The blanket credo of outstanding teaching is to allow a student to recognize existing patterns and then lead the trainee through an iterative learning process that results in a deepened appreciation of the reason for that pattern. Such nuanced stepwise understanding frequently translates to a skill that can be applied to many apparently unrelated situations. In this installment of Teaching Rounds in Cardiac Electrophysiology, Tan et al provide a wonderful didactic example of how to begin with an observed pattern and then take us through several layers of study and leave us with multiple, usable skills.

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Railroad track–like patterns, which result from continued atrial pacing during slow ventricular tachycardia along with ventricular safety pacing and slight alterations in the time of ventricular tachycardia detection after the postatrial ventricular blanking period in 2 patients, form the template for their teaching. After thinking through this instructive example, the student of electrophysiology will understand when a visible pattern of cardiac events found on device interrogation suggest either cyclic oversensing, triggered pacing, or a combination of the 2.

Oversensing
The classical and most common cause for the railroad track pattern is cyclic oversensing of an intracardiac signal. Clinically, most relevant is T-wave oversensing, and the intervals and patterns depend on the relationship of the QT interval to the rate of the intrinsic rhythm. The determinants of bipolar recording of a localized repolarization signal are poorly understood and difficult to predict at implant. Ideally, achieving a large-amplitude R wave at implant will obviate most of the difficulty with large local T wave recordings; however, a decrease in R wave or increase in the local T wave over time or change in position or use of membrane-active drugs may occur and potentially cause inappropriate T-wave detection and even elicit unnecessary device therapy. If the R wave remains substantially larger than the T wave, then decreasing the sensitivity will likely solve the problem, but if not, lead repositioning would be required.

P-wave oversensing is far less common than T-wave oversensing and is largely limited to children or patients with small hearts or when the ventricular lead has been placed purposely close to the tricuspid annulus.

Double-counting of the R wave was a major clinical problem in older versions of cardiac resynchronization therapy devices, which used the left ventricular lead as part of its sensing circuit. With single- or dual-chamber devices, R-wave double-counting may occur when the lead is within or surrounded by abnormal or fibrotic myocardium from a previous infarct, ablation, or scar from arrhythmogenic right ventricular cardiomyopathy.

Typically, lead problems produce noncyclic noise from unclear mechanisms that will not produce a railroad track type of repetitive pattern. Rarely, insulation breaches, as well as fractures to ring electrodes, may produce cyclic oversensed signals, likely from compression of the lead timed with cardiac systole.

Triggered Pacing
When combining sensed and paced events on a retrieved device tracing, a railroad track pattern will be seen with any type of triggered pacing. For example, in all dual-chamber devices, ventricular pacing after an atrial-sensed or -paced event in a patient without intrinsic atrioventricular (AV) conduction will in this sense produce a railroad track pattern. The specific pattern will depend on the relative interval between the triggering event and the triggered event compared with the cycle length of the triggering events. Because this is universal in dual-chamber systems, we do not consider atrial-sensed ventricular-paced events as railroad tracking.

If, however, the atrial event is fixed to or follows with a fixed cycle length, a ventricular event, then, as explained by Tan et al, ventricular-based pacing where each ventricular event starts the atrial escape interval, and in the absence of an intrinsic atrial activity or another ventricular event, will result in railroad tracking (a ventricular sensed or ventricular tachycardia–sensed event followed by atrial pacing). Tracking of atrial events should result in ventricular pacing of the programmed sensed AV interval. However, another form of tracking when a ventricular electrogram is sensed during the cross talk sensing window would be to produce tracking at a shorter than expected AV interval from ventricular safety pacing. In the examples provided by Tan et al, both of these mechanisms of tracking were operative, and the interaction in turn produced varying time of sensing of the slow ventricular tachycardia as a result of the postventricular atrial blanking period initiated after the trigger atrial pacing.

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Railroad Tracks for the Invasive Electrophysiologist

Repetitive patterns of sensing may be seen during mapping of a specific chamber during an ablation procedure either from some form of double-counting or from Mobitz I type of interelectrogram block.

Triggered Activity

It may be difficult to distinguish the double-counted signals from locally recorded repolarization signals, mechanical artifacts, or sensing of another cardiac chamber. Stimulation from the recording electrode and careful analysis of which signals can be captured, and as a result moved toward the pacing artifact, can help in making these determinations.4,5

Just as premature ventricular contractions from triggered activity may result in bigeminy with a fixed coupling interval, so also local intracardiac electrograms may show potentials that are timed to an initial R wave from triggered ectopy with exit block.6

Reentry

Just as R-wave double-counting may occur when the pacing lead is in an area of highly abnormal myocardium, so also during catheter mapping reentrant arrhythmias in a diseased ventricle or atrium, two signals may be recorded at some sites producing the railroad track-type pattern. These may represent double potentials as a result of severe conduction slowing or block, localized reentry with spontaneous exit block, or entrance without exit into a terminal (cul-de-sac) structure, such as the papillary muscle, after ablation.7 Recognizing when cyclically sensed multiple signals are present and recognizing which signal represents local activity at the site of the distal ablation electrode when performing entrainment maneuvers may be critical for correct interpretation.8

Combinations of the above causes for multiple cyclic signals, along with Wenckebach-type conduction from one region to another through diseased myocardium, may produce complex patterns, but the student of electrophysiology being aware and having practiced the maneuvers to discern these signals can quickly identify the essence of the recognized pattern.

Situational Behavior

The cases presented by Tan et al1 also explain the importance of not only recognizing and interpreting repetitive signals, but also appreciating that a specific pattern may occur only with a particular device and be dependent on how a device is programmed. The pattern described in the cases discussed would not have occurred if the device implanted was a Boston Scientific device where once ventricular tachycardia is detected, the pacing mode switches to a VDI mode, or if in the patient’s Medtronic (Minneapolis, MN) device, ventricular tachycardia occurred in a nonmonitored zone. The patient’s situation should also be considered when programming. For example, a long AV interval may be unnecessary in a patient with complete AV block or rate responsive pacing is not required when sinus node function is normal.

Why?

The essence of any teaching point made to a student is to explain why a phenomenon occurs and why it matters. Not only do Tan et al1 explain to us in stepwise fashion the sustained and unusual railroad track pattern observed, but they point out the potential for ventricular undersensing and AV dyssynchrony with potential hemodynamic consequences.

Disclosures

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