Determining inferior vena cava–tricuspid isthmus block after typical atrial flutter ablation

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Cavotricuspid isthmus role in typical flutter

In typical atrial flutter, circular activation around the tricuspid ring is possible because the terminal crest prevents short-circuiting on the posterior wall, and the myocardium between the inferior vena cava (IVC) and the lower rim of the tricuspid ring is the obligatory pathway to close the circuit in the low right atrium (RA) (Figure 1). This IVC–tricuspid ring isthmus (cavotricuspid isthmus) has become the preferred target for ablation because it is the narrowest point of the circuit, it is easily accessible, and it is located far from the AV junction. Variations of the circuit all share the cavotricuspid isthmus as the obligatory path in the low RA (Figure 1).

Checking conduction/block at the isthmus

The cavotricuspid isthmus extends from the low anterior RA to the low septal RA, located posteromedially. During typical atrial flutter, activation through the cavotricuspid isthmus can be traced from its anterior to its posterior end (or vice versa in reverse typical atrial flutter) by sequential recordings with a roving catheter or by placing a multipolar catheter along the course of the cavotricuspid isthmus (Figure 2). Once typical atrial flutter is interrupted, conduction is checked during pacing at both ends of the cavotricuspid isthmus, the anterior isthmus (or the low anterior RA) and the posterior isthmus (or the low septal RA) (Figure 1). By placing an additional catheter in the coronary sinus (CS) or by advancing a multipolar reference catheter from the anterior RA to the CS, CS os pacing often is substituted for pacing the low septal RA because of catheter stability (Figure 2). The possibility of block at the eustachian ridge should be considered when pacing at the CS os or the posteroinferior septal RA, because pacing beyond this line delays arrival of activation to the cavotricuspid isthmus and could mimic block (see later and Figure 1).

RA activation sequence outside the cavotricuspid isthmus

With intact cavotricuspid isthmus conduction, ascending activation from pacing the low septal RA collides with descending activation on the anterior wall. With pacing from the low anterior RA, the opposite occurs, with collision of ascending and descending activation fronts on the septal RA. Cavotricuspid isthmus block after ablation prevents ascending activation on the RA wall opposite the pacing point. However, ablation can cause long local conduction delays, indistinguishable from complete block (Figures 1 and 3B). Nevertheless, recording RA activation sequence is helpful because the appearance of changes in activation marks at least some degree of effectiveness and indicates when to check for complete block by recordings along the ablation line.

ECG changes with cavotricuspid isthmus block

P-wave configuration when pacing the low RA can reflect cavotricuspid isthmus block when loss of ascending activation on the RA wall opposite the pacing site changes the terminal P wave from negative to positive in leads II, III, and aVF (Figure 3). P-wave duration also can increase, especially with pacing the anterior isthmus (Figure 3). Because P-wave change reflects RA activation and not cavotricuspid isthmus activation, it will not allow differentiation between complete block and very slow conduction. However, P-wave change is a useful indicator of some effect taking place during RF application and helps to monitor recovery of isthmus conduction during a postablation confirmation period.

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Direct recording of isthmus conduction

Collision of two activation fronts

The demonstration of extremely slow conduction through the cavotricuspid isthmus after ablation shows the need for direct recordings from the cavotricuspid isthmus to confirm block. A multipolar catheter, introduced from the IVC and curved in the RA to rest on the cavotricuspid isthmus, is commonly used. If the catheter tip is advanced to the CS os, it also can be used to pace both sides of the ablation line (Figure 2). Alternatively, a multipolar catheter can record and pace multiple sites of the anterior and septal RA, from high to low, using the ablation catheter to record the ablation line (Figure 2).

A complete activation sequence of the low RA, including the cavotricuspid isthmus, displays a double activation front in the presence of conduction block: one early, entering from the pacing site, the other very late, entering the opposite end of the cavotricuspid isthmus. At the block site, the electrogram shows two deflections separated 60 to 150 ms by an isoelectric segment. However, the presence of these double electrograms should be checked along the entire ablation line, from the tricuspid ring to the IVC because the width of the cavotricuspid isthmus is enough to show local block at one point and persistent conduction with continuous electrogram recordings at another. In the presence of slow conduction, even if activation of the RA opposite the pacing site is reversed, cavotricuspid isthmus recordings show electrograms, often prolonged and fragmented, bridging the interval between the stimulus and the opposite side of the cavotricuspid isthmus.

