Teaching Rounds in Cardiac Electrophysiology

Chasing Red Herrings
Making Sense of the Colors While Mapping

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Case Presentation
A 50-year-old man presented with sustained wide complex tachycardia and was treated with cardioversion. He gave a history of 2 such episodes within the past 7 years, requiring cardioversion each time. Ten years previously, he had undergone surgical repair of tetralogy of Fallot. Review of operative notes indicated that the procedure included patch closure of the ventricular septal defect, right ventricular outflow tract resection, repair with a transannular patch, and pulmonary valve replacement with a porcine valve.

ECG recorded during the tachycardia showed a regular wide complex tachycardia at a rate of 240 beats per minute of left bundle branch block morphology with left axis deviation. ECG in sinus rhythm showed PR interval of 200 ms, right bundle branch block with normal axis, and QRS duration of 170 ms. Echocardiography showed mild right ventricular dilatation, and the peak gradient across the pulmonary valve was 32 mm Hg.

Mapping was performed using an electroanatomic system (CARTO 3, Biosense Webster, Diamond Bar, CA). Wide complex tachycardia at a cycle length of 260 ms with the same morphology as the clinical tachycardia was induced during catheter placement and could not be pace terminated. Ventriculo-atrial dissociation and negative His-ventricular interval confirmed ventricular tachycardia. Surface ECG was used for timing reference, and a window of −125 to +125 ms was used to map the right ventricle during tachycardia. The activation and voltage maps in a modified anteroposterior view are shown in Figure 1A. Figure 1B shows each of the recorded activation times as a point, plotted along with the ECG. What is the interpretation and what should be the ablation strategy?

Discussion
Ventricular tachycardia is a known complication after surgery for tetralogy of Fallot. It is usually attributable to macroreentry around a scar in the ventricular septum or right ventricular outflow tract. Transection of the circuit usually requires linear ablation across the isthmus between one of these scars and a natural barrier formed by the pulmonary or tricuspid annulus. The voltage map constructed using cutoffs of >1.5 mV for normal tissue, <1.5 mV for scar, and <0.46 mV for dense scar shows a low-voltage region in the basal right ventricular outflow tract. Activation map is suggestive of re-entry between the tricuspid annulus and this low-voltage region with an early meets late pattern. The scale bar shows that the earliest and latest activation times span the whole window. These are usually considered indicators of macroreentry, and the appropriate ablation strategy would be an ablation line connecting the tricuspid annulus to the scar.

A closer look at Figure 1B shows that QRS is broad and the reference point is toward the second half of the QRS. Therefore, the annotation window begins at ±20 ms ahead of QRS onset. Activation happening 30 ms ahead of QRS onset would then be marked in the end of the window and mimic macroreentry. The clue here is the absence of any other points earlier in diastole, suggesting that this is not macroreentry. One other possibility is that some portion of the chamber has not been adequately mapped, which was excluded by a review of the map. Reannotating the points using a window of −170 to +80 ms clearly shows a focal onset with centrifugal activation (Figure 2). The earliest point showed activation 35 ms ahead of QRS onset and was located at the scar border near a region with double potentials (blue circles). Pacing from this site entrained the tachycardia with concealed fusion (Figure 3), suggesting that this is microreentry within the scar exiting from the edge as a focal tachycardia. Tachycardia terminated on the second radiofrequency application at the site of earliest activation. Additional lesions were created extending a short distance along the scar border on both sides and subsequently ventricular tachycardia could not be reinduced.

The case highlights the importance of selecting an appropriate window of interest while mapping. In macroreentry, the intention is to map nearly the entire cycle, but in microreentry, it is important to focus on the earliest activation times.
and so the window of interest (WOI) is usually 10 to 20 ms less than the tachycardia cycle length. Usually, the WOI is divided equally before and after the reference. Sometimes, as in this patient, the mechanism of the tachycardia may not be clear before mapping. Especially in tachycardias with a broad QRS and with a reference point placed late in the cycle, the beginning of the WOI may extend only a little ahead of the QRS onset. In the case of a focal tachycardia, the colors in the local activation time map and the color scale may then suggest re-entry. Care should therefore be taken to ensure that local activation times not only span the breadth of the WOI, but are also distributed throughout the WOI. Selection of WOI may also be done with the onset of the window extending ≈50 ms before the QRS onset to avoid this error. A wrong interpretation can lead to a more difficult and unnecessary strategy of linear ablation.

The major learning point from this case is that information obtained from complex mapping systems has to be interpreted in the context of the selected WOI, the annotation of electrograms, and the activation times of individual points and not just by the final colors. Although the usual mechanism of ventricular tachycardia in tetralogy of Fallot is macroreentry, the activation map and the response to focal ablation suggest a focal origin in this case.

Disclosures
None.

References

Key Words: tachycardia, ventricular − tetralogy of Fallot

Figure 1. Original map. A, Electrograms from a single point at the left with activation late in the window and a local activation time (LAT) map in the middle with a pattern of early meets late. A voltage map is shown on the right with cutoffs of 1.5 and 0.46 mV for scar and dense scar, respectively. B, Two ECG leads from a single cycle along with time reference indicated by a broken line and other lines indicating the QRS onset and end of previous QRS. Chosen window of interest (WOI) is shown at the bottom. Gray circles indicate the LATs of individual points. This figure was plotted using data exported from the mapping system. PA indicates pulmonary annulus; and TA, tricuspid annulus.
Figure 2. A and B, Reannotated map. The same map is shown and is organized similar to Figure 1. However, the local activation times (LATs) are reannotated with a different window of interest (WOI; −170 to +80 ms). PA indicates pulmonary annulus; and TA, tricuspid annulus.
Figure 3. Concealed entrainment. ECG recorded during ventricular tachycardia shows wide QRS tachycardia of left bundle branch block morphology with left axis deviation. First 6 beats are recorded during pacing from the site of successful ablation. Tachycardia is entrained with no obvious fusion.
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