Reentry, Pseudo-Reentry, and Pseudo-Pseudo-Reentry

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A dichotomy exists as to the ease and success of ablation for focal origin when compared with macroreentrant tachyarrhythmias, and inexact diagnosis of the arrhythmia mechanism is often a factor. In this installment of Teaching Rounds in Electrophysiology, Selvaraj et al1 present findings in a patient with previous tetralogy of Fallot repair and ventricular tachycardia. They use this case to teach us how the visual interpretation of electroanatomic maps can be misleading, and most importantly, they underscore the value of defining arrhythmia mechanism.

When “Early” Site Ablation Is Ill-Advised

Once a reference point, which for ventricular tachycardia is often a recognizable portion of the QRS, is established and a window of interest, typically spanning the cycle length of the tachycardia, is chosen, one can readily recognize sites of early activation coded red on the activation map display. For focal source tachycardias, ablation at such sites is likely to be successful. However, caution is required when targeting these sites in some instances.

Fascicular Tachycardia

Automatic or localized reentrant fascicular tachycardia may have exits from the Purkinje system to the ventricular myocardium at potentially distant and multiple sites away from the true tachycardia origin. Early ventricular electrograms, when compared with the QRS, simply identify the breakout sites of the tachycardia, as well as sinus rhythm.

Supravalvar and Thoracic Vein Arrhythmia

Tachycardia that originates in one of the cul-de-sacs of the heart (atria or ventricle) may similarly enter the myocardium of the cardiac chamber at one or multiple locations that may be relatively distant from the true origin. Unless the true origin outside the cardiac chamber is identified, success is unlikely.

Epicardial Origin

The relationship between epicardial and endocardial activation is difficult to predict spatially or temporally. Thus, the earliest endocardial site may have little relevance to the actual arrhythmia origin in the epicardium.

Reentry

As pointed out by Selvaraj et al,1 in a reentry circuit, there is neither an early nor late point of activation, and thus the location of a site designated as early is simply a reflection of the arbitrarily chosen reference point on the QRS and window of interest.

Defining Reentry With Activation Mapping

A focal tachycardia with near-centrifugal activation spread away from the focus is readily identified with standard pictorial displays of activation mapping; however, defining reentry is more complex.

Cycle Length Approximation

Once the window of interest is set to be approximately the cycle length of the tachycardia, if activation times are found in the chamber being mapped that closely approximates the cycle length, then the reentry circuit has likely been mapped and thus indirectly defines the mechanism of arrhythmia as reentry. It is important to remember, however, that the colors need to indicate actual activation times from a point that was mapped and not activation that was interpolated by the system.

Early Meets Late

When we picture a reentry circuit, we arbitrarily define a head and a tail (early and late components to the circuit). Therefore, when an electroanatomic map displays the activation sequence of a tachycardia, we anticipate seeing an area where our earliest defined electrograms meet their latest counterparts. Once again, the electrophysiologist must be reminded that in a circuit there are no true early or late points, and that these are simply an artifact of how we define our reference electrogram and window of interest. In other words, red areas meeting purple areas are just as much early meeting late sites as could be green sites meeting yellow sites, etc.

Pseudo-Reentry

Selvaraj et al1 explain in their illustrative case how a map may resemble a reentrant circuit, as defined by the criteria above, but in fact may be of another mechanism.
Cycle Length Is Not the Length of the Cycle
Consider an atypical atrial flutter with a cycle length of 300 ms for which a midcoronary sinus electrode is used as the reference electrogram. The operator arbitrarily specifies the window of interest as 150 ms before, ≤150 ms after, the reference electrogram. By chance, if the first point taken for the map is 149 ms before the reference and the second point is 2 ms before this, then an early (~149 ms) and a late (+149 ms) point will be color coded spanning the tachycardia cycle length, suggesting that the cycle length has been mapped! However, the cycle or reentry circuit, even if present, is far from adequately mapped, thus the importance of having actual measured electrograms at relatively uniform and multiple points throughout the cycle length. A mapping system may interpolate the colors of activation between these early and late points, but the operator must be vigilant to this pitfall and confirm that there are actual points for each of the color-coded segment and within each individual segment as well.

Microreentry
Reentrant circuits exist because their circuit length is sufficiently long and conduction through the circuit sufficiently slow such that it exceeds the refractory period of the tissue at each site in the circuit. When slow conduction is present, the circuit length itself may be so small that an appearance of a focal source or automatic tachycardia can be seen. How does one distinguish an automatic tachycardia from microreentry when such an activation sequence is seen without using entrainment maneuvers? Because conduction is so slow within that region, fragmented or multicomponent fractionated electrograms are highly likely to be seen at that location with microreentry. In contrast, relatively short duration electrograms are seen at the earliest site of activation with automatic rhythms.

Focus With Unidirectional Block and Slow Areas of Conduction
If an automatic tachycardia arises close to a site of block, such as next to the Eustachian ridge or crista terminalis, and takes a path where slow conduction may be present downstream from its point of emanation, then one does not see the expected centrifugal spread away from a rather sequence mistakenly suggesting reentry (pseudo-reentry).

Pseudo-Pseudo-Reentry
Selvaraj et al1 offer 1 important explanation for the findings in their case. When they manually changed the window of interest, what seemed to be an early site meeting a late site could well have been a point-source–type tachycardia simply exhibiting its early site. However, they were able to demonstrate concealed entrainment at this site, suggesting that a circuit was indeed present when their catheter was placed at this location. They explain this disparity by proposing microreentry as the mechanism of tachycardia. However, because the electrogram at that site was not complex, other possibilities should also be borne in mind. This site may be the exit site from a nearby slow zone for what actually was a macroreentrant tachycardia (pseudo-pseudo-reentry). Entrainment at other sites would be required to make this distinction.

Electrophysiologists should pay careful attention to the patterns of the activation sequence and not any arbitrarily defined colors. Thus, if one sees a red and purple area, it could simply mean an early site with an even earlier site or a late site with an even later site (early and even earlier would be red and then purple, and late and even later would be purple and then red). Visualizing a pattern of activation and then relating the cycle length of a complete pattern to the cycle length of the tachycardia, realizing that there is no early or late to meet each other, can help avoid possible errors.

Cases such as these underscore the importance of entrainment.2 Although we are shown the example of concealed entrainment to determine whether the site was in the circuit, entrainment at a distant site could have been used to define the mechanism of the tachycardia. Entrainment at sites where constant fusion is seen yet the last entrained beat is not fused (classical criteria for entrainment)3 would help define that the tachycardia was indeed reentrant. Furthermore, entrainment at other sites, such as those within a nearby isthmus or on the other side of a potential isthmus, etc, and indeed at multiple other sites (for stable and reproducibly inducible tachycardias), where one has defined the cycle length of the tachycardia with mapping can not only conclusively prove the presence of a reentry circuit but may also provide multiple options for locations of linear ablation to abolish the arrhythmia.

Disclosures
Dr Asirvatham receives no significant honoraria and is a consultant with Abiomed, Atricure, Biosense Webster, Biotronik, Boston Scientific, Medtronic, Spectranetics, St Jude, Sanofi-Aventis, Wolters Kluwer, Elsevier. Dr Stevenson is coholder of a patent on needle ablation that is consigned to Brigham and Women’s Hospital.

References

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