A Novel Criterion for Conduction Block After Catheter Ablation of Right Atrial Tachycardia After Mitral Valve Surgery

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Background—One operative approach to the mitral valve, the superior transseptal incision, is proarrhythmic because of extensive atriotomies. The objective of this study is to describe complex atrial tachycardias (ATs) that occur after this approach and propose methods to verify lines of block as an end point for catheter ablation.

Methods and Results—Of the 69 patients who had electrophysiological studies for AT after mitral valve surgery, 20 patients had prior superior transseptal incisions. Of these, 14 had complex ATs involving the lateral right atrium (RA). There were 9 dual-loop, 4 single-loop, and 1 focal tachycardias. Lateral wall ablation was performed either by creating a linear lesion from the lateral atriotomy to the inferior vena cava, superior vena cava, or tricuspid annulus or by ablating focally in the lateral RA. After a single ablation procedure, conduction block in the lateral wall was verified in 10 of 14 patients using 1 of 2 distinct patterns of block. One pattern consisted of late activation in an anterolateral corridor of the RA, and a second pattern consisted of wide-spaced double potentials. Recurrent conduction through the lateral wall lesions was associated with intraprocedural and late recurrences of ATs.

Conclusions—The optimal end point for ablating ATs after mitral valve surgery with the superior transseptal approach is to establish lines of block that can be recognized by characteristic patterns of activation in the lateral RA. A novel criterion for lateral conduction block after catheter ablation is identification of a late-activated corridor in the anterolateral RA.

Key Words: ablation ■ atrial tachyarrhythmias ■ catheter ablation ■ mitral valve

The purpose of this study is to describe complex patterns of RA activation that occur in patients with ATs after the STS approach to mitral valve surgery and to describe methods to verify lines of block as an end point for ablating these arrhythmias.
Mapping and Ablation
All antiarrhythmic drugs were discontinued a minimum of 5 half-lives before the procedures, except for 9 procedures that were performed within 3 months of taking amiodarone and 1 procedure that was performed while a patient was on flecainide. The location and number of diagnostic catheters were at the operators’ discretion, but generally included a 7F decapolar catheter in the coronary sinus, a 6F quadripolar His bundle catheter, and a duodecapolar catheter arrayed counterclockwise in the RA to record from the lateral wall. The mapping catheters were 3.5- or 4-mm tip quadripolar ablation catheters (ThermoCool NAV, Biosense Webster, Diamond Bar, CA; Safire Blu, St. Jude Medical, St. Paul, MN).

Electroanatomic maps of the spontaneous clinical or induced AT were obtained. The critical limbs of the tachycardia circuit were delineated by activation and entrainment mapping. Entrainment was performed by pacing 20 to 50 ms less than the tachycardia cycle length. Sites with concealed entrainment and a postspacing interval within 30 ms of the AT cycle length were considered to lie within the tachycardia circuit. Left atrial endocardial mapping was performed when activation and entrainment mapping were inconsistent with an RA origin or supported an origin in the left atrium. Three-dimensional geometry and activation mapping of the atria were constructed with either CARTO (Biosense Webster) or EnSite NavX (St. Jude Medical) electroanatomic mapping system. A coronary sinus electrogram with a stable cycle length and 1:1 activation with the mapped chamber was chosen as a reference for local activation. Activation times were assigned based on the onset of bipolar electrograms, which were obtained with filter setting of 30 and 400 Hz. Macroreentry was defined as activation that could be recorded during the entire cycle length and fulfilled entrainment criteria from several segments. A focal tachycardia was defined as atrial activity originating from a single focus and spreading centrifugally.

Ablation Strategy
In cases of macroreentry, the basic strategy was to interrupt a critical isthmus needed to sustain the tachycardia. Linear lesions were created with sequential ablations to connect anatomic barriers that defined this critical isthmus. Focal tachycardias were targeted at sites of earliest activation. Power was adjusted between 10 and 50 W, and ablation was continued for 30 to 60 s at each site unless a rise in impedance occurred. Ablation was acutely successful if the tachycardia terminated during ablation and was not inducible with programmed stimulation.

