selected patients. There was no control group, and application may be limited in post-infarction patients with ICDs, but the results are promising and justify further clinical study.

Acknowledgments

Dr. Bilchick is supported by NIH grant K23 HL094761.

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