Ablation of Isthmus Dependent Atrial Flutter: When to Call for the Next Patient

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Introduction

Typical atrial flutter is a common reentrant atrial arrhythmia. The critical portion of the reentrant circuit is the rim of tissue between the tricuspid valve (TV) annulus and the inferior vena cava (IVC) (Fig.1). The reentrant circuit can operate in either clockwise or counterclockwise directions (Figs. 2–3). Elimination of conduction across the TV-IVC isthmus eliminates the tachycardia. The endpoint of ablation is to achieve bidirectional TV-IVC isthmus block. Successful ablation of TV-IVC isthmus dependent atrial flutter approaches 99%, has a 2%–3% recurrence rate, and rare serious complications. The purpose of this review is to define the various endpoints for ablation of TV-IVC isthmus dependent atrial flutter, assess some of the common pitfalls associated with each, and provide a practical approach to determine when the ablation line is complete.

Diagnosis and General Approach

From a clinical and therapeutic perspective it is advantageous to classify atrial flutter as either TV-IVC isthmus dependent or independent. An ablation line across the TV-IVC isthmus will only cure a patient of atrial flutter if the TV-IVC isthmus is a critical component of the tachycardia circuit. Therefore, prior to ablation,

Figure 1. A schematic illustration of the right lateral view of the heart with the lateral wall of the right atrium peeled away. The arrows depict the reentrant circuit of TV-IVC isthmus dependent atrial flutter in the more common counterclockwise direction. The circuit is adjacent to the crista terminalis (CT). The rim of tissue that is critical for atrial flutter is between the tricuspid valve (TV) and the inferior vena cava (IVC). Ablation that results in complete bidirectional block anywhere across the TV-IVC isthmus will eliminate atrial flutter. A septal ablation location is illustrated by the speckled bar across the TV-IVC isthmus. (Adapted from Atlas of Human Anatomy, Frank Netter, MD 1997, and published with permission from Medical Education and Publications, Novartis Pharmaceuticals Corporation.)
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Figure 2. Standard 12 lead surface electrocardiograms from a patient with counter-clockwise (left panel) and clockwise (right panel) TV-IVC isthmus dependent atrial flutter. (Courtesy of Bradley P. Knight, MD, University of Chicago, Chicago, IL.)

Figure 3. Intracardiac electrograms of TV-IVC isthmus dependent atrial flutter are shown. Counter-clockwise and clockwise TV-IVC isthmus dependent atrial flutter is present in the left and right panels, respectively. A duodecapolar catheter is used for recording right atrial activation. The distal pair of electrodes (RA_9) are positioned in the coronary sinus. Electrode pairs 2-7 (RA_{2-7}) are generally on the TV-IVC isthmus, while the more proximal pairs of electrodes are usually located on the lateral wall of the right atrium (RA_{8-9}), and either near or on the interatrial septum (RA_p). During counter-clockwise flutter, the activation proceeds sequentially up the atrial septum (RA_p) over the roof of the right atrium to the lateral free wall of the right atrium (RA_{9,8}), and then across the TV-IVC isthmus (RA_{7,6,5,4,3,2}). Past the coronary sinus (RA_1), and back to the atrial septum. The atrial activation sequence is reversed with clockwise atrial flutter. The ablation catheter is positioned medially on the TV-IVC isthmus (ABL_{D,P}). (Courtesy of Bradley P. Knight, MD, University of Chicago, Chicago, IL.)
confirmation that the tachycardia is dependent upon the TV-IVC isthmus should be obtained, i.e., demonstrate that concealed entrainment is present. This is achieved by pacing from the TV-IVC isthmus during atrial flutter and observing the postpacing interval, the atrial activation sequence, and the P wave morphologies. When the TV-IVC isthmus is a critical portion of the reentrant circuit, then concealed entrainment is demonstrable, and the postpacing interval is equal to the tachycardia cycle length (Fig. 4). Furthermore, the atrial activation sequence, and the P wave morphology observed during pacing are identical to those observed during the tachycardia. The morphology of the P wave, however, is often difficult to assess during this maneuver.

After confirmation that the atrial flutter is dependent upon the TV-IVC isthmus, ablation can proceed either during atrial flutter, sinus rhythm, or sinus rhythm with pacing from the coronary sinus (Fig. 5). This is true for any atrial flutter that is dependent upon the TV-IVC isthmus, even unusual forms.

