Atrial flutter ablation: Efficacy and cost-effectiveness of a single decapolar electrode to demonstrate bidirectional isthmus block


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Aims To evaluate whether a single decapolar electrode is a reliable and cost-effective substitute for the ‘Halo’ catheter to map the circuit and detect bidirectional isthmus block during atrial flutter (AFL) ablation.

Methods and Results Twenty-four patients underwent AFL ablation by using the decapolar electrode in the infero-lateral wall of right atrium (group A) while a ‘Halo’ catheter was used in 11 patients (group B). Both groups had similar clinical characteristics. Anti-clockwise rotation (20 patients), clockwise (3 patients) or both forms of AFL (1 patient) were detected in group A. All patients in group B had anti-clockwise AFL. Bidirectional isthmus block was completed in 22 patients of group A and in 9 of group B ($P$=NS) while incomplete isthmus block was detected in 2 patients in each group ($P$=NS). Mean fluoroscopy and procedure time was 27±47 min, 107±36 min in group A and 14±19 min, 114±65 min in group B ($P$=NS). AFL relapsed in 3 patients of group A (follow-up 7±4 months) and in 2 of group B (4±2 months).

Conclusion A single decapolar electrode is a reliable method to map the circuit and demonstrate bidirectional isthmus block during AFL ablation. The cost of the decapolar electrode is a quarter of that of the ‘Halo’ catheter. This represents a significant saving particularly for centres with a substantial number of AFL ablations.

Key Words: Catheter ablation, atrial flutter, decapolar electrode, cost-effectiveness.
All patients had clinically documented classical anti-clockwise or clockwise rotation AFL. Additionally in 1 patient of group A and in 2 of group B episodes of paroxysmal AF had also been documented. Atrial flutter was paroxysmal in 18 patients of group A and in 10 of group B. Incessant AFL was present in 6 patients of group A and 1 patient of group B. Three patients of group A had previously undergone an unsuccessful attempt at catheter ablation of AFL. All 35 patients in group A had previously undergone an unsuccessful attempt at catheter ablation of AFL. All 35 patients in group A had previously undergone an unsuccessful attempt at catheter ablation of AFL. All 35 patients in group A had previously undergone an unsuccessful attempt at catheter ablation of AFL. All 35 patients in group A had previously undergone an unsuccessful attempt at catheter ablation of AFL. All 35 patients in group A had previously undergone an unsuccessful attempt at catheter ablation of AFL. All 35 patients in group A had previously undergone an unsuccessful attempt at catheter ablation of AFL. All 35 patients in group A had previously undergone an unsuccessful attempt at catheter ablation of AFL.

Electrophysiological study

The study was performed in the fasting state under mild sedation. Written consent was given by the patient before the procedure. Both femoral veins and the right subclavian vein were used for the insertion of the electrodes. Bipolar or quadripolar electrodes were placed in high RA and His electrogram position. A quadripolar and occasionally decapolar electrode (when more than one arrhythmia was suspected) was used for the coronary sinus (CS). In patients of group A, a 6F decapolar catheter was 2-5-2 mm interelectrode distance (DAIG Corporation, Minnetonka, MN, U.S.A.) was deployed in the lateral wall along the crista terminalis with its tip at the IVC-TA isthmus area. This electrode was used to map the activation sequence during AFL and to detect the creation of isthmus block during the ablation procedure. The left anterior oblique view was used to locate the distal electrode poles medially of the right atrium-inferior vena cava junction that is considered as the middle-lateral part of IVC-TA isthmus. The remaining poles were deployed within the anterolateral wall of RA (Fig. 1). In patients of group B, a 7F, 20 pole, ‘Halo’ catheter (Cordis-Webster, Miami, FL, U.S.A.) with 2 mm interelectrode distance was situated around the tricuspid annulus for mapping the adjacent area.

