Tissue voltage discordance during tachycardia versus sinus rhythm: Implications for catheter ablation

Jason S. Bradfield, MD, FHRS,[*] William Huang, MD,[*] Roderick Tung, MD, FHRS,[*] Eric Buch, MD, FHRS,[*] Jean-Phillip Okhovat, BS,[*] Osamu Fujimura, MD, FHRS,[*] Noel G. Boyle, MD, PhD, FHRS,[*] Jeffrey Gornbein, DrPH,[†] Kenneth A. Ellenbogen, MD, FHRS,[‡] Kalyanam Shivkumar, MD, PhD, FHRS[*]

*From the *UCLA Cardiac Arrhythmia Center, David Geffen School of Medicine at UCLA, Los Angeles, California, [†]Department of Biomathematics, David Geffen School of Medicine at UCLA, Los Angeles, California, and [‡]VCU School of Medicine, Medical College of Virginia, VCU, Richmond, Virginia.*

BACKGROUND Electroanatomic mapping systems are an important tool to identify cardiac chamber voltage and assess channels of slow conduction.

OBJECTIVE To assess the correlation between electroanatomic mapping voltage maps obtained during macroreentrant tachycardia compared to sinus rhythm (SR) with a contact mapping system.

METHODS We retrospectively evaluated patients with atrial flutter (AFL) referred for radiofrequency ablation with electroanatomic voltage maps obtained during AFL and SR. The atrium was divided into predetermined segments. Overall atrial and segmental peak-to-peak bipolar voltages in AFL and SR were assessed. To directly compare a region within the same patient, tissue voltage differences during AFL and SR were assessed on the basis of mean voltage difference.

RESULTS Sixteen patients (87% men) had available voltage maps. Eighty-one percent had typical cavotricuspid isthmus-dependent right AFL. A mean of 441.7 $\pm$ 153.9 vs 398.1 $\pm$ 125.4 total points ($P = .22$) were sampled during AFL and SR, with a mean of 99.5 $\pm$ 58.9 vs 91.2 $\pm$ 60.4 points ($P = .45$) sampled per region. Overall right atrial mean voltage was significantly higher during AFL than SR (0.554 $\pm$ 0.092 mV vs 0.473 $\pm$ 0.079 mV; $P \leq .001$), with the lateral wall (0.707 $\pm$ 0.120 mV vs 0.573 $\pm$ 0.097 mV; $P = .0004$) and the cavotricuspid isthmus (0.559 $\pm$ 0.100 mV vs 0.356 $\pm$ 0.066 mV; $P < .0001$) also showing higher mean voltage during AFL. When compared within an individual patient, 19% (14 of 75) of the patient regions had a $>$0.5 mV mean voltage difference and 40% (30 of 75) had a $>$0.25 mV mean voltage difference.

CONCLUSIONS These data suggest that voltage maps performed during macroreentrant atrial arrhythmias often vary significantly from maps obtained during SR.

KEYWORDS Electroanatomic mapping; Atrial flutter; Tissue voltage; Catheter ablation

ABBREVIATIONS AFL = atrial flutter; **CTI** = cavotricuspid isthmus; **EAM** = electroanatomic mapping; **RA** = right atrial/atrium; **RFA** = radiofrequency ablation; **SR** = sinus rhythm

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Introduction

The identification of catheter ablation targets critical for arrhythmia maintenance depends on activation maps and an understanding of substrates. Entrainment mapping[1,2] is an established approach to mapping of macroreentrant arrhythmias. However, even the most fundamental concepts such as entrainment have limitations.[3,4]

In recent years, entrainment mapping has been supplemented by the development of electroanatomic mapping (EAM) systems to help identify cardiac chamber voltage, assess arrhythmia activation sequences, monitor lesion set formation, and minimize fluoroscopy use. Contact mapping systems are more widely used systems than noncontact mapping systems. While the use of EAM systems has been a valuable advancement for the mapping and ablation of complex arrhythmias, it is important to understand the limitations, as these systems are used more frequently.

Electroanatomic voltage mapping is traditionally performed in sinus rhythm (SR). In clinical practice, electrophysiologists often acquire voltage points at the same time that they acquire points for arrhythmia timing and subsequent ablation. This technique has been validated during SR primarily for ventricular tachycardia and atrial tachycardia in patients with congenital heart disease.[5] The correlation between scar seen on EAM and that seen on cardiac magnetic resonance imaging has also been validated[6,7] and EAM may be more sensitive than magnetic resonance

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imaging.[6] In addition, there is clear correlation between scar on EAM and that seen on the endocardium in pathologic specimens and more recently on epicardial pathologic specimens.[8,9] While these validation studies were performed in SR, in real-world clinical practice, points may be acquired during SR, clinical tachycardia, or a combination of the 2 if the patient is intermittently in tachycardia.

