Typical isthmus-dependent atrial flutter (AFL) recurrences after ablative therapy are attributable to restoration of conduction across the cavotricuspid isthmus (CTI). Documentation of complete transisthmus conduction block has been proven to be superior to cardioversion in terms of arrhythmia recurrence, and has become the gold-standard end point during AFL ablation. However, definite proof of complete conduction block is not always evident. Distinction from incomplete block with slow conduction across the CTI is essential to achieve a favorable arrhythmia control outcome after ablation. Local electrogram (EGM)-based criteria rely on the observation of a complete corridor of parallel double potentials (DPs) along the isthmus ablation line. An inter-DP interval ≥110 ms with little variation along the ablation line has been associated with conduction block. Assessments of the distance between both components of the DP in response to differential pacing from the distal and the proximal low lateral right atrium may distinguish slow conduction from complete CTI conduction block. The lack of increase in the His-to-Coronary sinus ostium atrial interval during incremental pacing (IP) from the low lateral right atrium may distinguish slow conduction from complete CTI conduction block.

Methods and Results—Sixty-six consecutive patients (age, 65±13 years; 18% female) were prospectively included. A <10 ms increase in the His-to-Coronary sinus ostium atrial timing during low lateral right atrium IP at cycle length of 600 ms through 300 ms was compared with the previously reported IP maneuver for the confirmation of complete CTI block. On the basis of the IP maneuver, complete CTI block (phase 2) was achieved in 59 patients, in 13 of whom an intermediate phase of functional CTI block (phase 1) was observed. In the remaining 7 patients, the IP maneuver did not allow for assessment of complete CTI block because of the presence of inconclusive potentials in the CTI ablation line. As compared with the IP maneuver, the incremental His-to-Coronary sinus ostium maneuver was consistent with functional CTI block during phase 1 in all cases and conclusive of complete CTI block in 98% of cases during phase 2.

Conclusions—The incremental His-to-Coronary sinus ostium maneuver is analogous to the IP maneuver in distinguishing complete CTI block from persistent CTI conduction. This maneuver may provide confirmation of CTI block in those patients in whom assessment of local electrogram–based criteria is not feasible because of inconclusive potentials in the CTI ablation line. (Circ Arrhythm Electrophysiol. 2013;6:784-789.)

Key Words: ablation • cavotricuspid isthmus • complete block • incremental His-to-coronary sinus maneuver • incremental pacing • typical flutter

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feasible, because multiple and fragmented potentials are commonly observed in relation to a broad or nonlinear ablation. We therefore developed a novel simple maneuver analogous to the IP maneuver based on examination of the atrial EGMs at the His and CSO regions, thus avoiding the need for evaluation of local EGMs throughout the CTI ablation line. We hypothesized that no or mild increase in the His-to-CSO timing of atrial EGMs during incremental atrial pacing from the LLRA would serve as a surrogate of the previously established IP maneuver for the diagnosis of complete CTI block after AFL ablation.

Methods

Patient Population

Sixty-six consecutive patients undergoing CTI radiofrequency catheter ablation for typical isthmus-dependent AFL were prospectively included. The ablation procedure was performed after informed consent was obtained. All oral antiarrhythmic drugs were discontinued 5 half-lives before the procedure, except for amiodarone, which was interrupted 48 hours before ablation.

Electrophysiological Study and CTI Ablation

CTI ablation was performed in the fasting state under local anesthesia and conscious sedation. A diagnostic steerable 6F catheter was placed via the right femoral vein in the lateral right atrium; this included a steerable quadripleolar catheter in 34 patients and a steerable 20-pole catheter in 32 patients. A diagnostic steerable quadripleolar catheter was introduced through the right femoral vein into the CSO in all patients. Bipolar EGMs were filtered through a band pass of 30 to 500 Hz and were recorded on a multichannel polygraph (C.R. Bard Inc, NJ) at a speed of 100 mm/s and at a gain of 0.1 mV/cm. A 7F irrigated-tip catheter was used for CTI mapping and ablation.

Radiofrequency ablation was performed during atrial pacing from the CSO or during AFL. The ablation line was drawn from the tricuspid annulus edge, with local large ventricular and small atrial EGMs, to the inferior vena cava edge. Radiofrequency energy was delivered with a power limit of 35 to 40 W.