Data Collection and Review
Operative reports were obtained for patients who met inclusion criteria and were reviewed by 2 authors (A.N.K. and S.M.M.). Surgeries were classified according to the surgical approach: (1) left atriotomy, (2) dissection in the interatrial groove, (3) transseptal approach, or (4) the STS approach. Patients who underwent the STS approach are the focus of this study. Concomitant maze surgery was also noted, and these patients were not included in the main analysis because the goal of this study was to describe arrhythmias related to the atriotomy lines as opposed to gaps in the maze lesion sets.

Follow-up
Patients were followed and monitoring was performed at the discretion of the treating physician. For the purposes of this study, patients were contacted by telephone if the medical record did not contain results of a follow-up encounter, which included ECGs, Holter monitors, outpatient telemetry, or device interrogation reports.

Statistical Analysis
Continuous variables are expressed as median and interquartile ranges (25%–75%). Differences between groups were analyzed with the Mann-Whitney test for continuous variables and Fisher exact test or \( \chi^2 \) test for categorical variables (Medcalc 12.2.1.0, www.medcalc.org). All reported \( P \) values were based on 2-sided tests and were compared with a significance level of 0.05.

Results
Patient Population
A total of 69 patients (aged 73 [61–79] years, 49 men) with prior mitral valve surgery who collectively had 86 electrophysiology studies between January 2006 and January 2012 were included in this study. Operative reports were available for review in 63 (91%) patients. Ten patients had reoperations, and the reports for the first operation were available for 3 of these patients, yielding 66 operative reports that were reviewed. The operative approach was a left atriotomy or dissection in the interatrial groove in 56 patients (55%), transseptal approach in 3 patients (5%), the STS approach in 26 patients (39%), and an aortotomy in 1 patient. There were no significant differences between patients who had the STS and other approaches in terms of age at surgery, sex, reoperation, concomitant surgery, or time from surgery to ablation (online-only Data Supplement Table SI).

Twenty patients underwent the STS approach without concomitant maze procedure. Of this group, 4 patients (20%) had multiple ATs or unmappable tachycardias during the electrophysiological studies, which precluded definitive mapping. Among the remaining 16 patients who had the STS approach without maze, 2 (12%) had only cavotricuspid isthmus (CTI)–dependent atrial flutter and 14 (88%) had other complex but mappable ATs.

For comparison, 25 patients had left atriotomies (either posterior left atriotomies or dissection in the interatrial groove) without concomitant maze, and 11 (44%) presented with CTI-dependent flutter alone, 6 (24%) with other complex ATs, and 8 (32%) with multiple unmappable ATs or atrial fibrillation \((P=0.006 \) for comparison with STS approach). Baseline demographics of the 14 patients with STS surgery and mappable complex ATs are presented in Table 1.

Tachycardia Properties During Initial Procedures
In all 14 patients, mapping during sinus rhythm and AT revealed areas of scar in the lateral RA wall, corresponding to the previous surgical incision. Twenty ATs were induced during the first electrophysiology study in these patients, of which 15 tachycardias were fully mapped. In 8 patients, a characteristic pattern of activation was recorded with a multipolar catheter in the lateral wall during AT, consisting of progressively narrowing double potentials bridged by an area of fractionation (Figure 1). This was interpreted as descending and ascending wave fronts in the lateral wall separated by a line of block because of the atriotomy scar, with an area of fractionation forming a pivot point between these wave fronts. Concealed entrainment with short postspacing intervals could be demonstrated from various locations in the lateral wall in 10 patients, confirming participation of the lateral wall in the AT circuit. In 7 of these cases, entrainment pacing was performed in both anterior and posterior locations in the lateral wall or from the bridging area of fractionation, and each of these fulfilled criteria for participation in the tachycardia circuit (Figure 2).
Critical limbs of the tachycardias, which were identified by entrainment and electroanatomic mapping, revealed 9 dual-loop tachycardias, each of which included the lateral wall and CTI as critical limbs (Table 2). There were 4 single-loop tachycardias involving the lateral wall and 1 focal tachycardia in the lateral tricuspid annulus. In 1 patient, there were 2 tachycardias that rotated in opposite directions but used the same limbs around the atriotomy scar. Adenosine was administered during 13 tachycardias. All were adenosine-insensitive, except for the focal tachycardia in patient 11 that was adenosine-sensitive.

