Right Atrial Angiographic Evaluation of the Posterior Isthmus
Relevance for Ablation of Typical Atrial Flutter

Hein Heidbüchel, MD, PhD; Rik Willems, MD; Hennie van Rensburg, MD; Jef Adams, MS; Hugo Ector, MD, PhD; Frans Van de Werf, MD, PhD

Background—Gaining anatomic information about the posterior isthmus is not generally part of flutter ablation procedures. We postulated that right atrial (RA) angiography could rationalize the ablation approach by revealing the conformation of the isthmus.

Methods and Results—In 100 consecutive patients, biplane RA angiography was performed before ablation to guide catheter contact with the isthmus along its length. Angiography showed a wide variation in the width of the isthmus (17 to 54 mm; 31.3±7.9), its angle with the inferior vena cava in the right anterior oblique projection (68° to 114°; 90.3±9.0°), and its lateral position relative to the inferior vena cava in the left anterior oblique projection. A deep sub-Eustachian recess was revealed in 47%, with a mean depth of 4.3±2.1 mm (1.5 to 9.4). A Eustachian valve was visualized in 24%. Ablation resulted in bidirectional conduction block (which could be transient) in all, with a median of 2 dragging radiofrequency (RF) applications (2.3±2.5 RF applications; 57°C, ≤99 seconds each). Permanent block was achieved in 99%, with a median of 3 RF applications (3.4±3.0). The presence of a Eustachian valve or concave isthmus was associated with statistically more RF applications; the same trend was seen for patients with deep pouches. The number of RF applications decreased statistically throughout the study, indicating a learning curve. No patient had a recurrence after a follow-up of 13±11 months.

Conclusions—Right atrial angiography reveals a highly variable isthmus anatomy, often showing particular configurations that can make ablation more laborious. Rational adaptation of the ablation approach to these anatomic findings may contribute to successful ablation. (Circulation. 2000;101:2178-2184.)

Key Words: atrial flutter ■ catheter ablation ■ angiography ■ structure
catheter) and entrainment pacing confirmed the participation of the isthmus in the arrhythmia circuit. Bidirectional block was verified by pacing from the proximal CS and posterolateral right atrium (RA) while mapping the atrial activation sequence and double potentials along the entire ablation line.

Radiofrequency (RF) energy was delivered with the use of thermistor ablation catheters with 6- or 8-mm tips (target 57°C; ≤50 W). If required by the anatomic configuration, sometimes a 4-mm-tip catheter with appropriate curve was introduced later during the procedure. An SR-0 and/or SFAF sheath (Daig Corp) was used to support the ablation catheter in 8 and 9 patients, respectively. In 86%, current was delivered during pacing in the proximal CS and in 14% during flutter. During the initial RF applications (≤99 seconds each), the catheter was dragged from the TA toward the IVC. Applications were stopped prematurely on catheter dislocation or the occurrence of an impedance rise (n=4) or an audible “pop” (n=15). After 1 or more RF applications without block, the ablation line was mapped for a residual gap, and subsequent RF applications were directed to this gap.

After ablation, subcutaneous low-molecular-weight heparin was given for 1 week and aspirin for 6 weeks, except in patients with a history of atrial fibrillation, in whom oral anticoagulation was continued.

RA Angiography
Biplane angiography was performed after mapping and entrainment and shortly before RF energy delivery, allowing maximal concordance of the catheter positions during angiography and ablation. Right anterior oblique (RAO) and left anterior oblique (LAO) views were individually adjusted so that the His bundle catheter projected strictly parallel to the x-rays in the LAO view and that the CS catheter made an angle of ~10° to 15° in the RAO view. The mean RAO and LAO angles were 43±10° (15° to 70°) and 49±10° (26° to 75°). A first injection was made with a 6F or 7F pigtail located at the superior vena cava (SVC)-RA junction and a second at the IVC (40 mL; 18 mL/s). A single injection inside the RA did not always result in clear delineation of the SVC, IVC, and CS and tricuspid orifices, right atrial appendage, and isthmus. The angiograms were digitally acquired, allowing replay and storage of RAO and LAO frames as references during the subsequent ablation.

In 51 patients, a quantitative analysis of different RA anatomic structures was made on the latest atrial diastolic frame (confirmed by the opening of the tricuspid valve in the next frame). Measurements were calibrated by interelectrode spaces projecting perpendicular to the given cine view. The width of the isthmus in the RAO view was measured between the IVC and the lower hinge point of the tricuspid valve (points A and B in Figure 1A). The isthmus often could be divided into a recess (interposterior to the CS ostium) and a flat vestibule (between this recess and the TA). The width of each was measured. The perpendicular distance between the line connecting A and B and the deepest point of the isthmus was quantified. Also, the angle between line A-B and a line parallel to the ablation catheter in the terminal IVC was evaluated. In the LAO view, the distance between the lateral aspect of the IVC orifice and the position of the ablation line (points C and D) was measured.