Identification of CTI Conduction Block

The CTI ablation line was identified as a continuous corridor of DPs separated by an isoelectric line during pacing from the CSO.

Table 1. Assessed Criteria for CTI Block

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Cutoff Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descending sequential activation along the lateral wall and the CTI when pacing from the CSO</td>
<td>&gt;110 ms</td>
</tr>
<tr>
<td>Descending sequential activation along the septal wall and the CTI when pacing from the LLRA</td>
<td>&gt;70 ms</td>
</tr>
<tr>
<td>Peak-to-peak time between the 2 CTI potentials</td>
<td>&gt;110 ms</td>
</tr>
<tr>
<td>Isoelectric line time between the 2 CTI potentials</td>
<td>&gt;70 ms</td>
</tr>
<tr>
<td>His-to-CSO timing of &gt;40 ms during pacing at a cycle length of 600 ms from the LLRA</td>
<td>&gt;110 ms</td>
</tr>
</tbody>
</table>

Incremental His-to-CSO Maneuver

Before AFL ablation, the atrial EGM registered in the CSO region during pacing from the LLRA, anterior to the Crista Terminalis and in the vicinity of the isthmus line, results from counterclockwise conduction of the stimulus across the CTI through the right posteroseptal region. In contrast, the atrial signal registered in the His-bundle region is secondary to conduction of the stimulus through the anterior and anteroseptal aspect of the tricuspid annulus. After CTI ablation, counterclockwise conduction is interrupted at the CTI level during pacing from the LLRA, and activation would be expected to travel sequentially from His to CSO, with a His-to-CSO EGM interval that has been reported of >40 ms.6 We hypothesized that, in the presence of slow conduction and functional CTI block after ablation, the His-to-CSO interval would significantly increase (≥10 ms) in response to IP from the LLRA. Conversely, during complete CTI conduction block, the His-to-CSO interval should not significantly vary (<10 ms) during incremental LLRA pacing (Figures 1 and 2). Incremental LLRA pacing was started at a CL of 600 ms, followed by pacing at 500, 400, and 300 ms for ≥5 pulses for each CL. We chose the cutoff value of 10 ms based on data on His-to-CSO atrial conduction time that we obtained in a separated cohort of age- and sex-matched patients without structural heart disease and normal atrioventricular conduction pattern undergoing electrophysiological study for another purpose. In this population, we evaluated the His-to-CSO interval during incremental atrial pacing from the His-bundle area, observing an average increment of His-to-CSO conduction time of 3±3 ms. Measurements were taken by 2 blinded investigators, with no differences between them (data not shown).

Statistical Analysis

Categorical variables were compared using Fisher exact test in the event of an n≤5 for ≥2 values (all analyses). Continuous variables (expressed as mean±SD) were compared using a paired Student tTest. A P value ≤0.05 was considered statistically significant. Sensitivity and specificity were determined for each maneuver taking the IP maneuver as the reference maneuver. All analyses were performed using Numbers '09 software, version 2.3 (Apple Inc, Cupertino, CA).

Results

Study Population

Patient population characteristics are summarized in Table 2. Most patients were male and had no structural heart disease. Only 18 out of the 66 patients were in sinus rhythm at the time of the procedure. Before ablation, the His-to-CSO timing did not change significantly during IP...
from the LLRA in patients in sinus rhythm (from 18±13 ms at pacing CL of 600 ms to 20±14 ms at 300 ms; P=0.65). This increase in the His-to-CSO interval was <10 ms in all cases, supporting the validity of the predefined cutoff value for this increase. The proximal delay during IP (between the pacing stimulus and the His region) was measured as a marker of absence of significant intra-atrial conduction disturbances in our population, with an average increment of 2±1 ms (data not shown).

**Incremental His-to-CSO Maneuver During Phase 1 CTI Block**

During CTI ablation, an intermediate phase of functional CTI block (phase 1) confirmed by IP was observed in 13 out of the 66 patients, despite other established maneuvers, suggesting CTI block (Table 3). In all these cases, the His-to-CSO interval during pacing from the LLRA at a CL of 600 ms was >40 ms (49±18 ms). However, during IP a >10 ms increase in the His-to-CSO interval was registered in all 13
Table 2. Main Population Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Overall Population (N=66)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>65±13</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>54 (82)</td>
</tr>
<tr>
<td>Female</td>
<td>12 (18)</td>
</tr>
<tr>
<td>Type of flutter n (%)</td>
<td></td>
</tr>
<tr>
<td>Paroxysmal</td>
<td>25 (38)</td>
</tr>
<tr>
<td>Persistent</td>
<td>41 (62)</td>
</tr>
<tr>
<td>Structural heart disease, n (%)</td>
<td>20 (30)</td>
</tr>
<tr>
<td>Left ventricle ejection fraction &lt;55%, %</td>
<td>20</td>
</tr>
<tr>
<td>Left atrium diameter &gt;40 mm, %</td>
<td>53</td>
</tr>
</tbody>
</table>