Bipolar intracardiac electrograms filtered between 30 to 50 Hz were recorded on a computerized multichannel system (Prucka Engineering). A Biotronic UHS 20 programmable stimulator was used to deliver electrical impulses with a pulse duration of 2 ms at twice diastolic threshold. If the patient was in sinus rhythm, sustained AFL was induced either by incremental atrial pacing from two atrial sites (high RA and CS) or by using burst atrial pacing in order to map the circuit, define the type of AFL and to ascertain whether the atrial flutter could be entrained from the RA.

Ablation procedure

Radiofrequency ablation was performed with a Stocquart generator that delivered continuous unmodulated current at 500 kHz. A thermocouple multicurve, 4 mm tip (Medtronic MarinR) ablation catheter, positioned below the decapolar catheter, was used (Fig. 1). The power output was titrated to achieve a temperature of 60°C to 65°C at the ablation site. Radiofrequency energy was applied for 30 s at each site unless there was an impedance increase or catheter displacement. Ablation was anatomically guided and directed from the tricuspid annulus to inferior vena cava. The aim was to create a linear lesion by applying multiple sequential spot lesions. Radiofrequency applications were repeated until AFL termination and/or achievement of BIB. Where this line did not prove to be adequate, additional lines between the orifices of the IVC and the CS os and between the septal tricuspid annulus and the CS os were applied.

When radiofrequency energy was delivered during fixed-rate proximal CS pacing, a change in the activation pattern at the lateral RA wall from a partially ascending wavefront to an entirely descending one was considered as a criterion of clockwise conduction block at the isthmus area. PACing from the low lateral RA (LLRA) was subsequently performed in order to assess the bidirectional characteristics of the block. Evidence for anticlockwise block at the isthmus area was considered when the proximal CS (CSP) was activated after the high RA and His bundle region. We used the term incomplete isthmus block when the distal bipole of the mapping catheter, placed at the lateral part of the IVC–TA isthmus, was activated slightly before or at the same time as bipole 3–4 during CSP pacing. Although the presence of incomplete isthmus block suggests slow conduction through the region of ablation, this was considered as an alternative end-point of the procedure.
Table 1  Patient electrophysiological and ablation data

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=24)</th>
<th>Group B (n=11)</th>
<th>p</th>
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<tbody>
<tr>
<td>AFL-CL (msec)</td>
<td>230 ± 32</td>
<td>231 ± 27</td>
<td>0.83</td>
</tr>
<tr>
<td>Anti-clockwise AFL</td>
<td>20</td>
<td>11</td>
<td>0.20</td>
</tr>
<tr>
<td>Clockwise AFL</td>
<td>3</td>
<td>0</td>
<td>0.31</td>
</tr>
<tr>
<td>Anti-clockwise &amp; clockwise AFL</td>
<td>1</td>
<td>0</td>
<td>0.69</td>
</tr>
<tr>
<td>Other arrhythmias (AVNRT/AF)</td>
<td>3/2</td>
<td>1/2</td>
<td>0.49</td>
</tr>
<tr>
<td>No of RF applications</td>
<td>34 ± 23</td>
<td>34 ± 31</td>
<td>0.89</td>
</tr>
<tr>
<td>PT (min)</td>
<td>107 ± 36</td>
<td>114 ± 65</td>
<td>0.62</td>
</tr>
<tr>
<td>FT (min)</td>
<td>27 ± 47</td>
<td>14 ± 19</td>
<td>0.14</td>
</tr>
<tr>
<td>BIB</td>
<td>22</td>
<td>9</td>
<td>0.37</td>
</tr>
<tr>
<td>IIB</td>
<td>2</td>
<td>2</td>
<td>0.37</td>
</tr>
<tr>
<td>Success</td>
<td>22/24 (92%)</td>
<td>9/11 (82%)</td>
<td>0.37</td>
</tr>
<tr>
<td>Recurrence</td>
<td>3/24 (12.5%)</td>
<td>2/11 (18%)</td>
<td>0.51</td>
</tr>
<tr>
<td>Follow-up (months)</td>
<td>8 ± 4</td>
<td>5 ± 2.3</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Data presented are mean values ± SD.