Statistical Analysis
Summary values are given as mean±SD if a normal distribution was expected; otherwise median and range are used. Unpaired t tests were used in the comparison of normal distributions, and Mann-Whitney rank sum tests or Kruskal-Wallis statistics were used in the absence of the assumption of a normal distribution (eg, the number of RF applications). A value of P<0.05 was considered significant.

Results
Anatomic Observations
Figure 1A shows contrast injections at the SVC and IVC orifices, each visualizing the terminal part of the respective vena cava and its RA junction. The isthmus generally could be evaluated better during the IVC injection, as expected. Angiography revealed a profound variability in isthmus anatomy. Its width varied from 17 to 54 mm (31.3±7.9) (Figure 2). Also, the angle between the ablation catheter (in
its terminal part in the IVC) and the isthmus varied from a sharp angle of 68° to an open angle of 114° (90.3±9.0°) (Table 1). An isthmus width of ≥39 mm or catheter-IVC angle of ≤81° were both seen in only 18%. Each could result in difficulty reaching the tricuspid aspect of the isthmus. Their combination was present in 5% (Figure 2A). An isthmus <21.5 mm was seen in 12%.

More striking than differences in width was the recognition of special anatomic configurations. In 31%, the maximal perpendicular distance between a line connecting both ends of the isthmus and the isthmus itself was ≤2 mm, leading to an almost straight appearance (Figures 1A and 2A). In 22%, however, the isthmus showed a more or less concave aspect (Figure 3A), with a mean depth of 4.1±2.1 mm (2.2 to 9.3 mm) (Table 1). In the remaining 47%, the isthmus could be divided in a flat vestibular part against the TA and a pouchlike recess at the IVC side (Figure 3, B, C, and D). Their lengths were 12.7±3.6 and 17.3±5.1 mm, respectively. The average depth of this sub-Eustachian pouch was 4.3±2.1 mm. It was deeper than 5 mm in 18%. The presence

**Table 1. Angiographic Appearance of Posterior Isthmus**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients (male/female)</td>
<td>100 (81/19)</td>
</tr>
<tr>
<td>Age, y</td>
<td>55±13 (13–77)</td>
</tr>
<tr>
<td>Isthmus width, mm</td>
<td>31.3±7.9 (17–54)</td>
</tr>
<tr>
<td>Straight aspect*</td>
<td>31</td>
</tr>
<tr>
<td>Concave aspect*</td>
<td>22</td>
</tr>
<tr>
<td>Concavity depth, mm</td>
<td>4.1±2.1 (2.2–9.3)</td>
</tr>
<tr>
<td>Vestibule-recess</td>
<td>47</td>
</tr>
<tr>
<td>Vestibule (tricuspid side, mm)</td>
<td>12.7±3.6 (5.4–19.2)</td>
</tr>
<tr>
<td>Recess (IVC side, mm)</td>
<td>17.3±5.1 (9.5–27.4)</td>
</tr>
<tr>
<td>Recess depth, mm</td>
<td>4.3±2.1 (1.5–9.4)</td>
</tr>
<tr>
<td>Prominent Eustachian valve, n</td>
<td>24</td>
</tr>
<tr>
<td>Angle between ablation catheter in terminal IVC and isthmus</td>
<td>90.3±9.0° (68–114°)*</td>
</tr>
</tbody>
</table>

*Maximal perpendicular distance between the line IVC–tricuspid ring and the isthmus was ≤2 mm (straight) or >2 mm (concave).
of a limited “neck” sometimes gave it an aneurysmal aspect (Figure 3D).

Moreover, in 24% of the patients, a Eustachian valve could be visualized between the IVC orifice and the isthmus. Often, it had a membranous aspect, but it could be thick (as shown in Figure 4A).

None of the morphological features (length or depth of the isthmus or its parts, or presence of a recess or Eustachian valve) was related to age, sex, or the presence of structural heart disease.

Relevance for the Ablation Approach

The angiographic images helped to evaluate the position of the ablation tip in the RAO projection before and during RF application. Current application at the TA was started only after electrical confirmation (ie, atrioventricular amplitude [A/V] ratio of <0.50) and angiographic confirmation that the ablation catheter straddled the annulus (Figure 2A). The initial ablation catheter was chosen after the angiography and was generally a 2.5-in catheter with a proximal pull-wire (6-mm tip; 85% in the last 50 cases). In 18 patients with a long isthmus (≥40 mm), the insertion of a 3-in catheter was necessary in 6 and/or the insertion of a guiding sheath in 7.

Two different ablation approaches were taken when a deep pouch was encountered: In 94% (44 of 47), the ablation catheter was explicitly directed into it (often with the use of a catheter different from the one chosen to ablate the vestibular part of the isthmus), whereas the aneurysm was avoided in 3 by ablation at the septal side of it.

