Teaching Rounds in Cardiac Electrophysiology

Postablation Scar-Related Atrial Tachycardia
Turning the Spotlight on P-Wave Analysis and Window Settings

Wei Ma, MD; Michael Shehata, MD; Eugenio Cingolani, MD; Ashkan Ehdaie, MD; Sumeet S. Chugh, MD; Xunzhang Wang, MD

Left atrial flutter (AFL) and localized scar-related atrial tachycardia (AT) are the most common tachyarrhythmias that follow catheter or surgical ablation for atrial fibrillation. Three-dimensional activation mapping can be challenging due to large and often multiple areas of scar interspersed with areas of delayed conduction, resulting in complex reentrant circuits.1 In our experience, there are 3 components of mapping that are crucial to localizing the re-entry circuit and guiding catheter ablation: (1) analysis of the P wave on surface ECG, (2) right and left atrial (LA) intracardiac activation sequence from multielectrode catheters positioned at the right atrium (RA; 20 poles) and proximal coronary sinus (CS; 10 poles; Figure 1A), and (3) careful attention to the mapping window settings based on P-wave analysis and the cycle length of the tachycardia.

See Editor’s Perspective p 760

Mitral and Tricuspid Annular Flutter: P-Wave Analysis and Right and LA Activation

Counter clockwise tricuspid annular atrial flutter (CCW-TA-AFL) has a distinct pattern of surface ECG and intracardiac activation, with onset of the positive P wave in lead V1 coinciding with a fast upright vector in leads II, III, and aVF (Figure 1B1). The atrial activation at the septal high RA during CCW-TA-AFL precedes the positive P wave in V1 (Figure 1B1).2 This relationship between RA activation and the distinct P wave in V1 is similar during CCW-TA-AFL and counter clockwise (CCW) mitral annular atrial flutter (MA-AFL; Figure 1B1, 1B2, and 1B3). The shallow upsloping portion of the P wave in leads II, III, and aVF is much earlier than the onset of P wave in V1 during CCW or CW-MA-AFL and also coincides with LA activation (Figure 1B2 and 1B3). The earliest RA activation during CCW-MA-AF is observed at the high RA septum, propagating to the RA free wall and septum, with simultaneous activation in the RA and CS (Figure 1B2 and 1D). The earliest RA activation during CW-MA-AFL is observed at the proximal electrodes of the RA catheter adjacent to the low or mid RA septum, propagating to high and low RA simultaneously (Figure 1B3 and 1E). However, in the case of a previous tricuspid annular (TA) isthmus ablation, RA activation may present in a CCW pattern. Regardless of the type of annular AFL, the distinct P wave and timing in V1 is related primarily to RA activation (Figure 1).

CS Activation From Distal to Proximal: Distinguishing Localized LA Tachycardia From CW-MA-AFL

In localized scar-related LA tachycardia, the P wave in V1 can be wide or relatively narrow, with earliest atrial activation at the distal CS, similar to the pattern of CW-MA-AFL. A distinct P wave in V1 or the late component in a widened P wave in V1 always coincides with RA activation (Figure 2B–2D). In both CW-MA-AFL and localized scar-related AT originating from the lower lateral LA, atrial activation at the proximal CS precedes atrial activation of the lateral RA. The onset of the P wave in leads II, III, or aVF coincides with early LA activation and precedes the distinct P wave in lead V1 (Figure 2A and 2B). However, the P wave in localized scar-related AT will be superiorly directed in leads II, III, and aVF but not in CW-MA-AFL (Figure 2B). In the case of a higher lateral LA localized tachycardia, atrial activation of the proximal CS may be simultaneous with the lateral RA because of fast conduction from LA to RA (Figure 2C and 2D). Based on the location of the tachycardia focus, vector of conduction and voltage in the LA, LA activation may or may not generate a portion of the P wave in lead V1 (Figure 2C). With these high lateral LA localized tachycardias, a widened P wave may be observed in V1, coinciding with the onset of the P wave in leads II, III, and aVF (Figure 2D). However, a widened P wave in V1 is relatively rare and most often found in cases of high lateral localized AT with a minimally LA scarring, which is uncommon in these cases.

During activation mapping of localized left AT, the mapping window of interest can be selected based on P wave morphology. When a clear P wave is seen in leads II, II, and aVF, selecting the window of interest at 60 ms before the onset of the P wave will cover conduction time within the entire LA, which will be less than the total tachycardia cycle.