AFL=atrial flutter, AFL-CL=atrial flutter cycle length, AF=atrial fibrillation, AVNRT=atrioventricular nodal re-entry tachycardia, RF=radiofrequency ablation, PT=procedure time, FT=fluoroscopy time, BIB=bidirectional isthmus block, IIB= incomplete isthmus block.

Results

No statistical difference was found between group A and group B in terms of age, sex, presence of heart disease, type of AFL, and number of antiarrhythmic drugs used before ablation.

Patient electrophysiological data and radiofrequency ablation characteristics are presented in Table 1. The same ablation technique, by sequential point by point applications of RF energy, without moving the catheter during the energy delivery, was followed in both groups. No dislocation of the decapolar catheter was observed during movements of the ablation catheter.

In those patients where atrioventricular nodal reentrant tachycardia and AFL were both induced during the electrophysiological study, atrioventricular nodal modification was initially performed followed by AFL ablation. Radiofrequency energy was delivered during proximal CS pacing in 17 patients of group A and 10 of group B while in the remaining patients with persistent AFL which was not terminated by over-drive stimulation, the energy was applied during the tachycardia.

Split potentials in isthmus area during CSp and LLRA pacing have been recorded in some of our patients however we did not look systematically for them[5,6].

In all patients where a BIB had been completed, typical AFL was rendered non-inducible. However in 1 patient of group A, a left atrial origin AFL was still inducible at the end of the procedure. Atrial flutter was still inducible in 50% (2/4) of those patients where only incomplete isthmus block had been detected.

Follow-up

Patients were monitored for 24 h and were discharged without antiarrhythmic medications. No complications related to the procedure were observed. In group A recurrence of AFL occurred in 3 patients (Table 1). In two of those only incomplete isthmus block had been achieved. A second radiofrequency ablation procedure was performed in one of these patients with successful creation of BIB this time using again a decapolar electrode for detection of isthmus block. In the third patient despite the presence of BIB at the end of the initial procedure, AFL relapsed two days later. During a repeat study ‘non isthmus dependent AFL’ was inducible. The patient was considered to have widespread disease in the right atrium and therefore we proceeded to atrioventricular nodal ablation with dual chamber pacemaker implantation.

In group B, 3 patients were still symptomatic during the follow-up. Atrial flutter was recorded in 2 of those (1 with BIB and 1 with incomplete isthmus block). In the
third patient with a history of paroxysmal AFL/AF and incomplete isthmus block, only episodes of paroxysmal AF were documented in 24 h Holter monitoring.

**Discussion**

In the present study, we have used a decapolar electrode to substitute for the ‘Halo’ catheter during AFL ablation. Our results support the concept that a single decapolar electrode deployed in the antero-lateral and inferior wall of the RA is equally as effective in identifying the type of AFL and detecting the creation of BIB during AFL ablation.

Atrial flutter is a macroreentrant arrhythmia involving the whole RA. A multipole ‘Halo’ catheter deployed around the tricuspid annulus is generally used, in order to map the circuit, and to assess the development of BIB during AFL ablation. Simplified methods, requiring a reduced number of catheters for isthmus block detection, have been reported by other groups. Willems et al. using a single transfemoral 20-pole catheter mapped the entire posterior tricuspid isthmus including CS and right atrial free wall while Shah et al. described a simple two catheters technique for assessment of complete isthmus block by looking for double potentials.

In our study we used a simple decapolar electrode which was inserted from the inferior vena cava and coiled in such a way that 3 of the Dipoles were in contact with the anterolateral wall and 2 along the inferior part of the RA (Fig. 1). Our data confirm, that from this electrode and the additional information from the His bundle electrode, high RA catheter, and the electrode inserted in the CS we could identify the activation pattern of the circuit and define the type of flutter. A distal to proximal anti-clockwise activation sequence was recorded in those patients with an ECG suggesting typical AFL. Conversely, a clockwise distal to proximal direction of activation was found where there was an upright flutter wave morphology in the inferior leads and an inverted one in V1 indicating the presence of uncommon AFL. Lack of definite anti-clockwise or clockwise activation of the anterior and inferior wall classified the AFL as atypical.

