Trans-myocardial bipolar electrogram: A strategy for mapping and determining efficacy of bipolar ablation of deep foci

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Abstract
Mapping and ablation of intramural ventricular tachycardia (VT) remain a challenge. We developed a trans-myocardial electrogram recording across distal tips of two separate ablation catheters placed on contralateral sides of the myocardium to record a trans-myocardial bipole and a novel pacing electrode configuration. This trans-myocardial bipole was applied during bipolar ablation in a patient with septal VT. Local activation in this trans-myocardial bipole was similar to the earliest activation recorded from detailed activation maps from both sides of the septum. Pacing from this trans-myocardial bipole resulted in a perfect morphology match. After bipolar ablation, the trans-myocardial bipolar voltage decreased by 82%, and pacing threshold increased by 800%. These findings correlated with VT noninducibility.

KEYWORDS
ablation, bipolar ablation, mapping, VT, VT ablation

1 | INTRODUCTION
Mapping and radiofrequency ablation (RFA) of intramural ventricular tachycardia (VT) remain a challenge, resulting in higher VT recurrence in septal VTs.1 Recently, several techniques have been proposed to produce deeper lesions,2,3 however, mapping these intramural foci and determining the efficacy of lesion formation continue to be an ongoing challenge. We hypothesized that an inter-catheter electrode in a trans-myocardial bipolar configuration might provide a valuable tool for trans-septal activation and pace mapping. This could also be a measure of ablation efficacy pertinent to the tissue between catheters.

2 | OBJECTIVES
To assess the feasibility of a novel trans-myocardial inter-catheter electrode configuration for pace and activation VT mapping, and to identify ablation endpoints during bipolar RFA.

3 | METHODS AND RESULTS
The patient was a 57-year-old male with nonischemic cardiomyopathy who had recurrent VT despite endo-epicardial unipolar RFA of both ventricles. Prior mapping suggested deep septal focus. We mapped the VT utilizing an HD-grid and Livewire catheters (Abbott Laboratories). Earliest activation was mapped to the anterior basal septum (Right ventricle (RV) ahead of left ventricle (LV)). We then adjusted the Prucka (Cardio Lab, GE) connections to map and pace between the tips of two opposing ablation catheters placed at the earliest point on each side of the septum (distance = 12 mm). Inter-catheter (trans-septal here) activation, voltage, and pace mapping were performed.

3.1 | Activation mapping
Sustained VT could not be induced. However, a single beat of the clinical VT could be reproducibly induced and mapped. Conventional bipolar mapping demonstrated the earliest signal to be on the
**FIGURE 1**  (A) Partial RV and LV electro-anatomical map, inter-catheter distance is 12 mm. In each site, catheter positioned at the earliest local activation site based on detailed high-resolution mapping using multi-electrode mapping catheters. (B) Perfect pace-map (paced between the two catheters tips across the septum) with output minimally higher than capture threshold. The PVC is in the gray color with the paced beat overlaid on top of it in brown color [Color figure can be viewed at wileyonlinelibrary.com]

**FIGURE 2**  (A) Preamblation local voltage. ABL d and p are local bipolar voltages from RV septum catheter; Sept bipol is trans-septal inter-catheter voltage; and ABL dL and pL are local bipolar voltage from LV septum catheter. (B) Reduction in trans-septal voltage after bipolar RFA
anterior basal septum (RV 22 ms and LV 5 ms ahead of surface QRS). Inter-catheter electrogram (EGM) timing was similar to the RV septal catheter.

3.2 | Pace mapping

Pacing was performed between the two catheter tips with the right catheter tip as the cathode and the left as the anode. Pacing at the lowest capture threshold revealed a perfect pace match of the clinical VT (see Figure 1).

3.3 | Lesion monitoring

After mapping was completed, two irrigated 4 mm tip Flexibility catheters (Abbott Laboratories) were used on both sides serving as active ablation at the RV and as the return electrode on the LV. Five bipolar RF lesions applied at 20-30 Watts for 60 seconds. During sinus rhythm, the inter-catheter electrogram measured 2.9 mV and was reduced to 0.52 mV after bipolar RFA (82% reduction). See Figure 2 for trans-septal electrogram before and after bipolar ablation.

3.4 | Efficacy determination

Trans-septal pacing threshold increased from 2 V@2 ms to 16 V@2 ms (800% increase). These findings correlated with clinical VT noninducibility.

4 | DISCUSSION

We describe for the first time the feasibility and utility of inter-catheter trans-myocardial mapping and pacing as a novel, readily available technique for activation and pace mapping. This technique allows for three-dimensional mapping, which is useful in deep VT circuits or foci. It assists in lesion monitoring by attenuation of inter-catheter EGM. It also helps to define ablation endpoints by an increase in inter-catheter pacing threshold, after bipolar RFA. We noted that timing measured in the inter-catheter bipole was similar to that measured on the RV bipole. An inter-catheter bipolar EGM is an EGM unlike the regular bipoles we are used to. This is because of the fact that the tips of the two catheters are integrating electrical activity between them to provide a summation of activity within the tissue (the septum in this case) they sandwich. We annotated the prominent dV/dt in the inter-catheter bipole, and though this may be the convention to pick up the activity underlying a bipole, this method may fail to pick up earlier (far-field) signals compared to traditional bipoles from either side of the septum, and thus could have resulted in later annotation in this trans-myocardial bipole. Further use of this bipolar configuration may educate us on a better annotation method. Since this could be performed without additional cost or risk, we encourage the electrophysiologists to study this configuration prospectively. This novel technique could be of greater value if it were to be integrated into modern electro-anatomic mapping systems.

5 | CONCLUSIONS

Inter-catheter electrode configuration allows for activation and pace mapping of VT originating from deep septal foci. Attenuation of trans-myocardial bipolar electrogram amplitude and increase in pacing threshold in such a configuration could be useful endpoints during bipolar RFA.

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