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PII: S2666-5018(22)00235-5
DOI: https://doi.org/10.1016/j.hroo.2022.09.017
Reference: HROO 304

To appear in: Heart Rhythm O2

Received Date: 24 June 2022
Revised Date: 14 September 2022
Accepted Date: 21 September 2022

Please cite this article as: Tetreault-Langlois M, Frontera A, Hadjis AE, Incessant ventricular tachycardia with simultaneous recording of separate exits with common isthmus wavefront propagation, Heart Rhythm O2 (2022), doi: https://doi.org/10.1016/j.hroo.2022.09.017.

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Differential propagation through a common isthmus during dual exit VT

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Funding: none.

Disclosures: Dr. Alexios Hadjis discloses consultant fees from Abbott, Medtronic, and Biosense Webster.

Keywords: Ventricular tachycardia; shared isthmus; dual exit; separate exit; high-density mapping; diastolic pathway mapping

The patient reported in this paper provided written informed consent for VT mapping and ablation.
**Case report**

**Background**

The mechanisms of bimorphic ventricular tachycardia (VT) have been studied since the 1980s. Miller et al. described possible mechanisms that could explain variable QRS morphologies on surface ECG: different expressions of the same VT circuit due to preferential exit points along a shared isthmus, distinct circuits closely placed, and widely unconnected arrhythmogenic sites. The first two mechanisms seem to account for most cases of bimorphic VT seen in clinical practice. Bogun et al. (2) reported that a shared isthmus with different exit points may account for up to 40% of bimorphic VTs in ischemic cardiomyopathy. However, the dynamic three-dimensional nature of isthmus conduction in bimorphic VT has yet to be clearly elucidated.

**Case summary**

This is the case of a 77-year-old woman known for ischemic cardiopathy with a left ventricular ejection fraction (LVEF) 20-25% and a history of sustained monomorphic VT with implantable cardioverter-defibrillator (ICD) implanted. She presented to an outside hospital with VT storm. The patient was transferred to our center for hemodynamically stable VT with alternating QRS morphologies, left bundle left inferior axis and left bundle right superior axis, that was incessant despite several attempts of pharmacological and electrical cardioversion. The patient was brought to the electrophysiology (EP) lab for urgent ablation. Electroanatomic imaging of the entire diastolic pathway recorded two separate exit EGMs preceding each morphologically distinct QRS. Isthmus EGMs, recorded within the same mapping catheter location, demonstrated a beat-to-beat alternating wavefront pattern. The two different exit sites (one anteroseptal– one
inferolateral) from an extensive anteroapical scar, led the wavefront to travel in two separate outer loops as demonstrated by the two different timings of QRS to isthmus (figure 1). Timing from each alternate QRS offset to early diastolic potentials was identical, thus supporting equivalent entrance timing for both morphologies and corresponding common isthmus.

In cases with left bundle morphology and only partial diastolic pathway activity recorded, we routinely map the right ventricular septum to identify the missing segments, assess for an intramural component, and potentially prepare for bipolar ablation if needed. In this particular case, given we were able to record the entire diastolic pathway in the LV endocardium, we did not pursue further right sided mapping.

Ablation at the site of the common isthmus resulted in immediate termination of the VT (figure 2). All areas that recorded diastolic activity and were operational during VT were subsequently targeted for ablation. Following ablation of the entire diastolic pathway, programmed extra stimulation resulted in no inducible VT.

**Discussion**

It is well established that the primary mechanism of VT in structural heart disease is electrical reentry within scar tissue. In ischemic cardiomyopathy, surviving myocyte bundles serve as conduction channels through fibrosis and thus create VT circuits. These circuits can be composed of different loops, with the isthmus being the segment where all loops connect. It is known that ablation at the site of the isthmus has the best chance to successfully disrupt the circuit and terminate the arrhythmia (3).

Patients with ischemic cardiomyopathy in VT may present with different QRS morphologies upon surface ECG. These bimorphic VTs may occur spontaneously or may be induced by stimulation during EP study. These patients are less likely to respond favorably to ablation therapy, reflecting a more complex arrhythmia substrate. One mechanism that may account for multiple VT morphologies on surface ECG is different exit points along a common isthmus, which has been
shown to occur in almost half of patients with underlying ischemic heart disease (2)

High-density mapping of VT circuits allows to better localize and characterize the structure and function of arrhythmogenic zones. In the case described above, high-density mapping of the VT circuit demonstrated distinct exit EGMs from a single isthmus and allowed successful catheter ablation of the arrhythmia.

During activation mapping of the VT, we did not pursue entrainment maneuvers for fear of terminating the clinical tachycardia with failure to reinduce, or changing the clinical tachycardia. Our assessment of isthmus was not only based on EGM timing, but also on isthmus electrogram morphology, as reported by Ciaccio et al (4). The isthmus EGMs manifest low amplitude and relatively shorter duration as compared to the entrance and exit sites. Termination of VT within 4 seconds of ablation strongly suggested participation of the isthmus in the VT circuit.

Furthermore, the difference in timing and cycle length observed arise from the different exit points from the isthmus and the subsequent time from the late diastolic signals to the onset of the QRS. This phenomenon highlights an alternate functional block within the common isthmus demonstrating the dynamic and three-dimensional nature of the reentry isthmus, which was previously thought of as a two-dimensional structure. (4)

**Conclusion**

The above case demonstrates:

- Recording of separate exit EGMs from a common isthmus during VT with dual exits is feasible utilizing high-density mapping.
- Differential propagation through a common isthmus during dual exit VT also may lead the wavefront to travel in two separate outer loops.

**References**


Figure 1. Activation mapping during VT: Alternating isthmus electrogram wavefront prior to two distinct exit EGM patterns preceding the alternating QRS morphologies. Distinct entrance EGM patterns from QRS offset to isthmus further indicate separate entrances.
**Figure 2.** Ablation at the common isthmus results in near immediate termination of VT. Red dotted line depicts transecting line of ablation across isthmus.
**Key Findings**

1. Recording of separate exit EGMs from a common isthmus during bimorphic VT is doable using HD mapping.
2. Differential propagation through a common isthmus may lead the wavefront to travel in two separate outer loops.
3. The difference in timing and cycle length observed arise from the different exit points from the isthmus and the subsequent time from the late diastolic signals to the onset of the QRS. This phenomenon highlights an alternate functional block within the common isthmus demonstrating the dynamic and three-dimensional nature of the reentry isthmus, which was previously thought of as a two-dimensional structure.