Partial Cavotricuspid Isthmus Block Before Ablation in Patients With Typical Atrial Flutter

Atsushi Takahashi, MD, Dipen C. Shah, MD, Pierre Jaïs, MD, Meleze Hocini, MD, Jacques Clementy, MD, Michel Haïssaguerre, MD
Bordeaux-Pessac, France

OBJECTIVES
The purpose of this study was to prospectively evaluate preexisting partial isthmus block in the context of an electrophysiologically directed linear ablation strategy for typical atrial flutter (AF).

BACKGROUND
Double potentials (DPs) separated by an isoelectric interval have been recognized as markers of local block. However, the presence and significance of DPs in the cavotricuspid isthmus during AF before ablation have not been evaluated.

METHODS
Thirty consecutive patients with AF (counterclockwise: 24, clockwise: 6) were studied during AF. Sequential withdrawal mapping was performed in the cavotricuspid isthmus from the tricuspid valve (TV) to the inferior vena cava (IVC) edge with electrograms coinciding with the center of the surface electrocardiographic plateau during counterclockwise AF or with the initial downslope of the positive flutter wave during clockwise AF. Atrial electrograms along this line were categorized as double, single or fractionated potentials (SPs or FPs). After demarcation of the zone of contiguous DPs, radiofrequency (RF) catheter ablation was performed during AF only at sites with SPs or FPs (other than DPs) on the mapped line. If isthmus conduction still persisted after AF termination, additional RF applications were delivered using the same electrophysiologic strategy of avoiding DPs with an isoelectric interval during low lateral right atrial pacing for filling in the gap of residual conduction.

RESULTS
Before ablation, no DPs were recorded in the isthmus in 19 patients (63%); DPs were recorded only at the IVC edge in five patients, and only at the TV edge in one patient. A contiguous line of DPs extending through more than half the isthmus to the IVC edge was documented in five patients (17%; group DP). In group DP, AF was terminated with 1.4 ± 0.5 applications (vs. 5.8 ± 3.5 in the remaining patients: p < 0.01). Complete isthmus block was achieved with a total of 3.4 ± 0.5 applications (vs. 12 ± 6 in the remaining patients: p < 0.01).

CONCLUSIONS
Seventeen percent of patients undergoing ablation of AF have preexisting partial isthmus block indicated by a large contiguous zone of DPs separated by an isoelectric interval. Electrophysiologically directed linear ablation avoiding confluent DPs can prevent unnecessary applications for effective cure of AF. (J Am Coll Cardiol 1999;33:1996–2002) © 1999 by the American College of Cardiology

Catheter ablation for typical atrial flutter (AF) targeting the region of the septal or lateral isthmus between the tricuspid valve (TV) and the inferior vena cava (IVC) or the eustachian ridge is highly effective (1–10). The number of radiofrequency (RF) applications required to achieve complete isthmus block is very variable (8–11). This may be related to variation in isthmus size—both anatomic and functional including unrecognized bystander segments of the isthmus. Double potentials (DPs) separated by an isoelectric interval have been recognized as markers of local block (12–17). However, the presence of DPs in the cavotricuspid isthmus during typical AF before isthmus ablation has not been evaluated. In this study, we prospectively evaluated the prevalence, significance and practical implications of DPs separated by an isoelectric interval in the cavotricuspid isthmus during AF in the context of an electrophysiologically directed linear ablation strategy.

METHODS
Patients. Thirty consecutive patients with typical AF were prospectively studied. They included 28 men and two women with a mean (±SD) age of 68 ± 9.2 years (range 52 to 88). Twenty-four patients had typical counterclockwise AF with a negative sawtooth pattern in inferior leads and six had clockwise isthmus dependent flutter, confirmed by intracardiac mapping. At least one episode of atrial fibril-
The coronary sinus ostium. Withdrawal mapping was then positive flutter wave (during clockwise AF) were recorded at counterclockwise AF) and coinciding with the peak of the end of the surface ECG plateau in inferior leads (during clockwise AF were confirmed by sequen-tial mapping. This meant that electrograms coinciding with isthmus activation during clockwise AF were matched by sequential withdrawal mapping in the cavotricuspid isthmus was performed at high gain (0.1 mV/cm) from the margin of the tricuspid valve to the inferior vena cava in the line of electrograms coinciding with the center of the surface electrocardiographic plateau in inferior leads during counterclockwise (CCW) AF (left panel) and coinciding with the initial downslope of the positive flutter wave during clockwise (CW) AF (right panel). ABL = bipolar electrogram from ablation catheter.