After the TV-IVC isthmus linear lesion has been created, demonstration of complete bidirectional block is required. The key issue is how one differentiates between slow conduction and no conduction across the TV-IVC isthmus. All of the techniques which are used to assess for complete bidirectional TV-IVC isthmus block assess the relative conduction times of the right atrium and the TV-IVC isthmus. As the block across the TV-IVC isthmus becomes more complete, less atrial tissue is depolarized via conduction across the TV-IVC isthmus.

Because differentiation between slow conduction and no conduction can be difficult, it is important to use a variety of techniques to demonstrate the presence of complete bidirectional TV-IVC isthmus block. Unidirectional block is quite unusual; however, demonstration of bidirectional TV-IVC block is the generally accepted endpoint. With each of the techniques discussed, bidirectional conduction block across the TV-IVC isthmus is demonstrated by pacing on the lateral wall of the right atrium and observing counterclockwise block, and by pacing from the coronary sinus and demonstrating clockwise block. Complete bidirectional TV-IVC isthmus block may be rate related. Hence, when evaluating for TV-IVC isthmus conduction, pacing should be performed with a long drive cycle length.

**Techniques to Identify Bidirectional TV-IVC Isthmus Block**

**Double Potentials**

Double potentials along the ablation line during ablation for TV-IVC isthmus dependent atrial flutter is generally considered the gold standard for
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Figure 5. A 45° left anterior oblique fluoroscopic view of the heart with the catheters positioned for ablation of TV-IVC isthmus dependent atrial flutter. A duodecapolar catheter is positioned as described in Figure 3. The distal electrode pair is in the coronary sinus (E_D), electrode pairs E_2-7 are on the TV-IVC isthmus, electrode pairs E_8-9 are on the lateral wall of the right atrium, and the proximal electrode pair (E_P) is on the roof of the right atrium near the interatrial septum. The circle indicates the ostium of the coronary sinus (CS). Electrode pairs E_0 to E_4 are positioned medial to the intended ablation line.

determining complete bidirectional block.\(^2\) Double potentials exist on both sides of a line of block. When there is a gap in a line of block, the isoelectric period between the double potentials shortens the nearer the electrograms are to the gap. At the gap in the line of block, double potentials are no longer present, and the electrogram is typically long and fractionated, but can also be discreet.

The data to date suggest that when the interval between double potentials is > 110 ms, then bidirectional TV-IVC isthmus block is present (Fig. 6).\(^8\) When the interval between double potentials is < 90 ms, then bidirectional block is not present. There may or may not be complete bidirectional TV-IVC isthmus block when the interval between double potentials is 90-110 ms. However, if there is complete bidirectional TV-IVC isthmus block, then the interval between the double potentials will be constant along the length of the ablation line and > 90 ms. However, theoretically at least, a patient may have an interval > 110 ms between double potentials and not have complete bidirectional block. This is an issue worth considering particularly in the setting of an extremely slow TV-IVC isthmus dependent atrial flutter.

Sometimes the amplitude of double potentials is too small to assess. When this occurs, other techniques are required to assess for complete bidirectional TV-IVC isthmus block.
This figure illustrates a variety of endpoints for ablation of TV-IVC isthmus dependent atrial flutter and their pitfalls. In the left panel before any applications of radiofrequency energy were delivered, the transisthmus conduction interval is 35 ms, and an obvious chevron activation sequence is observed. After delivery of several applications of radiofrequency energy (middle panel), the transisthmus conduction interval is 120 ms, a chevron pattern is present but the wavefronts collide more inferiorly in the right atrium (RA₄ as opposed to RA₅, in the left panel). Complete bidirectional TV-IVC isthmus block is observed in the right panel. Widely split first (DP₁) and second (DP₂) components of the double potentials (140 ms) are recorded from the ablation catheter. Note that atrial activation occurs sequentially from the proximal electrode pair to the most distal electrode pair which is just lateral to the ablation line. The transisthmus conduction interval is 170 ms. The middle panel demonstrates a transisthmus conduction interval of 120 ms which can be associated with complete bidirectional TV-IVC isthmus conduction block, but is not in this instance. The atrial activation sequence changed gradually. Careful inspection reveals a chevron pattern, indicating some activation across the TV-IVC isthmus, though clearly occurring more slowly than in the left panel and more rapidly than in the right panel. In the right two panels, coronary sinus pacing is performed at a rapid rate. In this instance, the 2:1 atrioventricular conduction block facilitated identification of the double potentials, and allowed easy differentiation of the second component of the split potentials from the ventricular electrogram. If not noted, all units are in ms. All abbreviations are as previously noted.