### Approaches to Ablation

In cases of dual-loop tachycardia, ablation was initially performed in the CTI in most patients (n=8), because the initial activation patterns and entrainment revealed participation of the CTI. In cases of dual-loop tachycardias, ablation in the CTI led to change in activation pattern (n=7), with slowing of the tachycardia cycle length by 13 to 69 ms (median, 25 ms).

Lateral wall ablation was performed either by creating a linear lesion from the lateral atriotomy to the inferior vena cava (IVC), superior vena cava, or tricuspid annulus or by ablating focally in the lateral RA. Ablation in the lateral wall...
terminated ATs in all patients, with the exception of 1 patient in whom ablation was performed during pacing (Table 2).

**Verification of Line of Block: Pattern 1**

Conduction block in the lateral wall was verified in 10 of 14 patients during their first ablation procedure. In 4 patients, conduction block was verified by a marked delay of activation in the anterolateral segment of the RA (pattern 1). This pattern is demonstrated and interpreted from a representative patient shown in Figures 3 and 4. After ablation was performed in the CTI, there was a change in lateral wall activation, but the tachycardia persisted. Ablation was then performed in the lateral wall between the lateral atriotomy and the IVC, during which the AT terminated and sinus rhythm resulted. Figure 3A demonstrates 2 wave fronts in the lateral wall during sinus rhythm initially after termination of the AT, with a posterior descending wave front and an anterior wave front. The anterior wave front was fused in the mid-lateral wall, consistent with conduction through the CTI. After further ablation in the CTI, activation of the anterior wave front changed to reflect conduction through a gap in the lateral wall (Figure 3B). Further ablation from the lateral wall to the IVC resulted in a block along the lateral wall in addition to the CTI. Coincident with this development, the anterior wave front activated in a descending direction and was markedly delayed (Figure 4). When both lines of block were achieved, the low anterolateral RA was activated late after the coronary sinus. Time from P-wave onset to low anterolateral wall ranged from 183 to 262 ms (median, 198 ms), and the conduction time from proximal coronary sinus to low anterolateral wall ranged from 88 to 202 ms (median, 115 ms). Sinus activation thus proceeded sequentially from the posterior RA, over the roof activating the posterior septum in a descending manner, under septal incision and activated the tricuspid annulus in a counterclockwise manner (Figure 4B). The 2 ablation lines essentially compartmentalized the anterolateral RA to produce a dead-end corridor. In the case shown in Figures 3 and 4, AT remained inducible with a slower cycle length when the lateral wall demonstrated the breakthrough pattern seen in Figure 3B. AT became noninducible when the lateral wall showed complete block across both lines, as indicated in Figure 4. This pattern of a descending and delayed anterior wave front occurred in patients who had separate ablation lines created in the CTI and the lateral wall, either as linear lesions to the IVC or focally in the lateral wall. In one other case (patient 8), the pattern of activation at the end of the first procedure reflected a line of block in the lateral wall but not the CTI.
Verification of Line of Block: Pattern 2

In 5 patients, conduction block along the line was verified by widely spaced double potentials (2 components with a clear iso-

electric interval; Figure 5) recorded along the ablation line either during normal sinus rhythm or with pacing close to the line (pat-

tern 2). The median interval between double potentials was 138

ms (range, 94–222 ms). This pattern was present in patients who had ablation from the incision to tricuspid annulus, from the inci-
sion to superior vena cava, and focal ablation in the lateral wall.