Electrophysiologic study and cavotricuspid isthmus mapping. After informed consent, all patients underwent an electrophysiologic study in the fasting state and after stopping all antiarrhythmic drugs except for amiodarone at least 48 h in advance. Two catheters were introduced through the right femoral vein into the right atrium. A 6-F quadripolar catheter with an interelectrode distance of 5 mm (Bard Electrophysiology, Tewksbury, Massachusetts) was placed for pacing at the low lateral right atrium with electrograms from the distal bipole coinciding with the beginning of the surface electrocardiogram (ECG) plateau in inferior leads during counterclockwise AF or with the nadir of the flutter wave during clockwise AF. A 7-F quadripolar deflectable catheter with a 4-mm tip electrode (Cordis-Webster, Bald-win Park, California or Medtronic, Minneapolis, Minnesota) was used for cavotricuspid isthmus mapping and ablation. Surface ECG (leads I, II, III, V1) filtered through a bandpass of 1 to 500 Hz, bipolar intracardiac electrograms filtered at 30 to 500 Hz and amplified at high gain (0.1 mV/cm) were simultaneously recorded with a polygraph (model Midas, PPG Biomedical Systems, Overland Park, Kansas) at paper speeds of 100 mm/s. A programmable stimulator (Cardiostimulateur Orthorhythmique, Savita, Paris, France) with a 2-ms output pulse width and four times threshold amplitude was used. Descending lateral, ascending septal right atrial activation and lateral to medial isthmus activation during counterclockwise AF and ascending lateral, descending septal and medial to lateral isthmus activation during clockwise AF were confirmed by sequen-tial mapping. This meant that electrograms coinciding with the end of the surface ECG plateau in inferior leads (during counterclockwise AF) and coinciding with the peak of the positive flutter wave (during clockwise AF) were recorded at the coronary sinus ostium. Withdrawal mapping was then performed in the cavotricuspid isthmus from the margin of the TV to the IVC in the line of electrograms coinciding with the center of the surface ECG plateau in inferior leads during counterclockwise AF and coinciding with the initial downslope of the positive flutter wave during clockwise AF (Fig. 1). This ensures a catheter tip position perpendicular to the advancing wave front, and moreover catheter displacement to either side can be nonfluoroscopically recognized by the altered timing of the site electrogram. Recognition of seemingly minor changes in position is facilitated by the naturally lower conduction velocities in this region during AF. Atrial electrograms on this line were categorized as DPs (if separated by an isoelectric interval of more than 30 ms), single potentials (SPs) and fractionated potentials (FPs). The extent of contiguous DPs on the line (uninter rupted by SPs or FPs) was fluoroscopically estimated in the right anterior oblique view as large (more than or equal to half the isthmus from the TV to the IVC edge), intermediate or small (less than one third of the isthmus width). Low amplitude DPs were recorded after ablation at sites of RF delivery (during AF and low lateral atrial pacing) and used to recognize the position of the incomplete ablation line (18,19). The maximal amplitudes of DPs (at sites with both potentials of equal amplitude) mapped before ablation and on sites after RF delivery just before AF termination were compared.

Ablation procedure. Radiofrequency current application was delivered (unipolar 550-kHz unmodulated sine wave output between the distal ablation catheter tip and a 575-cm² cutaneous patch electrode placed over the left scalpula with a target temperature of 65 to 70°C lasting for 60 to 90 s) sequentially and point by point without moving the catheter during RF delivery. Sites with single or fractionated electrograms coinciding with the center of the surface ECG plateau during counterclockwise AF or coinciding with the initial downslope of the positive flutter wave during clockwise flutter were targeted until the zone of DPs separated by an isoelectric interval was reached which was specifically excluded from ablation. If isthmus conduction

Abbreviations and Acronyms

- AF = atrial flutter
- DP = double potential
- ECG = electrocardiogram
- FP = fractionated potential
- IVC = inferior vena cava
- RF = radiofrequency
- SP = single potential
- TV = tricuspid valve

