Published in final edited form as:

Pacing Clin Electrophysiol. 2012 December ; 35(12): e345–e348. doi:10.1111/j.1540-8159.2011.03213.x.

Impact of Scar, Viable Myocardium and Epicardial Fat on Substrate Identification of Ventricular Tachycardia in a Case with Nonischemic Cardiomyopathy

Takeshi Sasaki, MD, James Mudd, MD, Charles Steenbergen, MD, PhD, Menekhem M. Zviman, PhD, Christopher F. Miller, MBA, and Saman Nazarian, MD

Departments of Medicine/Cardiology (T.S., M.M.Z., C.F.M., S.N.) and pathology (C.S.), Johns Hopkins University School of Medicine, Baltimore, Maryland; and the Department of Medicine/Cardiology (J.M.), Oregon Health Sciences University, Portland, Oregon

Abstract

A 56-year-old man with nonischemic cardiomyopathy underwent orthotopic cardiac transplantation after endocardial and epicardial radiofrequency catheter ablation for pleomorphic ventricular tachycardia. The myocardial substrate and epicardial fat were comprehensively analyzed with 3-dimensional electroanatomic maps, late gadolinium enhanced ex-vivo cardiac magnetic resonance, and histological examination. The association of scar, viable myocardium, and epicardial fat with endocardial and epicardial electrogram voltage and duration was quantitatively defined. This case provides a unique opportunity to explore the reliability of electrical surrogates of scar in nonischemic cardiomyopathy.

Introduction

Radiofrequency catheter ablation (RFCA) is increasingly used as an adjunct to implantable cardioverter defibrillators (ICD) and medical therapy for management of ventricular tachycardia (VT) in non-ischemic cardiomyopathy (NICM).¹⁻⁴ Three-dimensional electroanatomic mapping (3D-EAM) in NICM often localizes VT critical zones to epicardial (EPI) sites adjacent to the mitral valve annulus.² Mapping in such areas can be limited by the presence of fat,^{5,6} mid-wall scar,¹ and risk of coronary artery injury. Improved understanding of the association between the scar substrate as defined by cardiac magnetic resonance (CMR)^{4,7} and corresponding electrogram (EGM) surrogates may facilitate RFCA procedures. This case report explores the association of ex-vivo CMR defined viability and fat with endocardial (ENDO) and EPI 3D-EAM.

Case Report

A 56-year-old man with severe NICM, awaiting cardiac transplantation, presented with multiple ICD shocks for drug refractory VT storm. At electrophysiology study, multiple hemodynamically unstable monomorphic VTs with different cycle lengths were inducible (Figure 1A). Sinus rhythm ENDO 3D-EAM (CARTO, Biosense-Webster, Diamond Bar, CA) of the left ventricle revealed multiple low voltage areas (LVA) defined as bipolar amplitudes <1.5 mV (Figure 1B). Substrate modification was performed by irrigated (40 W, ThermoCool, Biosense-Webster, Diamond Bar, CA) RFCA targeting left ventricular ENDO

Address for Correspondence: Takeshi Sasaki, MD; Johns Hopkins University; Carnegie 592C, 600 N. Wolfe Street; Baltimore, MD 21287; Phone: 443-614-2751; Fax: 410-502-4854; tsasaki1@jhu.edu.

Disclosures – The authors report no relevant conflicts of interest.

LVAs with fractionated or delayed potentials and pace map morphology match to a clinically recorded VT1. Due to the pseudo-delta like initial precordial QRS activation of the remaining VT morphologies, EPI mapping was pursued in a subsequent procedure. EPI 3D-EAM revealed a large LVA along the lateral left ventricle (Figure 1B). Irrigated RFCA (40W) was applied to regions inside the LVA with identical pace map morphology to VT2-4. The remaining inducible VTs were not pursued due to the length of the procedure. The patient's VT burden significantly decreased following ablation (>20 shocks on the day prior to EPI RFCA, versus 1 shock the week post RFCA). However, given his ongoing heart failure and refractory VT, the patient underwent orthotopic heart transplantation 8 days after RFCA.