Incomplete Verification of Line of Block

In 3 patients, line of block across the lateral ablation line could not be verified at the end of the first procedure, and in 1 of 8

patients who had ablation in the CTI, conduction block could not be verified in this line. In one other patient, verification of either line of block was not performed because of the fact that there was ablation of a focal tachycardia. In all cases, AT was not inducible at the end of the initial procedure.

Subsequent Procedures

There were recurrent arrhythmias in 7 of the 14 patients, leading to repeat electrophysiology studies with a median interval of 14 months (range, 1.3–49 months). Of the 3 patients who did not have line of block verified in the lateral wall after the first procedure, 2 presented for another procedure; the 1 patient without block in the CTI also presented for reablation.

Table 2. Procedural and Ablation Characteristics

<table>
<thead>
<tr>
<th>Patient</th>
<th>Pivot Point</th>
<th>Single/Dual</th>
<th>Response to ADO</th>
<th>Lateral Ablation</th>
<th>CTI</th>
<th>Other</th>
<th>Critical Limbs</th>
<th>Lesion→Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Y</td>
<td>Dual</td>
<td>Insensitive</td>
<td>✓</td>
<td>✓</td>
<td>...</td>
<td></td>
<td>CTI→Change in activation pattern</td>
</tr>
<tr>
<td>2 (procedure 1)</td>
<td>Y</td>
<td>Dual</td>
<td>Insensitive</td>
<td>✓</td>
<td>✓</td>
<td>...</td>
<td></td>
<td>Incision to IVC→Termination</td>
</tr>
<tr>
<td>2 (procedure 2)</td>
<td>Y</td>
<td>Dual</td>
<td>Insensitive</td>
<td>✓</td>
<td>✓</td>
<td>...</td>
<td></td>
<td>Incision to IVC→Change in activation pattern</td>
</tr>
<tr>
<td>3</td>
<td>N</td>
<td>Dual</td>
<td>Insensitive</td>
<td>✓</td>
<td>✓</td>
<td>SVC</td>
<td></td>
<td>Incision to TA→Termination</td>
</tr>
<tr>
<td>4 (procedure 1)</td>
<td>Y</td>
<td>Dual</td>
<td>Insensitive</td>
<td>✓</td>
<td>✓</td>
<td>...</td>
<td></td>
<td>Incision to TA→Change in activation pattern and slowing</td>
</tr>
<tr>
<td>4 (procedure 2)</td>
<td>Y</td>
<td>Single</td>
<td>Insensitive</td>
<td>✓</td>
<td>✓</td>
<td>...</td>
<td></td>
<td>Incision to TA→Termination</td>
</tr>
<tr>
<td>5 (procedure 1)</td>
<td>Y</td>
<td>Single</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>...</td>
<td></td>
<td>Focal Lateral Wall→Slowing and termination</td>
</tr>
</tbody>
</table>
| 5 (procedure 2) | Y       | Single      |                | ✓                | ✓   | ...   |               | Incision to IVC→*
| 6       | Y           | Dual        | Insensitive    | ✓                | ✓   | ...   |               | Incision to IVC→Dissociated rhythm |
| 7 (procedure 1) | N       | Dual        |                | ✓                | ✓   | ...   |               | Incision to TA→Termination |
| 7 (procedure 2) | Y       | Single      |                | ✓                | ✓   | ...   |               | Incision to IVC/SVC→Termination |
| 8 (procedure 1) | N       | Dual        | Insensitive    | ✓                | ✓   | ...   |               | Incision to IVC→*
| 8 (procedure 2) | †       | †           |                | ✓                | ✓   | ...   |               | CTI→* |
| 9       | N           | Single      | Insensitive    | ✓                | ✓   | ...   |               | Focal Lateral Wall→Termination |
| 10      | Y           | Single      | Insensitive    | ✓                | ✓   | SVC   |               | Incision to SVC→Termination |
| 11      | N           | Focal       | Sensitive      | ✓                | ✓   | ...   | Low lat RA    | Focal Ablation in Lateral TA→Termination |
| 12 (procedure 1) | N       | Dual        | Insensitive    | ✓                | ✓   | ...   |               | Focal Ablation in Lateral TA→Termination |
| 12 (procedure 2) | ‡       | ‡           |                | ✓                | ✓   | ...   | Multiple ATs/AF | Incision to SVC→* |
| 13      | Y           | Dual        | Insensitive    | ✓                | ✓   | ...   |               | Incision to TA→Termination |
| 14 (procedure 1) | N       | Dual        | Insensitive    | ✓                | ✓   | ...   |               | Incision to TA→Termination |
| 14 (procedure 2) | N       | Single      |                | ✓                | ✓   | ...   |               | CTI→Termination |