![Image](361x640 to 503x715)
still remained after AF termination, sequential withdrawal mapping was repeated during low lateral right atrial pacing on the previous ablation line indicated by low amplitude DPs and additional RF current was delivered for filling in the gaps on the line indicated by single or fractionated electrograms (18). Radiofrequency delivery was immediately discontinued in the event of an increase in impedance or dislocation of the electrode. Confirmation of isthmus block was performed using right atrial activation and local electrogram based criteria including the achievement of the following activation times using sequential recording: 1) stimulation artifact to the atrial electrogram at the His bundle recording site < stimulation to the atrial electrogram at the coronary sinus ostium < stimulation to the second potential of DPs on the ablation line during low lateral atrial pacing; stimulation to low lateral right atrium < stimulation to the second potential on the ablation line during coronary sinus ostium pacing and 2) a complete and continuous line of DPs separated by an isoelectric interval from the margin of the TV to the IVC during low lateral right atrial pacing (19).

After the procedure, 50 U/kg of heparin was administered intravenously, and patients remained in hospital for 4 to 5 days. All received low molecular weight heparin for 3 days after the procedure, and antiarrhythmic drugs were not administered except in the event of other arrhythmias requiring drug treatment.

**Follow-up.** After discharge, follow-up assessment was through periodic visits to the supervising cardiologist including ECG recording for documentation of recurrence. In the event of recurrence, a repeat electrophysiologic study and ablation were advised.

**Statistical analysis.** Continuous data were expressed as mean ± SD. Statistical comparisons were performed using the Student t test, Fisher exact test or chi-square analysis as appropriate. A p value < 0.05 was considered to be statistically significant.

**RESULTS**

**Cavotricuspid isthmus mapping.** All 30 patients had typical AF with a mean cycle length of 250 ± 29 ms at the beginning of the procedure. Sequential withdrawal mapping in the cavotricuspid isthmus during typical AF documented no DPs in 19 patients, DPs in a small area at the IVC edge in 5 patients and at the TV edge in 1 patient. In five (17%; group DP) with counterclockwise AF, a large zone of DPs separated by an isoelectric interval was documented in all cases extending to the IVC edge (Fig. 2 and 3). No patient had preexisting DPs only in the center of the isthmus, and none had an intermediate size zone of DPs. The DP group had a longer cycle length AF (280 ± 24 ms vs. 243 ± 26 ms; p < 0.01), which was associated with both a longer surface ECG plateau phase in inferior leads (150 ± 22 ms vs. 127 ± 22 ms) and the remaining part of the flutter cycle length (130 ± 5.8 ms vs. 117 ± 11 ms). There was no significant difference in age and the incidence of right atrial enlargement, episodes of atrial fibrillation, structural heart disease, history of cardiac surgery and amiodarone use before ablation between them and the remaining patients (Table 1). The interspike interval of the double potentials was widest at the IVC edge (100 ± 34 ms at the IVC edge and narrowest at the site nearest the SPs or FPs recording site [58 ± 15 ms]). The second potential of DPs recorded in the cavotricuspid isthmus was activated after the atrial electrogram at the coronary sinus ostium and progressively delayed during withdrawal mapping to the IVC edge associated with anticipation or no change in the timing of the first potential. The maximum amplitude of DPs mapped before ablation was significantly greater than those of DPs on the ablation line just before AF termination (0.76 ± 0.6 mV vs. 0.19 ± 0.03 mV; p < 0.01).

**Ablation results.** All 30 patients underwent successful RF catheter ablation with the achievement of bidirectional isthmus block. Atrial flutter in group DP was terminated with a single application in 3 patients: at a site recording FPs in 1 patient (Fig. 1) or a SP in 2 patients (Fig. 2); and with two applications in 2 patients. The mean application number required for AF termination was 1.4 ± 0.5, which was significantly less than those for the remaining patients (5.8 ± 3.5) (p < 0.01). Atrial flutter could not be terminated with a single application in any of the latter patients. Complete bidirectional isthmus block was achieved with a total mean application number of 3.4 ± 0.5 in group DP, which was also significantly less than those for the remaining patients (12 ± 6) (p < 0.01). Procedure and fluoroscopic time in group DP were shorter than those of the remaining patients (55 ± 7 min vs. 114 ± 41 min; p < 0.01, 14 ± 3.7 min vs. 44 ± 24 min, respectively; p < 0.05). No complications occurred.

