JACC: CARDIOVASCULAR IMAGING
VOL. 6, NO. 1, 2013

ISSN 1936-878X/$36.00
PUBLISHED BY ELSEVIER INC.
http://dx.doi.org/10.1016/j.jcmg.2012.06.009

EDITORIAL COMMENT

The Value of Image Integration for Epicardial Catheter Ablation of Ventricular Tachycardia*

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After several decades of work that established mechanistic understanding of re-entrant circuits, the evolution of ventricular tachycardia (VT) ablation has been driven by the need for an improved anatomic delineation of myocardial substrates. In 1999, the detailed validation of a clinical electroanatomic mapping system led to the feasibility of "substrate-based" ablation strategies that did not rely exclusively on activation mapping (1). Shortly after, the efficacy of short linear lesions to transect or encircle scar was shown to result in meaningful reduction of recurrent VT with endocardial approach (2,3). While the technique of percutaneous

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epicardial access was described by Sosa et al. (4) in 1996, the growth of epicardial mapping and ablation has accelerated in recent years to address the 3-dimensional and transmural nature of myocardial scar in patients with prior failed endocardial ablation and in substrates with a predilection for epicardial scar (i.e., arrhythmogenic right ventricular dysplasia, nonischemic cardiomyopathy, hypertrophic cardiomyopathy, Chagas cardiomyopathy) (5–9). The ability to access and map various surfaces of the heart has been an important advance and has infused the optimistic mentality that the "grass may be greener" on the opposite side of a given mapped surface. However, recurrence of VT remains significant for scar-mediated reentrant substrates (30% to 50%) (10).

VT ablation failures may be summarized into 2 broad categories: anatomic and biophysical. Physical inaccessibility may be present with pericardial adhesions in a patient with prior cardiac surgery, although minimally invasive hybrid techniques have been developed (11). More recently, efforts devoted to attacking the "third space," or intramural sites of origin, have increased. Biophysical limitations remain a significant factor, whereby intervening structures such as layered thrombus or calcification on the endocardium and epicardial fat on the endocardium can hinder effective radiofrequency delivery. Further anatomic limitations that prohibit energy delivery due to fear of collateral damage, i.e., phrenic nerve or coronary artery, remain frustrating barriers to ablation success (12).

In this issue, van Huls van Taxis et al. (13) analyze the feasibility and accuracy of integration of pre-acquired computed tomography scans with real-time electroanatomic mapping and relate the success of ablation target sites to epicardial anatomy. The authors use a novel method of registration, whereby the ostium of the left main is engaged and confirmed with contrast injection as a single landmark. With a relatively low level of mapping density (105 $\pm$ 65 points), the authors were able to achieve a surface registration error of 2.8 $\pm$ 1.3 mm in this cohort.

It should be emphasized, however, that registration with multidetector computed tomography does not obviate the need for coronary angiography. Although registration can never be without error, differences in chamber dimensions are likely to be present between the time of pre-procedural imaging and the procedure itself and changes in geometry due to the cardiac rhythm and chamber filling

*Editorials published in *JACC: Cardiovascular Imaging* reflect the views of the authors and do not necessarily represent the views of *JACC: Cardiovascular Imaging* or the American College of Cardiology.

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variations. Most operators consider a distance of >5 mm from coronaries during all phases of the cardiac cycle as a safety margin for ablation, therefore 1 standard deviation from the error would make any point within 9 mm potentially within a range where coronary injury is a concern, necessitating coronary angiography. Further, as the authors correctly acknowledge, the visualization of obtuse marginal and diagonal branches is commonly insufficient on merged imaging. While the injury of smaller branches with radiofrequency may not result in significant myocardial injury in terms of ventricular function, acute ischemia may result in VT or ventricular fibrillation.

In this study the authors confirm the important relationship of increasing fat thickness on attenuation of bipolar voltage (14–16). In contrast to previously published studies which suggested 4 to 5 mm of fat resulting in attenuation of bipolar voltage, the authors found that 33% of mapping points covered by >4 mm of fat still exhibited bipolar voltages of >1.5 mV. However, reverse registration was used for validation in the present study. Points at border or threshold transition zones within the radius of registration error may account for discrepancies.

In this cohort of 28 patients who underwent combined endocardial and epicardial mapping, 54% of VTs were successfully ablated and 39% of VTs were successfully ablated from the epicardium. Further, 21 VTs in 13 patients could not be ablated, and 6 were not ablated due to proximity to coronary artery. Of note, 4 of these sites were in the same patient. It is not noted if a corresponding predicted site on the endocardium was attempted.

A central message of the present work is that areas of >7 mm fat thickness were associated with ablation failure. This finding is based on 4 unsuccessful sites at fat thickness of 7 to 22 mm. Among these, 2 were in idiopathic substrates, whereby epicardial target sites were "predicted" by endocardial mapping. However, although epicardial access was obtained in all patients, the epicardial data is not commented upon.

The value of imaging is greatly increased if the pre-procedural findings can prompt a shift in ablation strategy. Although the findings of increased epicardial fat prior to mapping may portend a worse prognosis, it appears that comprehensive mapping is still likely to be required in all cases. A more detailed look from the corresponding endocardial side with ablation at higher power and duration may be an alternative strategy in cases where thick epicardial fat is encountered. Surgical ablation has been shown to provide definitive treatment in selected cases in regions in close proximity to coronaries, or underneath fat and the demonstration of scar location in relation to local anatomy can assist planning for surgical exposure.

Several limitations to the present study must be mentioned. The definition of a successful site did not require termination of VT. Ablation in a region followed by noninducibility (which is known to be probabilistic) deemed all of those sites as successful. Conversely, a successful ablation can be performed in a broad isthmus, whereby VT remains inducible afterward. By the methodology used in this paper this latter site would be considered ineffective.

Further, in patients with perivalvular scar, such as patients with nonischemic cardiomyopathy, epicardial fat may overly scar. Therefore, the thickness of fat that results in an attenuated bipolar electrograms in these regions may vary. Concomitant imaging of scar with magnetic resonance imaging may be useful, as computed tomography does not consistently demonstrate contrast enhancement of scar. As much processing is required to generate the images and reverse registration, the reproducibility of the methodology remains unknown. Interoperator and intraoperator registration variability may increase the registration error.

Since the advent of epicardial mapping, combined ablation and mapping to address the transmural and 3-dimensional nature of scars has been shown to improve outcomes. However, the gap between comprehensive mapping and effective ablation appears to be larger on the epicardium compared with the endocardium due to collateral anatomic constraints. The authors should be congratulated on the present work, which provides quantitative and descriptive data to demonstrate the challenges and frustrations when we map on the "other side of the fence." Almost 2 of 3 cases of epicardial ablation failures in this cohort were related to proximity to coronary artery or prohibitive fat thickness. This highlights the need for newer ablation technologies and approaches. Methods to deliver energy through or "beyond" epicardial fat or coronaries, such as intramural needle ablation or high-intensity focused ultrasound may emerge as promising alternatives to radiofrequency to make the grass a few shades greener.

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Key Words: ablation ▪ electroanatomic mapping ▪ epicardial ▪ image intergration ▪ ventricular tachycardia.