ADO indicates adenosine; AF, atrial fibrillation; AT, atrial tachycardias; CTI, cavotricuspid isthmus; IVC, inferior vena cava; Proc, procedure; RA, right atrium; SVC, superior vena cava; and TA, tricuspid annulus.

*Ablation performed during normal sinus rhythm.
†Noninducible for sustained AT.
‡Multiple unmappable ATs and AF.
of CTI-dependent flutter. Of the 10 patients who did have line
of block verified in the lateral wall in the first procedure, 4
presented for a second ablation.

Recovery of Conduction and Ablation in Repeat
Procedures
Conduction recurred in the lateral wall alone (1 patient), the
CTI alone (2 patients), or both the lateral wall and CTI (2
patients). In the example of patient 2 (Figure 6), there was
recovery of conduction in both the lateral wall and CTI, as
evident by the decrease in the conduction delay from the
coronary sinus to lateral wall from 115 to 25 ms. Consistent
with this, tachycardias with critical limbs in both the lateral
wall and CTI were inducible until lines of block were
re-established in both regions. In 1 patient, lines of block were
still present in both the lateral wall and CTI during the repeat
procedure. Consistent with this, the recurrent clinical AT
involved re-entry in the posterior wall but not the anterior
wall or the CTI. The status of the original ablation lines could
not be evaluated in 1 patient as a result of multiple unmappable
tachycardias and atrial fibrillation in the subsequent procedure.

Conduction block, in either pattern 1 or pattern 2, was
confirmed in 11 of 13 patients with well-defined macroren-
trant tachycardias after the last procedure. During a median

Figure 3. Conduction block in the lateral wall after
ablation in the cavotricuspid isthmus (CTI) and
lateral wall (patient 1). A, Lateral wall activation in
sinus rhythm after termination of atrial tachycardias
with ablation in the lateral wall between the atriotomy
and the inferior vena cava (IVC). The anterior
wave front is fused in the lateral wall, which reflects
activation through the CTI. After ablation in the CTI
(B), activation of the lateral wall changes, with earli-
est activity in mid-lateral wall, reflecting propaga-
tion from the posterior to the anterior right atrium
(RA) through a gap in the lateral wall. Note that
block must have existed in the lateral wall in A, but
conduction recovered subsequently in B, C and D.
Schematic interpretations of the wave front propa-
gation in A and B. Electrograms as described in
previous figures. LA indicates left atrium; RV, right
ventricle; and SVC superior vena cava.