To date, there have been no studies evaluating whether there are significant differences between voltage maps obtained during macroreentrant tachycardia compared to SR with a contact mapping system. With the growing use of substrate-based ablation techniques for scar-related ventricular tachycardia ablation[10] and the application of a substrate-based approach to the ablation of complex atrial arrhythmias,[11] it is clinically meaningful to understand whether a voltage map obtained during clinical tachycardia can be used interchangeably with the voltage map in SR.

If the voltage during tachycardia differs significantly with that obtained during SR, then possible channels of conduction between regions of scar may be inaccurately depicted and lead to misguided substrate-based ablation strategies. The purpose of this study was to assess EAM voltage maps obtained in AFL vs SR in the same patient at the time of diagnostic electrophysiologic study and radiofrequency ablation (RFA) of macroreentrant AFL.

Methods

We retrospectively evaluated patients with macroreentrant AFL referred for RFA with distinct EAM voltage maps obtained during SR and AFL during the same study. Baseline characteristics collected included age, sex, ejection fraction, antiarrhythmic medication use, and history of previous RFA.

Procedural characteristics collected included AFL cycle length, AFL intracardiac activation sequence, site of successful RFA, number of RFA lesions, and number of voltage points obtained for each map. Voltage maps were obtained using a commercially available mapping system (Ensite Velocity, St Jude Medical, Minneapolis, MN). Peak-to-peak bipolar voltage was assessed, and EAMs were reviewed on a scale of 1.5–0.5 mV.

The method for obtaining voltage points was at the discretion of the operating physician. Ultra-high-density multipolar mapping was used in multiple cases as previously described by our group.[12] To minimize the risk of pseudo-scar from poor contact, if multipolar mapping suggested a region of scar, point-by-point mapping with the ablation catheter was used to verify voltage.

The tricuspid or mitral annulus was defined on the basis of the assessment of voltage points with a 1:1 atrioventricular ratio. Ventricular points were excluded. Voltage maps were segmented into anatomic segments by a physician who was blinded to the map voltage data. For right atrial (RA) maps, the chamber was divided into 5 segments: lateral wall, septum, cavotricuspid isthmus (CTI), anterior wall, and posterior wall. For left atrial voltage maps, the chamber was divided into 6 segments on the basis of previous work by Teh et al[13]: anterior, lateral, roof, posterior, septum, and floor/mitral isthmus. Voltage points were retrospectively binned on the basis of predetermined anatomic region.

Regions were excluded from the analysis if there were less than 10 available points for analysis in either the AFL or the SR map. In addition, for the analysis of the percentage of concordant/discordant regions, effort was made to avoid sampling points along the ablation line in patients with CTI-dependent AFL as this would clearly effect voltage measurements in this region.

Statistical analysis

Mean voltage comparisons were carried out by using the mixed analysis of variance model described below, and results are given as geometric mean ± SEM. Categorical variables were compared by using the Fisher exact test. Continuous variables other than voltage were expressed as mean ± SD, and 2 groups were compared by using the paired Student *t* test.

Mixed model for comparing overall mean voltage and by region

Quartile plots show that voltage has a normal distribution on the log scale. This is why geometric means, not arithmetic means, are reported on the original (mV) scale. Since log scale voltage follows the normal distribution, a parametric mean comparison on the log scale was carried out by using a mixed analysis of variance model. In this model, condition (AFL or SR), region, and the condition × region interaction are fixed effects and patient is a random effect. The random patient effect component allows multiple observations on the same person to be nonindependent (correlated).

Results

Sixteen patients had voltage maps available for review in AFL and SR. Baseline patient characteristics are listed in Table 1. Eighty-seven percent of the patients were men with a mean age of 61 ± 11 years. The mean left ventricular ejection fraction was 46% ± 15%. Twenty-five percent (4 of 16) of the patients had undergone previous RFA. Thirty-eight percent (6 of 16) of the patients were on antiarrhythmic medications.

Thirteen of 16 (81.3%) patients had typical CTI-dependent right AFL. Two (12.5%) patients had macroreentrant left AFL after previous pulmonary vein isolation for atrial fibrillation, with an additional patient (6.3%) having scar-related, non-isthmus-dependent right AFL after previous cardiac surgery. Of those with typical CTI-dependent AFL, 11 of 13 (84.6%) had a counterclockwise activation pattern. For patients who had CTI-dependent AFL, the mean tachycardia cycle length was 247 ± 49 ms and the mean number of ablation lesions delivered was 28.3 ± 24.3. (Table 2)

A mean of 441.7 ± 153.9 points were sampled for the AFL maps, and a mean of 398.1 ± 125.4 points were sampled for the SR maps ($P = .22$). The mean number of voltage points per region was 99.5 ± 58.9 for the AFL maps and 91.2 ± 60.4 points for the SR maps ($P = .45$).