Teaching Points With 3-Dimensional Mapping of Cardiac Arrhythmia

Mechanism of Arrhythmia and Accounting for the Cycle Length

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Tachycardias can be broadly considered as falling into 2 categories: focal and macroreentrant. Focal tachycardias originate from a discrete region. The mechanism may be automaticity or a small reentry circuit. Activation of the cardiac chamber spreads away from that site. In most cases the cycle length of the tachycardia is longer than the time required for activation of the chamber of origin. Thus, the ECG and recordings from within the chamber of origin reveal an isoelectric period of no electric activity preceding the earliest point of activation and after completion of conduction to the site of latest activation in the entire chamber. Thus, an activation sequence map of the chamber typically shows activation during only a portion of the tachycardia cycle length, typically less than 50%.

With macroreentrant tachycardias, some part of the chambers (ventricles for ventricular tachycardia) is electrically activated at any given time during the cardiac cycle. A complete and carefully performed activation map should account for the entire tachycardia cycle length. This concept of cycle length approximation of the total activation times accounted for the entire tachycardia cycle length. This concept should be considered:

- **Incomplete anatomic definition.** The operator should determine whether the appropriate anatomic boundaries of the chamber of interest have been completely mapped. In the ventricles, have the supravalvar extensions of the ventricular myocardium and the mitral annulus been reached? Has the true apex been mapped?
- **Mapping in the wrong chamber.** Entrainment may have determined that a reentrant mechanism is operative; however, a small fraction of the cycle length may be mapped in the right ventricle. This suggests that the reentrant circuit itself may be in the left ventricle, or possibly a large portion is either midmyocardial or epicardial with the endocardial RV map unable to account for the cycle length of tachycardia.
- **Anatomic variant in the chamber of interest.** When mapping right atrial tachycardias, failure to identify a sub-Eustachian pouch may prevent complete mapping. When the right atrium is very large, the free wall of the atrium may not be reached.

With an appropriately chosen window of interest (see Teaching Point 1 in the December, 2010 issue of The Journal), the cycle length of the tachycardia should be accounted for. A common error in ablation based on activation mapping of a macroreentry circuit is creation of a color-coded picture that appears to be a reentry circuit but accounts for only a portion of the circuit, for example, only 150 ms of a 400 ms cycle length tachycardia. When the mechanism of tachycardia is thought to be reentry and yet a large portion of the cycle length has not been accounted for in the map, the following should be considered:

- **A missing chamber.** In certain patients with congenital heart disease, a portion of the chamber may be excluded from catheter access via the venous route (Figure). For example, with certain types of the Fontan procedure, a portion of the right atrium is excluded by the Fontan patch (neo–left atrium). An important clue that this chamber (the neo–left atrium) must be specifically mapped is when the cycle length of the tachycardia cannot be appropriately accounted for with right atrial mapping alone. Specifically accessing the neo–left atrium via transbaffle puncture or retrograde access will allow accounting for the entire cycle length.

- **Inappropriate delineation of scar.** A very common reason for failure to account for the entire tachycardia cycle length is failure to realize that low-amplitude electrograms may represent viable tissue and contain areas of slow conduction, accounting for a significant portion of the cycle length.

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of the tachycardia. With these locations inappropriately tagged as scar, the full tachycardia cycle length cannot be accounted for, and the circuit is not completely defined. When the circuit cannot be accounted for, it is useful to review or reinterrogate points thought to be scar to look for any consistent electrogram (consistent relative to the cardiac cycle) that can be included as activation times in the map. Similarly, when fragmented signals or double potentials designated scar, or used only for creating anatomy (“location-only” points) or the wrong component of the electrogram is selected for activation mapping, the map may fail to account for the cycle length of the tachycardia. Some experienced operators, however, will purposely take such locations as location-only points (fragmented signals, double potentials) and specifically reanalyze these locations after more of the activation sequence has been defined to help guide selection of the appropriate component of the signal for defining activation, based on timing of activation at adjacent sites.7

- **Wrong diagnosis.** Finally, the actual arrhythmia mechanism may not have been reentry. Although reentry is more common in diseased hearts, automatic tachycardias do occur, and the possibility should be considered when a large part of the cycle length simply cannot be defined even with the considerations above.

### Can the 3-Dimensional Electroanatomic Map Define the Mechanism of Tachycardia?

Pacing to assess entrainment of tachycardia is an important method to define tachycardia mechanism. In some cases, however, the operator wishes to avoid pacing during tachycardia for fear of transitioning one tachycardia to another tachycardia or terminating a tachycardia that was difficult to induce. In such cases, can the map itself help us understand tachycardia mechanism?

Theoretically, the maps should look very different with automaticity and reentry. With focal source tachycardia, an early point of activation with centrifugal uniform spread from that site is expected, whereas with reentry, the circuit should be visualized. Several caveats to these simplified generalizations have to be kept in mind before using a 3D map to define tachycardia mechanism.

- **Focal tachycardia mimicking reentry.** The activation sequence of a focal automatic tachycardia can occasionally be confusing and interpreted as reentry. Conduction block from anatomic obstacles, such as the Eustachian ridge or crista terminalis, scars, incisions, or regions with slow conduction, particularly when they are close to the focus, can render the activation map very dissimilar to the expected centrifugal pattern of activation. The wave front skirting around these boundaries will give the appearance of reentrant circuits. A useful exercise to demonstrate this problem is to map during a sinus or paced rhythm in a diseased heart. Attempted interpretation of the activation map often leads to a vigorous discussion pointing out various reentrant circuits, figure-of-eight reentry, and so forth, even though no tachycardia is present.

- **Reentrant tachycardia mimicking a focal mechanism.** When the reentrant circuit is in the contralateral cardiac chamber or when the vast majority of the circuit is midmyocardial or epicardial, a point source emanation will appear, mistakenly leading to the diagnosis of automatic tachycardia. For example, a left atrial tachycardia may appear to have a focal septal origin during right atrial mapping.

In general, however, in patients with diseased hearts and when the appropriate chamber is being mapped, if the mapped cycle length exactly or near exactly equals the cycle length of the tachycardia, a reentrant mechanism is likely.

### Can the Mapped Activation Sequence Exceed the Cycle Length of the Tachycardia?

If the window of interest has been taken to be significantly longer than the cycle length of the tachycardia, then double counting of signals occurs as explained previously in teaching point 1, and the mapped cycle will be greater than the cycle length of the tachycardia.

The tachycardia cycle length may shorten during the procedure. One example of this is the possible acceleration of tachycardia as a result of using isoproterenol.

In very diseased hearts, there may be bystander regions of very late activation that actually activate simultaneously with the next beat of tachycardia at the site of the reentrant circuit. Thus, the difference between one electrogram within the circuit and another bystander site activating very late may exceed the cycle length of the tachycardia.
This finding may occasionally occur in automatic tachycardias also. For example, when both atria are being mapped and the origin of tachycardia is in the myocardial extensions within the superior vena cava, activation points within the left upper pulmonary vein may be very late, and the interval between the early site of the superior vena cava and the late site in the pulmonary vein could exceed the cycle length of the tachycardia.

In summary, an important consideration with activation mapping of arrhythmias is careful analysis of whether the range of activation approximates the cycle length of tachycardia.

**Disclosures**

None.

**References**


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