Ex Vivo CMR Imaging and Image Analysis

A gadolinium-based contrast followed by saline flush was injected through the coronaries of the recipient heart after excision. Ex-vivo 1.5T CMR was obtained (Espree, Siemens Medical Systems, Erlangen, Germany) using a T₁-weighed 3D gradient-echo sequence.⁸ Scar transmural and the thickness of EPI fat in each of 20 sectors per 12 myocardial planes were quantitatively measured by QMass software (Medis, Leiden, Netherlands). Hyperenhanced regions were identified and binned (0%, 1-25%, 26-50%, 51-75%, 76-100%) as previously described.⁴ Images were then retrospectively registered to ENDO/EPI 3D-EAM with custom software. Comparisons of continuous variables were made using Student's *t*-test or ANOVA. Univariate linear regression analysis was used to assess the relationship between EGM characteristics and EPI fat thickness in each scar transmural bin.

Findings

Greater scar transmural was significantly associated with lower bipolar ($P<0.001$, ENDO/EPI) and unipolar amplitudes ($P<0.001$, ENDO/EPI), and prolonged EGM duration ($P=0.02$ for ENDO, $P<0.001$ for EPI). EPI bipolar amplitude was significantly lower than ENDO bipolar amplitude in each scar transmural bin except in 76-100% transmural regions ($P<0.05$ in 0-75%, $P=0.1$ in 76-100%). Such a trend was not observed in unipolar amplitudes (Figure 2). Critical ablation sites were located within or on the border of scar. Macroscopic findings demonstrated EPI ablation lesions on the LV lateral wall associated with slight thinning of the overlying EPI fat. Consistent with prior reports, EPI fat was thicker in the right ventricular (RV) free wall, superior and inferior interventricular grooves, and left and right atrioventricular grooves.^{5,6} Dramatic localized thinning of the RV inferior wall near the distal coil of the ICD lead was noted (Figure 3). Univariate analyses revealed significant indirect associations between EPI fat thickness and bipolar ($P<0.05$) and unipolar EGM amplitudes ($P<0.05$), but not with EGM duration.

Discussion

Previous reports of ischemic VT have explored the association of scar transmural with corresponding local EGM characteristics.⁷ Scar formation in NICM differs from that in ischemic cardiomyopathy, and typically occurs in an EPI or midwall distribution.¹ To our knowledge, this is the first report regarding the association of scar, viable myocardium, and EPI fat on CMR and pathology, with ENDO/EPI 3D-EAMs findings in NICM. Our patient exhibited extensive EPI LVAs with fractionated and isolated delayed potentials opposing healthy ENDO regions.² Regions with thicker viable myocardium exhibited higher voltage amplitude and shorter EGM duration. Conversely, regions with thicker scar exhibited lower voltage amplitude and longer EGM duration. Importantly, based upon the present report, EPI fat may be a significant impediment to successful voltage mapping. Normal myocardial

areas with >7 mm of EPI fat exhibited <1.0 mV EPI bipolar and <5.0 mV EPI unipolar voltage amplitudes. Pacing capture threshold to distinguish EPI fat from scar is also suboptimal because even >10 mA pacing output on >5 mm of EPI fat may fail to capture the myocardium.⁶ Improved techniques for fat and scar image integration with greater attention to EGM duration based substrate identification may improve the efficacy of RFCA for patients with NICM.

Acknowledgments

The authors thank Dr. Dan A. Herzka, Ph.D. for ex-vivo high resolution magnetic resonance imaging.

Funding Sources – Takeshi Sasaki MD is funded by the Francis Chiaramonte MD Private Foundation. Dr. Nazarian is funded by a National Heart, Lung, and Blood Institute Career Development Award (K23HL089333).