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From the Division of Cardiology, Heart Institute, Cedars-Sinai Medical Center, Los Angeles, CA (W.M., M.S., E.C., A.E., S.S.C., X.W.); and Department of Cardiology, Tianjin Chest Hospital, Tianjin, People’s Republic of China (W.M.).
Correspondence to Michael Shehata, MD, Heart Rhythm Center, the Heart Institute, Cedars-Sinai Health System, Los Angeles, CA 90048. E-mail Michael.Shehata@cshs.org
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Figure 1. A, Right anterior oblique (RAO) and left anterior oblique (LAO) fluoroscopic projections with duodecapolar catheter with 2-10-2 mm spacing placed in the right atrium (RA) at the tricuspid annular and a decapolar catheter with 2-5-2 mm spacing placed in the proximal coronary sinus (CS). B1, Counter clockwise tricuspid annular atrial flutter (CCW-TA-AFL) with correlation of RA activation and P wave in leads V1, II, III, and aVF. B2, Counter clockwise mitral annular atrial flutter (CCW-MA-AFL) with simultaneous atrial activation in the RA and CS and earliest RA activation at 9 to 10 pair electrodes indicating early RA activation at the high RA septum. The shallow upsloping portion in leads II, III, and aVF is much earlier than the P-wave onset in V1. B3, CCW-MA-AFL with early RA activation located at the low or mid septum, propagating to high and low RA with atrial activation in the proximal CS preceding the lateral atrial activation of RA. C, Activation mapping of the RA during CCW-TA-AFL. The atrial activation at the septal high RA precedes P wave in leads V1, II, III, and aVF. D, CCW-MA-AFL with earliest atrial activation at the high septal RA. The atrial activation at the septal high RA precedes P wave in lead V1. E, CW-MA-AFL with earliest atrial activation at the low and mid septal RA. The atrial activation at the septal high RA precedes the P wave in lead V1. ABL D indicates ablation electrode distal; ABL P, ablation electrode proximal; CCW-CTI-AFL, counter clockwise cavotricuspid isthmus atrial flutter; CW-TA-AFL, clockwise tricuspid annular atrial flutter; RA D, right atrium distal; and RA P, right atrium proximal.
length. However, in cases where no clear P wave in leads II, III, and aVF is visualized, the conduction time from distal to proximal CS is ≈40 ms, and selecting a window that starts 100 ms before the atrial electrogram at the proximal CS is more useful, especially because distal CS activation is relatively close to the site of origin (Figure 2B–2D).

**CS Activation From Proximal to Distal: Distinguishing LA Tachycardia From CCW-MA-AFL**

Scar-related localized AT in the LA septum may have a similar activation pattern to CCW-MA-AFL with simultaneous atrial activation in the RA and CS and timing with a distinct narrow P wave in lead V1 and II, III, and aVF (Figure 3A). In this setting, selecting a window of interest 60 ms before the P wave or proximal CS activation will be adequate to capture the entire conduction time.

AT originating from the septal LA can have significantly delayed activation to the RA after extensive prior ablation in the septal LA (Figure 3B). One such example is provided by a patient who underwent ablation of both the right cavotricuspid isthmus for CCW-TA-AFL and linear ablation from the anterior MA to the right superior pulmonary vein for CW-MA-AFL. An AT with similar atrial activation to CCW-TA-AFL was induced (Figure 3B). Entrainment pacing from lateral RA and proximal CS excluded CCW-TA-AFL and CCW-MA-AFL (Figure 3C and 3D). Localized AT originating from the LA septum was confirmed by entrainment pacing (Figure 3C and 3D). In this case, setting the window of interest relative to the proximal CS activation is preferable because significantly delayed activation to the RA is present and thus the resulting P wave in V1 is late in relation to LA activation (Figure 3).

**Roof-Related AFL**

AT involving the roof of the LA can have a similar CS activation pattern to CW and CCW-MA-AFL or demonstrate a reverse chevron configuration or simultaneous activation of the CS. Three-dimensional mapping with early and late activation will usually cover the entire tachycardia cycle length. Entrainment pacing from the CS is important to differentiate localized scar-related AT originating from the middle of the
Figure 3. A, Counter clockwise mitral annular atrial flutter or localized scar-related atrial tachycardia (AT) at the septal left atrium (LA) can result in simultaneous atrial activation of the right atrium (RA) and coronary sinus (CS) correlated with the P wave in lead V1. B, Localized AT originating from the high septal LA demonstrates an atrial activation pattern of the RA and CS similar to counter clockwise tricuspid annular atrial flutter because of a delay in conduction from LA to RA. C, Entrainment pacing from the lateral RA with a significantly lengthened postspacing interval (PPI). D, Entrainment pacing from the proximal CS with a significantly lengthened PPI. ABL D indicates ablation electrode distal; ABL P, ablation electrode proximal; and CL, cycle length.

LA distant from the CS with a pattern of reverse chevron or simultaneous CS activation.

In a patient with a simultaneous CS activation pattern and successful entrainment at the proximal and distal CS, we established the presence of a large re-entry circuit involving the roof of the LA (Figure 4A1–4A3). CS activation was altered during linear ablation from the anterior MA to right superior pulmonary vein, with earlier atrial activation at the distal CS (Figure 4B1–4B3). Three-dimensional activation mapping and entrainment of the distal and proximal CS demonstrated that the reentrant mechanism involved the lateral roof of the LA.

Another patient had early atrial activation at the proximal CS propagating to the RA via the high septal RA (Figure 4C) and successful entrainment at the proximal CS (Figure 4C1–4C4). Three-dimensional activation mapping of the LA during tachycardia showed dense scar at a voltage setting of 0.3 to 1.0 mV, resulting in a small isthmus of viable atrial potential at the high septal roof near the right superior pulmonary vein (Figure 4C5 and 4C6). This tachycardia with a reentrant circuit involving the septal LA roof was terminated with ablation at this isthmus at the high septum (Figure 4C5).

These examples highlight the importance of analyzing the P wave and both right and LA intracardiac electrograms in the assessment of scar-related ATs. Using such an approach can assist in the successful mapping and ablation of these challenging arrhythmias.
Disclosures

None.

References


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