During a follow-up period of 14 ± 2.3 months (group DP: 13 ± 1.5 months vs. the remaining patients: 14 ± 2.3 months; p = NS), recurrence of typical AF was documented in two patients—both without DPs in the cavotricuspid isthmus before ablation. They underwent successful repeat ablation using the same strategy.

**DISCUSSION**

The present study shows that 17% of patients undergoing ablation of typical AF have preexisting partial isthmus block indicated by a large zone of DPs separated by an isoelectric interval, and ablation excluding this preexisting DP zone and directed at SPs or FPs successfully eliminated isthmus conduction. Therefore this electrophysiologically directed linear ablation strategy using DP mapping can avoid unnecessary applications for cure of typical AF.

**The prevalence of DPs in cavotricuspid isthmus.** Previous reports (12–17) have suggested that DPs result from sinus ostium pacing and 2) a complete and continuous line of DPs separated by an isoelectric interval from the margin of the TV to the IVC during low lateral right atrial pacing (19).
functional block by two asynchronous activation wave fronts. In a recent study in which three-dimensional right atrial endocardial activation mapping was performed during typical counterclockwise AF, DPs were constantly present in the posterior right atrium (17/17; 100%) and near the coronary sinus (15/17; 88%) as well (20). In the present study, DPs were documented in 11 patients, six in a small zone at the edges of the isthmus and five in more than half the cavotricuspid isthmus extending to the IVC edge. The discrepancy in the prevalence of DPs between the previous (20) and the present study may be due to mapping in a specific and limited area in the present study.

Basis of DPs before ablation. There was no significant difference in incidence of right atrial enlargement, structural heart disease and history of previous cardiac surgery, all of which may affect isthmus tissue, between patients with DPs in more than half the isthmus and the remaining patients. The second potential of these DPs recorded in the isthmus was activated after the atrial electrogram at the coronary sinus ostium. This indicates that the second potential was not part of the circuit. The second potential also progressively delayed during withdrawal to the IVC edge and was associated with anticipation or no change in timing of the first potential, probably depending upon the angle of incidence of the entering wave front to the line of block. However we did not track the activation of the second potential alone. The larger amplitude of these DPs compared with those recorded on the line after RF delivery points to the differing etiologies of the local line of block and suggests that the varying prevalence of DPs in each patient may depend on the varying extension of an anatomic nonconducting structure such as the eustachian ridge. Nakagawa et al. (10) have shown that the eustachian ridge recognized by DPs forms a fixed line of block which plays an important role in the septal approach for isthmus ablation in patients with typical AF. Wang et al. (21) reported, in a postmortem study, anatomic variations in the eustachian ridge which extended anterior to the coronary sinus ostium, posterior to the coronary sinus ostium or both, or did not exist (crista terminals terminated lateral to the inferior vena cava).
cava). In a single patient without structural heart disease, low amplitude (0.08 mV) double potentials were documented in a limited area at the tricuspid valve edge during isthmus mapping. The basis of such potentials is unclear but might be due to local degeneration.

**Implication for isthmus ablation.** On the basis of the knowledge of the flutter circuit derived from previous mapping studies (10,22,23), anatomic linear ablation directed anatomically guided linear ablation in the septal or lateral isthmus between the TV and the IVC or the eustachian ridge is widely prevalent for the treatment of typical AF (1–10). However this technique concentrating on creation of an anatomically guided ablation line between known obstacles neglects on-site electrograms before and after each RF application and especially the final gap for completion of isthmus block. Transmural ablation lesions in the isthmus can be recognized during recurrent AF by DPs separated by an isoelectric interval, and a single discrete gap represented by a single or a fractionated potential spanning the isoelectric interval of adjacent DPs can be selectively targeted to complete repeat ablation (18). In the present study, we prospectively used the same concept to search for preexisting DPs and excluded this bystander zone in the cavotricuspid isthmus so as to minimize the ablation area for patients without previous isthmus ablation. In fact, three patients with DPs occupying most of the isthmus before ablation (Fig. 2 and 3) had a single discrete gap recognized by local electrograms and a single application terminated AF, which is similar to the recurrent AF cases. In previous reports (10,23) DPs were