In the earlier studies, criteria for acute success in AFL ablation were arrhythmia interruption and the lack of inducibility. More recently, the creation of BIB at the IVC-TA isthmus has become a crucial end point criterion for successful AFL ablation. Our study confirms the initial hypothesis that a single decapolar electrode placed in the antero-lateral and inferior RA wall is an effective and sufficient tool for the detection of BIB. The crista terminalis and eustachian ridge form anatomical structures with poor or absent transverse conduction. Consequently in the presence of isthmus block, the wavefront of activation from the paced proximal CS is forced to ascend the septum and subsequently to activate the lateral and inferior RA wall in a descending direction (Fig. 2). Under these circumstances close mapping of the RA infero-lateral free wall should be adequate to detect changes in the atrial activation pattern during proximal CS pacing and additional detailed mapping points obtained from the superior aspect of this circuit are not particularly valuable information. We carefully deployed the decapolar electrode in order to cover this particular area of the RA. This resulted in an impressive demonstration of the development of clockwise isthmus block with a dramatic change of the activation pattern due to late activation of the low RA (Fig. 3a). The anticlockwise character of isthmus block was also indicated by the late activation of the proximal CS (after high RA and atrial component of His electrogram) during pacing from LLRA (Fig. 3b). In those cases where only incomplete isthmus block had been achieved, the decapolar electrode was again able to detect it by revealing the collision of the two wave fronts at the lower part of the lateral wall.

Our success rate of ablation and recurrence rate were similar in patients in whom a ‘Halo’ was used and those in whom a decapolar was used (Table 1). Our ablation success rates and recurrences were also comparable with those reported by other authors using a ‘Halo’ catheter. This suggests that the decapolar electrode is equally sensitive to the ‘Halo’ catheter to detect the presence of BIB and is supported by the absence of AFL recurrence in all patients with demonstrated complete BIB. On the contrary, recurrences of AFL were recorded only in those patients whom incomplete isthmus block had been detected from the decapolar catheter suggesting that it is unlikely there was BIB when atrial activation compatible with incomplete isthmus block

![Schematic representation of atrial activation during pacing from proximal coronary sinus (CS) following creation of complete isthmus block. The crista terminalis (CT) and eustachian valve (EV) form natural lines of block therefore the wavefront follows a route passing over the top of the right atrium and subsequently activating the inferolateral wall of the right atrium in a descending direction. Double lines indicate conduction block. IVC=inferior vena cava.](attachment:image.png)
was detected\textsuperscript{[13]}. In the single case of group B, where AFL reoccurred despite the detection of BIB by the ‘Halo’ catheter, partial recovery of isthmus tissue could be the explanation, however the patient was not restudied.

The procedure and fluoroscopy time was similar in the two groups (Table 1) and comparable with other investigators where only a ‘Halo’ catheter was used\textsuperscript{[5]}. We found that the deployment of the decapolar electrode in the antero-lateral and inferior wall of the RA was much easier and quicker compared with the ‘Halo’ catheter adjacent to the tricuspid ring. The stability of the catheter also proved remarkable throughout the procedure. Only in those cases with significantly dilated RA, additional manipulations were required during the study in order to reinstate the catheter to the original position. In these circumstances, the ‘Halo’ catheter may have proved to be the better catheter. In this study the decapolar electrode was inserted exclusively via the inferior vena cava. However, we have recently found that the same stability can be achieved by deploying the decapolar electrode in the antero-lateral and inferior RA wall through the superior vena cava in a J type configuration with the distal poles now lying in the mid RA and the proximal poles in the inferior RA.