Termination and Induction of Atrial Flutter

Atrial flutter can terminate during an application of radiofrequency energy. However, termination during an application of radiofrequency energy is rarely associated with complete bidirectional TV-IVC isthmus block, and should not be considered a reliable ablation endpoint (Fig. 7). Unlike with ablation of paroxysmal supraventricular tachycardia, the inability to induce atrial flutter is not a reliable endpoint for ablation. Additionally, incremental atrial pacing may lead to the inadvertent induction of atrial fibrillation.

Atrial Activation Sequence Associated with Bidirectional Block

The right atrial activation sequence during counterclockwise TV-IVC isthmus dependent atrial flutter occur sequentially down the lateral wall of the right atrium and adjacent to the crista terminalis, across the TV-IVC isthmus, past the coronary sinus, up the atrial septum, over the
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Figure 7. TV-IVC isthmus dependent atrial flutter terminates during an application of radiofrequency energy (left panel). Coronary sinus pacing is instituted (right panel). Transisthmus conduction is still present (right panel), and the wavefronts collide in the high lateral right atrial wall. All abbreviations are as previously noted.

The activation sequence is reversed with clockwise atrial flutter, but of course the TV-IVC isthmus is still the critical component of the reentrant circuit. When conduction block is incomplete, pacing from the coronary sinus during sinus rhythm generates an atrial activation sequence with a chevron pattern, i.e., atrial depolarization occurs across the TV-IVC isthmus, and at the same time depolarization proceeds up the atrial septum, and across the roof of the right atrium. The latest site of right atrial activation is along the lateral aspect of the right atrium, and usually arrives there simultaneously from the TV-IVC isthmus and the roof of the right atrium (Figs. 6 and 7). The wavefronts can collide, theoretically at least, anywhere in this area and the exact location depends upon the relative conduction velocities of the right atrium and the TV-IVC isthmus. Prior to ablation and with appropriate relative conduction velocities, the atrial activation sequence can theoretically be consistent with complete bidirectional TV-IVC isthmus block.

Complete bidirectional block is demonstrated by pacing from the coronary sinus and the lateral wall of the right atrium, and observing sequential atrial activation that terminates at the ablation line, on the contralateral side from the pacing site (Figs. 6 and 8).

A variety of subtleties in the atrial activation sequence can make identification of complete bidirectional TV-IVC isthmus block difficult. First, during applications of radiofrequency energy, gradual delay in the atrial activation sequence may be observed prior to achieving complete bidirectional TV-IVC isthmus block (Fig. 6). Second, when there is very slow conduction across the ablation line, activation of both the low lateral right atrium and the TV-IVC isthmus may be delayed, but relative to each other, may occur simultaneously and not sequentially (Fig. 6). Slow conduction across the TV-IVC isthmus may also be consistent with bidirectional TV-IVC isthmus block. Finally, both during and after applications of radiofrequency energy, intermittent or transient complete bidirectional block may also be observed.
**Transisthmus Conduction Interval**

The transisthmus conduction interval is measured while pacing from the coronary sinus, and the lateral wall of the right atrium during sinus rhythm. With pacing from either location the transisthmus conduction interval is measured from the stimulus artefact to the atrial electrogram on the contralateral side of the pacing site and the ablation line. Before ablation and while pacing from the coronary sinus, depolarization proceeds in the clockwise direction across the TV-IVC isthmus. When bidirectional block is obtained, the atrial tissue lateral to the ablation line is activated from the counter-clockwise direction, and the transisthmus conduction interval increases.[Figs. 6 and 8] When pacing from the low lateral wall of the right atrium, the transisthmus conduction interval is measured from the stimulus artefact to the atrial electrogram just medial to the ablation line. An increase of the transisthmus conduction interval of at least 50%, and to an absolute minimum value of 150 ms is associated with a sensitivity, specificity,
positive predictive value, and negative predictive value for identifying complete bidirectional block of 100%, 80%, 89%, and 100% respectively. The primary advantage of this technique is its simplicity, and its major limitations are the relatively low specificity and positive predictive value.