Ablation catheters with a very short curve able to reach the isthmus immediately behind the Eustachian valve (ie, 1.5-in Cordis-Webster or a “small curve” EPT Blazer) were used significantly more often in the presence of a valve (46% vs 5%, \( P<0.001 \)) to complete the ablation line (Figure 4, B and C).

Isthmus block often coincided with full completion of a dragging RF application from the TA to the IVC (Figure 1B). Interestingly, in 12 of the 46 patients in whom the first application resulted in block, it was achieved before completely finishing the dragging movement over the anatomically defined isthmus. This indicated that conducting tissue participating in the arrhythmia circuit was not contained throughout the entire width of the isthmus.

Also, the position of the ablation line in the LAO projection was variable. In 36 patients, it was positioned right-sided of the lateral IVC edge, resulting in an oblique course of the ablation catheter (Figure 5). The distance between the lateral aspect of the IVC and the mid ablation catheter position on the isthmus (C and D in Figure 1) varied from 13 to 0 mm (4.3±3.9 mm).

Ablation Results

Conduction block (which could be transient) was achieved in all patients with a median of 2 RF applications (2.3±2.5). Figure 6A shows their distributions: In the last 50 patients, no
more than 5 RF applications were required to achieve a first block. Early recurrence of conduction after prior block was seen in 51 patients. Additional applications led to permanent block in 99% of the patients, with a median of 3 RF applications (3.4 ± 3.0; Figure 6B). The median energy delivered before first or permanent block was 4913 J (6952 ± 8390 J) and 7540 J (9890 ± 10 725 J), respectively. In 1 patient, only transient block could be achieved from the 18th application. No permanent block was present after 25 RF applications, respectively. The corresponding energies delivered were 3820 J (5554 ± 3470 J) and 5920 J (6960 ± 4820 J). This effect was seen as a trend throughout all anatomic subgroups, but it did not reach statistical significance because of the smaller number of observations.

The mean procedure and fluoroscopy times in all patients were 119 ± 50 minutes and 26 ± 14.8 minutes (90 ± 24 minutes and 19.8 ± 6.6 minutes in the last 34 patients). One patient had a groin hematoma requiring surgical exploration. Minor complications occurred in 5 patients. The angiography itself and RF delivery did not result in any adverse event.

After a mean follow-up of 13 ± 11 months, no patient has had a recurrence of atrial flutter, including the patient with only transient block. Thirty patients had at least 1 episode of atrial fibrillation after a mean of 45 days.

Discussion

Previous anatomic reports studying post mortem human hearts have pointed to the anatomic variability of the isthmus, reporting an average width of 27 ± 3.3 mm (Reference 7) to 31 ± 4 mm. These values correspond well with our angiographic findings of 31.3 ± 7.9 mm. Interestingly, Wang et al6 reported on the presence of a prominent nonfenestrated Eustachian valve and of a thick, muscular-type Eustachian ridge in 10% and 20%, respectively, whereas we found evidence for such a structure in 24%.

There are very few anatomic data about this region in patients in general or in patients with flutter in particular. Cabrera et al11 recently reported on angiographic measurements in 23 patients and found a mean isthmus width of 37 ± 8 mm. Also, their values for the relative length of the tricuspid vestibule and IVC recess are close to ours. Trans-thoracic and transesophageal isthmus evaluation in 105 patients after ablation for atrial flutter revealed similar variability in width and isthmus-IVC angulation.

Thus far, almost no efforts have been made to adapt the ablation approach to the anatomic peculiarities of the isthmus in a given patient. Our findings show that a universal ablation approach for atrial flutter may not be optimal. We individualized the ablation approach, depending on the angiographic...
findings. In many patients, a combination of catheters was required to ensure adequate contact along the entire isthmus. This was especially true if there was a deep sub-Eustachian pouch, a concave deformation of the isthmus, or the presence of a Eustachian valve. These more complex anatomic configurations also led to a significantly higher number of required RF applications.

Cabrera et al 8 described the IVC side of the isthmus as the membranous part because it did not contain musculature (and hence should not contribute to conduction). It could be up to 22 mm wide. This anatomic finding correlates with our observation that in 26% of the patients with isthmus block during the first application, it was achieved before completely finishing the dragging application from the TA toward the IVC.

Because this was not a randomized study between ablation with or without angiography, we cannot conclude that performing angiography is superior. Nevertheless, apart from the clear rationale of such an approach as outlined above, there are other arguments for the added value of angiography: (1) even when comparing only with those reports that used dragging RF applications, block was achieved in more patients and with fewer RF applications. 2,9,14,15 We did not use high-energy devices such as cooled electrodes 16 and we limited tip temperature to 57°C and power to 50 W; (2) there was a clear learning-curve effect between the first, second, and third thirds of our series (Table 2), without changes in types of catheter or RF generator settings.