patients, suggesting persistent CTI conduction, with a statistically significant average value of 26±21 ms (P=0.020).

Incremental His-to-CSO Maneuver During Phase 2 CTI Block

At the end of the procedure, complete CTI block according to the IP maneuver could be confirmed in 59 out of the 66 patients. In the remaining 7 patients (11%), the ablation line could not be appropriately assessed because of the presence of inconclusive, multiple, or fractionated potentials. These patients were withdrawn from the final analysis and, in these cases, CTI block was defined by classical criteria.

Among the 59 patients, 91% and 87% patients fulfilled classical criteria of clockwise and counterclockwise CTI block according to the activation sequence when pacing from the CSO and from the LLRA, respectively (Table 4). The peak-to-peak inter-DP interval was >110 ms in 72%, and the isoelectric interval between them was >70 ms in 80% of patients. Finally, the mean His-to-CSO interval during pacing at a CL of 600 ms from the LLRA was 51±15 ms. Importantly, this interval was <40 ms in 6 patients.

The incremental His-to-CSO maneuver showed a <10 ms increment in the His-to-CSO interval when pacing from 600 ms down to 300 ms in 58 out of the 59 patients (98%), with a mean increment of 1±3 ms (P=0.58). When using the IP maneuver as a reference for both phases 1 and 2, the proposed incremental His-to-CSO maneuver showed a 98% sensitivity and 100% specificity for the diagnosis of complete CTI block.

Discussion

The present study validates a novel maneuver to identify complete CTI conduction block during ablation of typical isthmus-dependent AFL. We demonstrate that the incremental His-to-CSO maneuver is feasible and analogous to the previously reported IP maneuver, allowing for discrimination between complete CTI conduction block and residual slow conduction through the CTI.22 This distinction is crucial because demonstration of CTI block is necessary to prevent AFL recurrences.12,13 Our data show that little (<10 ms) variation in the His-to-CSO atrial EGM interval in response to progressively faster (from 600 ms to 300 ms) pacing from the LLRA is indicative of complete CTI block, whereas a >10 ms increase of the His-to-CSO atrial interval with IP would support slow conduction and functional block across the CTI. The correlation of this technique to the previously validated IP maneuver seems excellent.

The incremental His-to-CSO maneuver does provide advantages compared with the IP maneuver. First, the incremental His-to-CSO maneuver does not require the identification of 2 differentiated potentials within the CTI ablation line. Identification of DPs is an important limitation of all diagnostic maneuvers that rely on CTI line mapping (local EGM-based criteria and IP pacing)6–12 because of inconclusive, multiple, or fragmented potentials corresponding to bystander slow conduction areas attributable to nonlinear CTI ablation, which are frequently observed (in 7 out of the 66 patients in our series, in 10 out of 55 patients in a previously reported series from our group,12 and in up to 39% of patients in other groups reported series).14 For these cases, it might be of interest that the measurement of the stimulus-to-atrial signal just lateral to the ablation line during incremental CSO pacing might be of interest for these cases, but because this maneuver, which is mechanistically very similar to the IP maneuver, is not validated, we did not perform it in our protocol.