Figure 4. Conduction block in both the lateral wall and cavotricuspid isthmus. In the same patient in Figure 3, further ablation in the
lateral wall between the atriotomy and the inferior vena cava (IVC) results in a descending and marked delayed anterior wave front, and
the lateral wall is activated after the proximal coronary sinus. Red dotted lines indicate activation time of the proximal CS. B, Schematic
interpretation of wave front propagation in sinus rhythm after conduction block has been achieved in both lines. It shows a wave front
originating from the sinus node in the posterior right atrium (RA) but does not traverse scar to the anterolateral RA (1). The wave front
activates the posterior septum in a descending direction (2), then ascends the anterior septum (3), finally activating the anterolateral RA in
a descending direction (4). Electrograms as described in previous figures. IAS indicates interatrial septum; IVC, inferior vena cava; LA, left
atrium; PA, pulmonary artery; RF, radiofrequency; and SVC, superior vena cava.
follow-up of 37 months (interquartile range, 18–46 months), atrial tachyarrhythmias recurred in 4 patients (recurrence rate 29%). One patient who originally had focal AT (patient 11) developed recurrent AT. Other recurrences in patients with macroreentrant AT were paroxysmal atrial fibrillation, paroxysmal AT, and chronic AT, each in 1 patient.

Discussion

This study shows that one particular operative approach to the mitral valve, the STS incision, results in complex patterns of RA activation as a result of the extensive atriotomies that involve the lateral RA, superior RA, and interatrial septum. These patients are therefore predisposed to re-entry involving the lateral wall atriotomy, which occurred more commonly in this series than CTI-dependent atrial flutter alone. These arrhythmias often took the form of dual-loop tachycardias involving the CTI and lateral atriotomy. A characteristic finding during ATs was a pattern of ascending and descending wave fronts that could be recorded from multipolar catheters that spanned the atriotomy in the lateral wall. With high-density mapping, an area of fractionation could be identified between these wave fronts, which represented a pivot point in the lateral wall, often between the atriotomy and the IVC. Identification of the second lateral wall circuit is crucial for successful ablation of these ATs, in that P-wave morphology and intracardiac activation of the anterior RA may suggest typical CTI-dependent flutter. Rapid scanning of the lateral wall with a multipolar catheter will identify a second wave front opposite to peri-tricuspid activation, and entrainment can indicate whether tissue posterior to the atriotomy participates as a second loop. Perpetuation of the tachycardia during CTI ablation, often with cycle length prolongation, should prompt investigation for the second lateral wall circuit. This situation is analogous to ATs that occur after other right atriotomies, as with atrial septal defect repair or myxoma resections. But in the STS approach, the atriotomies are more extensive and the additional ablation lines further compartmentalize the RA to a greater degree.

The STS approach is favored in some instances, particularly for reoperations in which the anatomic landmarks can be obscured by fibrosis and dissection of the posteriorly located left atrium is difficult. The STS atriotomies provide direct visualization of the mitral valve. But this approach may be proarrhythmic in several ways, including creating a posterior line of block in a circuit of typical flutter, providing a central obstacle during incisional AT, creating an area of slow conduction between the atriotomy and other structures (tricuspid annulus, IVC), and allowing for areas of conduction through incisions with significant slowing. Seiler et al found that the majority of re-entrant tachycardias after mitral valve surgery are right-sided and the circuit is most often typical CTI-dependent flutter. In contrast, we found that patients with AT or atrial flutter after the STS approach have more complex circuits. The vast majority of ATs in this series proved to be macroreentrant, although focal tachycardias may also occur after mitral valve surgery. These foci typically arise adjacent to areas of scar, as was seen in 1 patient in this series.

Ablation Approaches to Lateral Wall Re-entry and Verifying Lines of Block

Different ablation lines can be designed to interrupt the re-entrant arrhythmias that occur after this type of surgery. In our series, ablation was initially performed in the CTI in many patients because the presenting rhythm demonstrated characteristics of peri-tricuspid re-entry. This approach requires a second ablation line, which can be created between the lateral atriotomy and the IVC. If complete, these 2 ablation lines effectively segment the RA and result in a distinctive pattern of activation in the lateral wall (pattern 1). In sinus rhythm, the pattern
mitral isthmus.9–11 However, we observed 1 patient with this approach who later presented with isthmus-dependent flutter and was treated with ablation in the CTI (patient 14). This could be explained by breakdown in the lateral ablation line or a circuit involving tissue posterior to the atriotomy. In fact, variations of typical flutter have been described in which required components of the circuit exist in the posterior RA.12–14