Activation time across the cavotricuspid isthmus, often measured as the separation between the components of the double electrogram, has been used to indicate complete block. A positive predictive value of 100% has been proposed for a separation of 110 ms and a specificity of 80% for a 50% increase of transisthmus conduction time from baseline. These values are not absolute, and the gold standard remains the demonstration of opposite activation fronts colliding at the ablation line.8,9

Changes in local electrogram configuration

Cavotricuspid isthmus block shifts direction of activation on the side of the ablation line opposite from the pacing site, which changes electrogram configuration. Unfiltered unipolar electrograms show an RS configuration when activation moves through the area, changing to a single positive deflection when block occurs and the recording site becomes

Figure 1 Schematic representation of the right atrium in the left anterior oblique view. The tricuspid orifice is artificially increased to show the endocardium with the openings of the superior vena cava, inferior vena cava, and coronary sinus. A: Arrows show direction of activation during typical flutter (TFL) and lower loop (LL) macroreentry closing the circuit through the terminal crest. B: Activation in reverse typical flutter (RTFL). C: Activation sequence pacing the anterior end of the cavotricuspid isthmus before ablation showing collision of ascending and descending fronts on the septal wall. D: Activation sequence pacing the septal end of the cavotricuspid isthmus before ablation showing collision of ascending and descending fronts on the anterior wall. E: Activation sequence pacing the anterior end of the cavotricuspid isthmus after isthmus block showing fully descending activation on the septal wall. F: Activation sequence pacing the septal end of the cavotricuspid isthmus after isthmus block showing fully descending activation on the anterior wall. G: Activation sequence pacing the septal end of the cavotricuspid isthmus with partial block (slow conduction) showing fully descending activation on the anterior wall. H: Block at the eustachian ridge causing delay in arrival of activation to the cavotricuspid isthmus that can mimic cavotricuspid isthmus block.

Figure 2 Coronal (top left) and left anterior oblique (top right) magnetic resonance imaging cuts of the heart showing the position of the cavotricuspid isthmus (CTI). Bottom: Anterior oblique fluoroscopic views of (A) multipolar catheter covering the anterior right atrium, CTI, and proximal coronary sinus and (B) multipolar catheter covering the septal and anterior right atrium and ablation catheter on the CTI.
a dead end.10,11 The main problem with unipolar unfiltered electrograms is that they are technically demanding because of sensitivity to artifact, baseline motion, and far-field potentials. The bipolar electrogram shows only relative changes in configuration. Nevertheless, a change of polarity of the initial deflection of the electrogram closest to the ablation line opposite the pacing site is a reliable sign of block12 (Figure 3A, top panel).

**Dynamic changes: Differential pacing**

The double electrograms recorded from the ablation line may have variable separation (60–120 ms) often too narrow to reach the absolute numbers indicative of complete block. In this situation, changes induced by moving the pacing site away from the ablation line help demonstrate block. If the two components of the electrogram represent slow conduction from some unidentified gap in the ablation line, then pacing from higher on the septal or anterior walls increases the interval between stimulus and electrogram for both components in parallel. On the other hand, if the two components represent two opposing activations fronts, the deflection corresponding to the same side of the ablation line is delayed but that due to activation on the other side of the line is advanced, or not delayed, and the separation of the local electrograms decreases13 (Figure 4).