Other potential techniques for visualizing the isthmus conformation are intracardiac echocardiography or electroanatomic mapping. Further evaluation will be necessary to directly compare these approaches (which require special equipment) with the more widely available angiographic evaluation.

Although angiography may be useful for determining contact with the wall in the RAO projection and for targeting specific anatomic substrates, it provides little information for the positioning in the LAO projection. Catheter position in the LAO projection was mainly determined by the stability of the catheter on the isthmus, although we tried to avoid the septal aspect because of the higher risk of atrioventricular block 17,18 and the thicker myocardium at that site. Even if a more oblique positioning of the ablation tip was required, it did not lead to a higher number of RF applications.

Because the definition of “1 application” varies widely (from discrete lesions with stepwise repositioning between applica-

| TABLE 2. Number of RF Applications Required to Create Bidirectional Isthmus Block (First Occurrence—Possibly Transient—and Permanent) |
|---------------------------------------------|-------------|-------------|-------|-------------|-------------|-------------|-------|-------------|
|                                           | First Block |             |       | Permanent Block |             |       |
|                                           | X±SD (range) | Median | Rank P | Mean          | X±SD (range) | Median | Rank P | Mean          |
| Whole study                               | 2.3±2.5 (1–18) | 2 |       | 3.4±3.0 (1–22) | 3 |       |
| 1st third (n=33)                          | 3.2±3.9 (1–18) | 2 | 58.3 | 4.6±4.6 (1–22)* | 3 | 58.0 |
| 2nd third (n=33)                          | 2.0±1.4 (1–7) | 2 | 48.4 | 0.14 vs 1st | 3.3±1.7 (1–8) | 3 | 54.8 NS vs 1st |
| 3rd third (n=34)                          | 1.7±0.9 (1–4) | 1 | 44.9 | 0.05 vs 1st | 2.3±1.5 (1–6) | 2 | 37.8 0.008 vs 1st |
| Isthmus aspect                            |             |       |       |               |             |       |
| Straight                                  | 2.4±3.1 (1–18) | 2 | 48.6 | 2.6±1.5 (1–6)* | 2 | 42.5 |
| Concave                                   | 2.2±1.5 (1–7) | 2 | 54.7 | NS vs straight | 3.3±1.5 (1–7) | 3 | 56.8 0.05 vs straight |
| Pouch                                     | 2.3±2.4 (1–15) | 2 | 49.8 | NS vs straight | 3.9±4.1 (1–22) | 3 | 51.6 NS vs straight |
| Eustachian valve                          |             |       |       |               |             |       |
| Present (n=24)                            | 2.8±1.9 (1–9) | 2 | 65.8 | 4.5±3.7 (1.17) | 3 | 59.7 |
| Absent (n=76)                             | 2.1±2.6 (1–18) | 1 | 45.7 | 0.002 | 3.0±2.7 (1–22) | 3 | 46.9 0.05 |
| Isthmus lateral from IVC (LAO)            |             |       |       |               |             |       |
| No (n=64)                                 | 2.1±2.3 (1–18) | 2 | 48.8 | 3.0±2.1 (1–11) | 3 | 47.7 |
| Yes (n=36)                                | 2.6±2.7 (1–15) | 2 | 53.5 | NS | 4.0±4.2 (1–22) | 3 | 54.1 NS |

*No permanent block in 1 patient.
tions\textsuperscript{1,3} to dragging applications\textsuperscript{2,9,14,15}, it is difficult to compare the number of applications between different reports. Moreover, power settings and duration of the applications may vary. Therefore, in addition to the number of RF applications, we also reported the cumulative delivered energy (in Joules). It may serve as comparison for future reports.

We have no explanation for the inability to achieve permanent block in a single patient. Although the isthmus was relatively long, it had a straight aspect without any particular anatomic features. The repeated transient block and the wide separation of local electrograms without intermediate activity may suggest a deep connection. An irrigated-tip ablation catheter could be useful in such cases.\textsuperscript{16}

We conclude that RA angiography is easy to perform and well tolerated. It reveals a highly variable isthmus anatomy, often showing particular configurations. Obstacles such as Eustachian valves, aneurysmal pouches, or even a concave deformation of the entire isthmus lead to more difficult ablation sessions. However, adaptation of the ablation approach to these angiographic anatomic findings is rational and may help to ablate this drug-defying arrhythmia with high success.

Acknowledgments

This study was supported in part by a research grant from Astra Pharmaceuticals Belgium. Dr Heidbuechel is a Clinical Investigator of the Fund for Scientific Research-Flanders.

References

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Circulation. 2000;101:2178-2184
doi: 10.1161/01.CIR.101.18.2178

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2000 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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