Regardless of the ablation approach, verifying line of block across the ablation lesions is a critical end point for the procedure. This is supported by our finding that patients who achieved noninducibility but without strict verification of line of block developed recurrent arrhythmias that required reablation (in 3 of 4 patients without verification of block in the lateral wall or CTI). Even when ablation established a line of block, some patients developed recurrent arrhythmias and were found to have resumption of conduction across these lines. Transient conduction block in the lateral wall could be detected during some procedures, and intraprocedural resumption of conduction was associated with inducibility. When repeat ablation established lines of block, as verified through the techniques described here, patients had favorable long-term outcomes. These results are consistent with observations from other macroreentrant circuits, such as CTI-dependent atrial flutter, which show that a verified line of block is superior to noninducibility as an end point for ablation.15 Other studies have shown that recurrences are common in patients who undergo ablation of AT related to lateral atriotomies.4,16 This is probably related to the technical difficulty of achieving a durable line of block in the lateral wall, as evidenced by intraprocedural and late recovery of conduction across these lines.

Figure 6. Recurrent conduction in the lateral wall line of block (patient 2). A, Line of block in the lateral wall and cavotricuspid isthmus (CTI; pattern 1) is present after the first procedure. B, Recurrent conduction through the lateral line of block is seen during the second procedure after the clinical tachycardia recurs. C, Tachycardia is induced with programmed stimulation. D, Line of block in the lateral wall and CTI is restored with lateral wall ablation, and no further atrial tachycardias are inducible. In D, most electrograms on the multipolar right atrium (RA) catheter record from posterior to the line of block, but the mapping catheter is anterior to the line in the low lateral RA, and activation is markedly delayed. ABL indicates ablation catheter.

shows markedly delayed activation of the anterolateral RA. Wave front propagation is consistent with activation from the posterior RA (location of the sinus node) to the low interatrial septum, then counterclockwise around the tricuspid annulus. Thus, activation of the proximal coronary sinus precedes the lateral RA, and there is a descending wave front in the anterolateral wall. Stepwise ablation of the CTI and the lateral wall results in variations of this pattern, as shown in Figures 3 and 4.

An alternative ablation approach for dual- or single-loop re-entry involving the lateral wall is to create a single line from the lateral atriotomy to the tricuspid annulus. This is not conclusive whether this approach yields superior outcomes compared with other ablation lesions. This approach avoids segmentation of the RA into a late-activated anterolateral corridor. In addition, only 1 of 5 patients who had this approach developed a recurrence of lateral wall re-entry. Line of block can be verified by demonstrating widely spaced double potentials, especially when pacing near the line. This criterion has been described for other ablation lines, such as the CTI, left atrial roof, or lateral mitral isthmus.8–11 However, we observed 1 patient with this pattern of block who later presented with isthmus-dependent flutter and was treated with ablation in the CTI (patient 14).

Limitations
This study was a retrospective review of patients with the STS approach to mitral valve surgery, and not all patients in this series were prospectively evaluated for the patterns of block described here. Thus, in some patients the lines of block might not have been detected, even if they were established. Nevertheless, if a line of block was not identified even with this retrospective review, we found that ATs were likely to recur.

The upper limb of these re-entrant circuits was not defined in many cases. It is not known whether the septum is also involved in addition to the lateral wall. However, it is not necessary to define the complete circuit of these arrhythmias, and ablation is effective if critical limbs can be identified in the lateral wall and line of block can be confirmed.

The main results of this study are based on findings in 14 patients, who were identified from a larger population of 69 patients who had mitral valve surgery and ATs. This selection reflects the fact that most patients had left atriotomies and others were excluded because of unmappable tachycardias or maze surgery. Thus, other complex arrhythmias can be expected in patients who have different lesion sets, and other techniques must be considered to verify lines of block in these variable situations.