An increased mean number of radiofrequency applications compared with other reported studies was observed in both groups. We counted all RF energy applications, even those where the catheter had been displaced during the application, which may explain this difference. The exclusive use of 4 mm tip ablating catheter, even in cases refractory to conventional ablation (>21 of RF applications)\textsuperscript{[14]}, is another important reason. Kirkorian et al.\textsuperscript{[15]} reported an increased mean number of RF applications in a study where only a 4 mm tip catheter was used. Other studies showed that an 8 mm tip catheter is more effective, requiring a reduced mean number of RF applications to create complete isthmus block\textsuperscript{[4,5,14]}. Eight mm tip catheters were not available to us and this avoided the introduction of another confounding factor between the groups. Anatomical factors such as a dilated RA, large and concave deformation of the isthmus may also have explained this difference\textsuperscript{[16]}.

**Study implications**

The present study suggests that use of a single decapolar catheter electrode for AFL ablation can have a significant impact on the cost of the procedure. The current price (including VAT) in U.K. for the decapolar catheter (DAIG Corporation, Minnetonka, MN, U.S.A.) with its connector is £358 ($572), whilst that of a ‘Halo’ catheter (Cordis-Webster, Miami, FL, U.S.A.) with its 2 connectors is £1507 ($2411). We have calculated and drawn a graph of the expected cost implications in a low volume (≤50 cases/year), medium volume (≤150 cases/year) and high volume (≤300 cases/year) electrophysiology centre assuming that 30% of the cases are AFL. These data indicate a substantial cost saving, depending on the volume of flutter ablation procedures performed by an individual lab (Fig. 4).

**Study limitations**

Although a systematic assessment of complete isthmus block was performed, misinterpretation of BIB due to a
significant intra-atrial conduction delay at the low RA cannot be excluded. However the lack of clinical recurrences in all but one patient with detected BIB suggests that even in this case the intra-atrial conduction delay at the isthmus may be sufficient to cure the patients.

In our patients verification of BIB was limited to an analysis of the RA activation sequence during pacing from CSP and LLRA while special attention was not paid to the electrograms on the ablation line in order to confirm the completeness of the lesion[17].

We did not look specifically at P wave changes on the surface ECG as markers of successful isthmus ablation because the resulting subtle changes in P wave morphology limited their specificity and sensitivity[18].

Our procedures were performed with a complete electrophysiological study followed by ablation. Hence the HRA and the His catheter were used routinely for the electrophysiological study and were in place at the time of the ablation. A reduced number of catheters could have been used leading to a further reduction of the overall cost of the procedure. Especially, the HRA catheter could easily be omitted in both groups, while an electrode in the His position has also been considered redundant by other groups[10,17]. Recording of septal activation via a His-bundle catheter provides, however, a more accurate evaluation of septal activation and as a result the completeness of counterclockwise block is easier to diagnose. Furthermore, a His bundle recording seems to be mandatory to assess accurately the atrioventricular conduction properties and potentially to reduce the risk of the procedure with respect to the induction of a complete heart block when the septal isthmus is targeted[1].

We speculate that our findings would also apply if 8 mm tip ablation catheter had been used instead of a 4 mm tip catheter.

Although no data regarding the effect of AVNRT mapping and ablation on the total procedure and fluoroscopy time have been presented, it is unlikely that they would have significantly influenced the results due to a rapid ablation of this arrhythmia usually with a single application of RF energy.

In the present study, the follow-up consisted of clinical visits every 2 months during which a routine 12 lead ECG was taken. Late control electrophysiological studies or 24 h Holter monitoring were not systematically performed in the patients who remained symptom-free. Therefore, asymptomatic (non clinical) partial or full late recovery of conduction in the IVC-TA isthmus cannot be ruled out.

The results on cost saving apply only to the U.K. as reimbursement systems are different in other European countries or the U.S.

### Conclusions

This study demonstrates that a single decapolar electrode deployed in the antero-lateral and low RA is equally as effective as the ‘Halo’ catheter in mapping the flutter circuit and demonstrating the bidirectional isthmus block during AFL ablation. Consequently, the use of this catheter is a reliable, easily deployed alternative to the routinely used ‘Halo’ catheter. This confers a very substantial cost saving if electrophysiological practice changes from use of the ‘Halo’ to a decapolar dependent on the volume of flutter ablation procedures performed by an individual laboratory.

### References