Electrogram Polarity Changes Associated with Complete Bidirectional TV-IVC Isthmus Block

Before complete bidirectional TV-IVC isthmus block is present and coronary sinus pacing is performed during sinus rhythm, atrial depolarization of the TV-IVC isthmus occurs sequentially in the clockwise direction. Hence, the polarity of the initial depolarization is the same from each pair of recording electrodes that are on the TV-IVC isthmus (Figs. 8 and 9). When complete bidirectional block of the TV-IVC isthmus is achieved, depolarization of the electrode pair just medial to the line of block retains its original polarity. However, the atrial tissue lateral to the line of block is depolarized from the counter-clockwise direction. This is opposite to the original direction of depolarization, and accordingly, the polarity of the atrial electrograms on the TV-IVC isthmus that are lateral to the ablation line reverse (Figs. 8 and 9).

Common Pitfalls

The different techniques utilized to identify complete bidirectional TV-IVC isthmus block during ablation for atrial flutter described herein are easy to use, complimentary, and are typically determined from the same tracing (Table I; Figs. 6 and 8). This is helpful when there is transient complete bidirectional TV-IVC isthmus block. With transient complete block, the associated atrial activation sequence, transisthmus conduction interval, and the width of the double potentials associated with complete bidirectional block are known. The use of multiple techniques to assess complete bidirectional TV-IVC isthmus block is also helpful when a technique does not provide a clear answer regarding complete bidirectional block. For instance, if the double potentials are separated by 95 ms, then careful examination of the atrial activation sequence, or the use of other techniques to assess for bidirectional block, are called for. Finally, unusual forms of atrial flutter that utilize the TV-IVC isthmus exist. The approach to ablation of these tachycardias follows the same routine: demonstrate that the tachycardia is dependent on the TV-IVC isthmus, create a linear lesion across the isthmus, and then with the techniques described above, demonstrate that complete bidirectional block is present.

Complications

The overall incidence of serious complications associated with radiofrequency ablation of TV-IVC isthmus dependent atrial flutter has been estimated at 0.4% (Table II). The most common

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<th>Table I.</th>
<th>Sensitivity, Specificity, and Predictive Accuracy for Complete Bidirectional TV-IVC Isthmus Block</th>
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<tr>
<td>Criteria</td>
<td>Sensitivity (%)</td>
</tr>
<tr>
<td>DP$_{1-2}$ ≥ 90 ms</td>
<td>100</td>
</tr>
<tr>
<td>DP$_{1-2}$ ≥ 110 ms</td>
<td>83</td>
</tr>
<tr>
<td>DP$_{1-2}$ ≥ 90 ms + isoelectric interval</td>
<td>83</td>
</tr>
<tr>
<td>DP$_{1-2}$ ≥ 90 ms + negative DP$_2$ interval</td>
<td>77</td>
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DP$_{1-2}$ = interval separating the two components of the double potentials; DP$_2$ = second component of a double potential; PPV = positive predictive value; NPV = negative predictive value. (Modified from J Am Coll Cardiol 2001; 38:750–755, with permission from the American College of Cardiology Foundation.)
of these is complete atrioventricular block that occurs in 0.2% of patients.4

Newer Ablation Technologies and Three-Dimensional Mapping

Radiofrequency energy delivered via 8 and 10 mm ablation electrodes or via irrigated-tip catheters are now used for treating atrial flutter.19,20 The endpoints for ablation of TV-IVC isthmus dependent atrial flutter have been defined during ablation with “standard” 4 mm ablation electrodes. These endpoints probably still apply when ablating atrial flutter with larger electrode catheters, irrigated-tip catheters and with nonradiofrequency energy sources.

The specialized three-dimensional, noncontact, nonfluoroscopic mapping systems with intrinsic navigation systems have been utilized to identify the reentrant flutter circuit and achieve complete bidirectional TV-IVC isthmus block.21–25

The primary advantage of these systems is the navigation tools which provide assistance in creating continuous, linear ablation lesions, and reduce fluoroscopic exposure.

Conclusions

A variety of useful endpoints for ablation of TV-IVC isthmus dependent atrial flutter have been described. These include double potentials separated by 110 ms, the atrial activation sequence with pacing from the coronary sinus during sinus rhythm, transisthmus conduction interval, and electrogram polarity changes. Each of these techniques has limitations. Being familiar with all of these techniques allows the opportunity of using a variety of techniques to confirm when complete bidirectional TV-IVC isthmus conduction block has been achieved. This should be associated with a lower risk of recurrent atrial flutter. Furthermore, it allows the electrophysiologist to objectively determine when to “call for the next patient.”

References