Another potential advantage of the incremental His-to-CSO maneuver compared with the IP maneuver relies on the possibility of Crista Terminalis and intra-atrium conduction delay in some patients presenting with AFL. The latter is especially important in the setting of antiarrhythmic drugs. In this setting, a >20 ms increase in the interval between both CTI potentials during IP may be attributable to intra-atrial conduction delay of the second potential rather than to actual CTI slow persistent conduction. Although we did not specifically assess this issue, it is plausible that the incremental His-to-CSO

Table 3. Electrophysiological Maneuvers During Phase 1 CTI Block

<table>
<thead>
<tr>
<th>Criteria Accomplishment During Phase 1</th>
<th>Number of Patients (%)</th>
<th>Average±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descending activation along the lateral wall during pacing from the CSO</td>
<td>11/13 (85)</td>
<td>CSO-LLRA 131±52 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CSO-P2 146±49 ms</td>
</tr>
<tr>
<td>Descending activation along the septal wall during pacing from the LLRA</td>
<td>8/8 (100)</td>
<td>LLRA-CSO 134±52 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LLRA-P2 147±57 ms</td>
</tr>
</tbody>
</table>

His-to-CSO interval of >40 ms during pacing at a CL of 600 ms from the LLRA | 13/13 (100)             | 49±18 ms        |

Nonsignificant increment (<20 ms) between the 2 CTI potentials during IP from the CSO | 0/13 (0)                | 42±18 ms        |

Nonsignificant increment (<20 ms) between the 2 CTI potentials during IP from the LLRA | 2/11 (18)               | 35±19 ms        |

CL indicates cycle length; CSO, coronary sinus ostium; CTI, cavotricuspid isthmus; IP, incremental pacing; LLRA, low lateral right atrium; and P2, second potential in the CTI line.
shown that confirmation of complete CTI block by means of no follow-up data are provided in the present study. It has been proposed that the His-to-CSO interval after ablation may still theoretically function as the gold standard for the diagnosis of complete CTI block. The use of other previously established criteria would not have affected the positive correlation between the 2 proposed maneuvers based on incremental atrial pacing. It is important to note that the incremental His-to-CSO maneuver has never been elucidated.

Limitations

Not all previously reported criteria for the diagnosis of CTI block were assessed. However, the purpose of our study was to validate the incremental His-to-CSO maneuver as an accurate nonlocal EGM–based surrogate of the IP maneuver. In this sense, the IP maneuver was used as the gold-standard method to diagnose complete CTI block. The use of other previously established criteria would not have affected the positive correlation between the 2 proposed maneuvers based on incremental atrial pacing. It is important to note that the incremental His-to-CSO maneuver is only confirmatory of counterclockwise conduction block. No clockwise conduction block can be proven by this technique. As it was acknowledged previously in the description of the IP maneuver, a significant delay in the His-to-CSO interval after ablation may still theoretically be attributable to functional Crista Terminalis block. Finally, no follow-up data are provided in the present study. It has been shown that confirmation of complete CTI block by means of the IP maneuver is accompanied by a reduced incidence of typical flutter long-term recurrences.12,13 It remains unproven whether application of the incremental His-to-CSO maneuver might also result in a reduction of AFL recurrences during follow-up.

Acknowledgments

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Disclosures

None.

References

Achievement of complete cavotricuspid isthmus (CTI) conduction block reduces typical atrial flutter recurrences after ablation. The lack of increase in the His-to-Coronary sinus ostium atrial interval during incremental pacing from the low lateral right atrium distinguishes slow conduction from complete CTI conduction block. This distinction is crucial because demonstration of CTI block is necessary to prevent atrial flutter recurrences. The present study validates a novel maneuver to identify complete CTI conduction block. Several previously reported criteria may lack specificity in their ability to demonstrate complete CTI block. When the analogous local electrogram–based incremental pacing maneuver is used as a reference, the incremental His-to-Coronary sinus ostium maneuver reaches a sensitivity of 98% and a specificity of 100%. Of note, identification of double potentials (to which the previous incremental pacing maneuver depends on) is an important limitation of all diagnostic maneuvers that rely on CTI line mapping. The presence of inconclusive, multiple, or fragmented potentials corresponding to bystander slow conduction areas in the setting of a nonlinear computed tomography ablation may jeopardize the usefulness of these local electrogram–based maneuvers. The incremental His-to-Coronary sinus ostium maneuver does not require the identification of 2 differentiated potentials within the CTI ablation line and may provide confirmation of CTI block in those patients in whom assessment of local electrogram–based criteria is not feasible.
Incremental His-To-Coronary Sinus Maneuver: A Nonlocal Electrogram–Based Technique to Assess Complete Cavotricuspid Isthmus Block During Typical Flutter Ablation

Ermengol Vallès, Victor Bazán, Begoña Benito, Miguel Eduardo Jáuregui, Jordi Bruguera, Miguel Angel Guijo, Carmen Altaba and Julio Martí-Almor

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