Conclusions
Surgical exposure to the mitral valve through the STS approach creates a substrate for macroreentry in the lateral RA wall, in the form of single- or dual-loop tachycardias. The optimal end point for ablating these arrhythmias is to establish lines of block that can be recognized by characteristic patterns.
of activation in the lateral RA. The combination of ablation lines in the CTI and inferolateral RA effectively segments the anterolateral RA. Other lines can be verified by widely spaced double potentials. It is likely that similar but modified criteria will be useful in verifying lines of block for arrhythmias that occur after other surgeries that involve right atriotoomies.

Disclosures

Dr Liu reports a research grant from Biosense Webster (≥$100 000) and has had honoraria from St Jude Medical (<$10 000). Dr Cheung has participated in the speaker’s bureau for Medronic (<$10 000) and has received honoraria from St Jude Medical (<$10 000). Dr Markowitz has participated in the speaker’s bureau for Sanofi-Aventis ($>10 000) and has received honoraria from St Jude Medical (<$10 000) and Medtronic (<$10 000). The other authors have no conflicts to report.

References


CLINICAL PERSPECTIVE

Patients with prior mitral valve surgery are predisposed to re-entrant atrial tachycardias, with the superior transseptal approach to the mitral valve being particularly arrhythmogenic. In a cohort of 69 patients with atrial tachycardias and prior mitral valve surgery, we found that superior transseptal patients (n=25) were more likely to have tachycardias involving the lateral right atrium, often in the form of dual-loop re-entry, whereas patients with left atriotoomies (n=38) were more likely to have cavotricuspid isthmus–dependent atrial flutter alone. Ablation of lateral wall re-entry in superior transseptal patients could be accomplished through 2 strategies: (1) a dual lesion set involving ablation in the cavotricuspid isthmus and from the lateral scar to inferior or superior vena cava; or (2) from the lateral scar to the tricuspid annulus. In strategy 1, conduction block could be identified by a characteristic pattern of markedly delayed descending activation of the anterolateral right atrium during sinus rhythm. In strategy 2, conduction block could be verified by widely spaced double electrograms along the ablation line. Recovery of conduction across these lines was associated with recurrent atrial tachycardias, whereas re-establishment of these conduction patterns prevented reinduction and recurrences. We propose that these criteria for conduction block be used as end points for ablation of atrial tachycardias that complicate superior transseptal surgery for the mitral valve.
A Novel Criterion for Conduction Block After Catheter Ablation of Right Atrial Tachycardia After Mitral Valve Surgery

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**SUPPLEMENTAL MATERIAL**

<table>
<thead>
<tr>
<th></th>
<th>Superior transseptal (STS)</th>
<th>Non-STS</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N *</td>
<td>25</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Age at surgery, median [IQR]</td>
<td>65 [48,69]</td>
<td>66 [54,73]</td>
<td>0.62</td>
</tr>
<tr>
<td>Gender (female)</td>
<td>8 (31%)</td>
<td>9 (24%)</td>
<td>0.58</td>
</tr>
<tr>
<td>Re-operation</td>
<td>4 (15%)</td>
<td>5 (13%)</td>
<td>1.0</td>
</tr>
<tr>
<td>Concomitant surgery †</td>
<td>15 (58%)</td>
<td>19 (51%)</td>
<td>0.80</td>
</tr>
<tr>
<td>Time from surgery to ablation (mo), median [IQR]</td>
<td>30 [8,91]</td>
<td>53 [5,128]</td>
<td>0.55</td>
</tr>
</tbody>
</table>

* The operative approaches could not be determined in 6 patients. 1 patient had STS followed by re-operative non-STS surgery and is counted in the non-STS category for this comparison.

† Coronary bypass surgery, other valve surgery, maze, atrial septal defect closure