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**Figure 3**  
Top panel. A: Recordings from the right atrium (RA) and cavotricuspid isthmus with the setup shown in Figure 2B. aRoof = anterior roof; A1–A4 = anterior wall from top (1) to bottom (4) close to anterior isthmus; CTI = cavotricuspid isthmus; S1–S4 = septal wall from bottom (4) to top (1); pRoof = posterior roof. A: Before CTI block, pacing the low septum, close to the CTI, collision of activation occurs on the anterior wall. The CTI electrogram is recorded between the stimulus and A4. B: With CTI block, anterior wall activation is fully descending. The CTI shows a double electrogram, with the second component recorded after A4. C: Before CTI block, pacing the low anterior RA, close to the CTI, shows descending activation of the septal RA, with almost simultaneous S4 and S3 electrogram. The CTI electrogram is recorded between the stimulus and S4. D: After CTI block, pacing the low anterior RA, close to the CTI, now shows a fully descending activation of the septal wall with further delay and change in configuration of S3 and S4 electrograms. The CTI shows a very late electrogram inscribed after S4. Note marked prolongation of the PR interval as a result of increased P wave duration. B: False appearance of CTI block in typical atrial flutter recurring after ablation. Bottom panel. A: Descending activation sequence of the anterior RA wall from high (A1) to low (A3) pacing close to the septal CTI. B: Descending activation sequence of the septal RA wall from high (S1) to low (S3) pacing close to the anterior CTI. C: Typical atrial flutter with descending activation of the anterior wall and ascending of the septal wall, with a very slow cycle length as a result of very slow conduction through the CTI. Note the very wide, continuous, fragmented CTI electrogram.

**Figure 4**  
Differential pacing to diagnose cavotricuspid isthmus (CTI) block. Recordings are labeled as in previous figures. Atrial schemas are constructed as in Figure 1. Numbers on top of the CTI electrogram show the interval from stimulus to last component of CTI electrogram. Numbers below show separation of the two components of the CTI electrogram. A: With pacing the low anterior right atrium, close to the CTI, septal wall activation is fully descending. The CTI electrogram has two components, the last later than S4. B: Pacing 1 cm higher on the anterior wall. Note the second component of the CTI electrogram is closer to the stimulus and electrogram separation decreases. C: Descending anterior wall activation pacing the low septum, close to the CTI, and a double electrogram in the CTI. D: Pacing 1 cm higher on the septal wall. The interval from the stimulus to the second CTI electrogram component decreases, as does the separation between the electrogram components. The terminal portion of the P wave is positive in lead II.
Continuous in the laboratory. In fact, recovery of conduction can occur probably hours or days after ablation, because at least 5% of patients with bidirectional cavotricuspid isthmus block at the end of the procedure have recurrent flutter at follow-up of 6 to 12 months. Conduction recovery occurs in most of recurrences within 20 to 30 minutes of observation. This should be a minimum observation period after block is produced. Isoproterenol infusion has been proposed to disclose reversible block. However, no evidence indicates this is better than an observation period. In fact, the incidence of conduction recovery after isoproterenol is very similar to that reported during a waiting period.

Terminal crest permeability and clockwise block

It is generally assumed that the terminal crest blocks conduction during pacing at the usual cycle lengths of 500 to 600 ms, but this is not true in a large proportion of patients. It is especially during low septal or CS ostial pacing that conduction across the terminal crest can produce a collision pattern on the anterior RA wall, suggesting conduction across the cavotricuspid isthmus (Figure 4). Conduction through the terminal crest can be confirmed by recording a similar collision pattern pacing the low posterior RA with a shorter interval between the stimulus and the low anterior RA electrogram, which would be unexpected if it were due to conduction through the cavotricuspid isthmus (Figure 5).

Unidirectional cavotricuspid isthmus block

Unidirectional block has been observed in some cases after ablation, with a higher incidence of counterclockwise (anteroposterior) unidirectional block possibly as a result of local anisotropy. Because diagnosis of block can be technically difficult in a given direction, it appears important to confirm block in both directions in every case so that bidirectional block is the endpoint in all cases.

Persistent versus reversible block

Cavotricuspid isthmus block can be transient, lasting from a few seconds to minutes or more than 1 hour while observed continuously in the laboratory.

References


Figure 5 Conduction through the terminal crest mimicking cavotricuspid isthmus conduction. A: Collision of ascending (A4 to A3) and descending (aRoof to A3) activation on the anterior right atrium (RA) pacing close to the septal end of the CTI. B: Pacing the low posterior RA with the same collision pattern on the anterior wall, but a shorter stimulus A4 interval. Atrial schemas are constructed as in Figure 1.