References

1. McCrohon JA, Moon JC, Prasad SK, McKenna WJ, Lorenz CH, Coats AJ, Pennell DJ. Differentiation of heart failure related to dilated cardiomyopathy and coronary artery disease using Gallium-Enhanced cardiovascular magnetic resonance. *Circulation*. 2003; 108:54–59. [PubMed: 12821550]
2. Soejima K, Stevenson WG, Sapp JL, Selwyn AP, Couper G, Epstein LM. Endocardial and epicardial radiofrequency ablation of ventricular tachycardia associated with dilated cardiomyopathy. *J Am Coll Cardiol*. 2004; 43:1834–42. [PubMed: 15145109]
3. Cano O, Hutchinson M, Lin D, Garcia F, Zado E, Bala R, Riley M, et al. Electroanatomic substrate and ablation outcome for suspected epicardial ventricular tachycardia in left ventricular nonischemic cardiomyopathy. *J Am Coll Cardiol*. 2009; 54:799–808. [PubMed: 19695457]
4. Nazarian S, Bluemke DA, Lardo AC, Zviman MM, Watkins Sp, Dickfeld TL, Meininger GR, et al. Magnetic resonance assessment of the substrate for inducible ventricular tachycardia in nonischemic cardiomyopathy. *Circulation*. 2005; 112:2821–2825. [PubMed: 16267255]
5. Tung R, Nakahara S, Ramirez R, Lai C, Fishbein MC, Shivukmar K. Distinguishing epicardial fat from scar: Analysis of electrograms using high-density electroanatomic mapping in a novel porcine infarct model. *Heart Rhythm*. 2010; 7:389–395. [PubMed: 20185114]
6. d'Avila A, Houghtaling C, Gutierrez P, Vragovic O, Ruskin JN, Josephson ME, Reddy VY. Catheter ablation of ventricular epicardial tissue: A comparison of standard and cooled-tip radiofrequency energy. *Circulation*. 2004; 109:2363–2369. [PubMed: 15096448]
7. Condreanu A, Odille F, Aliot E, Marie PY, Magnin-Poull I, Andronache M, Mandry D, et al. Electroanatomic characterization of post-infarct scars. *J Am Coll Cardiol*. 2008; 52:839–42. [PubMed: 18755347]
8. Rivard AL, Swingen CM, Gallegos RP, Gatlin DL, Jerosch-Herold M, John R, Bianco RW. Evaluation of perfusion and viability in hypothermic non-beating isolated porcine hearts using cardiac MRI. *Int J Cardiovasc Imaging*. 2006 Apr; 22(2):243–51. [PubMed: 16247552]

Figure 1.

(A) Twelve-lead ECGs of all inducible VT morphologies. (B) ENDO and EPI voltage maps during sinus rhythm. LVAs were defined as <1.5mV and <1.0mV on bipolar voltage maps. LVAs and abnormal EGMs were more extensive on the epicardial map. VT1 was successfully ablated during the endocardial procedure; and VT2, VT3 and VT4 were successfully eliminated in the lateral region of epicardial left ventricle (black arrows).

Figure 2.

The figure illustrates the association of scar transmuralty with bipolar and unipolar EGM amplitudes and duration. Greater scar transmuralty was significantly associated with lower bipolar ($P < 0.001$ both EPI/ENDO) and unipolar amplitudes ($P < 0.001$ both EPI/ENDO), and with prolonged EGM duration (EPI, $P = 0.02$; ENDO, $P < 0.001$). In contrast to unipolar amplitudes, EPI bipolar amplitude was significantly lower than ENDO bipolar amplitude in each scar transmuralty bin. * $P < 0.05$, ** $P < 0.01$ vs. 76-100% transmuralty; † $P < 0.05$, †† $P < 0.01$ vs. 51-75% transmuralty; ‡ $P < 0.05$, ‡‡ $P < 0.01$ vs. 26-50% transmuralty.

Figure 3.

(A) High resolution ex vivo CMR. (B) Macroscopic findings of the explanted heart showed epicardial ablation lesions (6×39 mm) created in left ventricular (LV) lateral wall by the irrigated catheter (40W, red asterisk). Localized thinning of RV inferior wall near the distal ICD coil was also noted (white arrows). (C) Histological picture of ablation lesion (red arrow). The epicardial fat thickness (a: 1.3mm) was reduced overlying the ablation lesion (b: 0.8mm). The ablated myocardium (c: 1.7mm) was observed beyond the fat layer. The fibrosis in the viable myocardium was depicted as blue area stained by Masson's Trichrome (double black arrows).