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**Table 1.** Comparison of Clinical Characteristics in Patients With or Without Preexisting Partial Isthmus Block

<table>
<thead>
<tr>
<th></th>
<th>Group DP (n = 5)</th>
<th>Other (n = 25)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flutter cycle length (ms)</td>
<td>280 ± 24</td>
<td>243 ± 26</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>63 ± 4.6</td>
<td>69 ± 9.6</td>
<td>NS</td>
</tr>
<tr>
<td>RA enlargement</td>
<td>2 (40%)</td>
<td>3 (12%)</td>
<td>NS</td>
</tr>
<tr>
<td>Afib episodes</td>
<td>1 (20%)</td>
<td>8 (32%)</td>
<td>NS</td>
</tr>
<tr>
<td>Structural heart disease</td>
<td>2 (40%)</td>
<td>7 (28%)</td>
<td>NS</td>
</tr>
<tr>
<td>Previous cardiac surgery</td>
<td>1 (20%)</td>
<td>7 (28%)</td>
<td>NS</td>
</tr>
<tr>
<td>Drug use (amiodarone)</td>
<td>1 (20%)</td>
<td>12 (48%)</td>
<td>NS</td>
</tr>
</tbody>
</table>

Afib = atrial fibrillation; Group DP = patients with double potentials in more than half the isthmus during atrial flutter before ablation; Other = the remaining patients; RA = right atrium.
not found to be markers of preexisting partial isthmus block. This may be due to lack of on-site electrogram mapping before RF applications. The most important finding is that isthmus mapping based on the local electrogram provides an indication of the functionally active segment of the isthmus, which was much shorter than the anatomic isthmus in some cases, corroborated by the relative ease with which isthmus block could be achieved in these patients using this electrophysiologically directed linear ablation strategy. This technique can also be applied to ablation in the septal or the more lateral isthmus by changing the target of the surface ECG phase. Recurrence occurred in two patients without DPs before ablation despite achievement of bidirectional isthmus block; this might be due to a larger functionally active zone in the isthmus in patients without preexisting partial block.

Study limitation. The present study did not provide information about the relationship between the mapping-ablation line and its actual anatomic location, because mapping was only ECG-guided. However this line was at least not septal in position, because electrograms recorded on our line coincided with the center of the plateau phase of the flutter wave in inferior leads (during counterclockwise AF), in contrast to the end of the plateau in the case of electrograms from the coronary sinus ostium and the adjacent septum. The anatomic/structural correlate of the nonconducting structure producing DPs with isoelectric interval was also not determined. Recording of DPs depends upon the orientation of the line of block vis-à-vis the incident wave front. Because DPs were mapped in the isthmus before ablation only during counterclockwise AF, a preexisting line of block either during pacing in sinus rhythm or with a different orientation or during activation from their opposite direction (clockwise AF) may not result in similar DPs. As the sequential withdrawal mapping as well as electrophysiologically guided linear ablation in the cavotricuspid isthmus was performed using the center of the flutter wave on the surface ECG as a reference, it might be difficult to apply for patients with 1:1 atrioventricular conduction or wide QRS complexes because of the loss of flutter wave recognition on the surface ECG. However a right atrial reference electrogram (low lateral right atrium or coronary sinus or both) can be similarly helpful. Although a special ablation catheter incorporating a long distal tip of 8 mm allowing high power output may be useful for isthmus ablation by creating a larger linear lesion (24), we routinely used a 4-mm tip electrode ablation catheter with 2-mm interelectrode distance of the distal electrode pair. The electrogram resolution of a large tip catheter for DPs or FPs is unknown.

Conclusions. Sequential withdrawal mapping allowed identification of the functionally active segment of the isthmus, which was much shorter than the anatomic isthmus in 17% of patients with typical AF. An electrophysiologically directed linear ablation strategy using DP mapping can demarcate the zone of preexisting isthmus block and avoid unnecessary applications for cure of typical AF.

Reprint requests and correspondence: Dr. Atsushi Takahashi, Division of Cardiology, Tsuchiura Kyodo Hospital 11-7, Shinmachichi Manabe, Tsuchiurashi-cho, Ibaraki-ken, 300531, Japan.

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