Local electrogram assessment of unidirectional isthmus block is sufficient to predict the acute and long-term success of cavo-tricuspid isthmus ablation

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Ablation; Atrial flutter; Electrophysiology; Mapping.

Background. **This study investigated whether a minimal approach to typical atrial flutter ablation using an 8 mm tip catheter with a 150 W generator with only the documentation of clockwise block by means of local criteria predicts a good long-term outcome.**

Methods. **Seventy patients underwent typical atrial flutter ablation. A multipolar catheter was inserted into the coronary sinus (CS) and an 8 mm tip ablation catheter was used to ablate and map the isthmus. The ablation line was performed in the posteroseptal region. The clockwise block was confirmed by recording a corridor of double potentials along the line and by counterclockwise activation of the portion of the isthmus just beyond the lesion line as demonstrated by measuring the conduction times during CS pacing.**

Results. **In case of block, the mean distance between the two split atrial electrograms was 129 ± 31 ms. Acute isthmus block was achieved in all 70 patients. The median of the radiofrequency pulses was 10 (range 1-36). No immediate or late complications were noted. The long-term follow-up (19.5 ± 4 months) revealed recurrence of typical atrial flutter in 2 cases (2.8%).**

Conclusions. **Our results demonstrate that the acute success rate following typical atrial flutter isthmus ablation using an 8 mm tip catheter with a 150 W generator is high. No complications occurred. Moreover, the documentation of just the clockwise isthmus block using a minimal approach according to local electrogram criteria is a good predictor of the long-term success.**

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Introduction

Both anatomical and electrophysiological approaches have been employed for the ablation of typical atrial flutter (AFl)[1-13]. Nowadays the endpoint of the procedure is the achievement of a bidirectional block at the level of the inferior vena cava-tricuspid annulus (IVC-TA) isthmus since this correlates with a low incidence of recurrences. The definition of bidirectional block originates from the description of the possibility of achieving unidirectional blocks after isthmus ablation[14-18]. Recently, our group has demonstrated that patterns of incomplete or unidirectional blocks are due to conduction across the posterior region of the IVC orifice that in case of limited endocardial mapping after ablation may yield a pattern compatible with unidirectional block in spite of the presence of a bidirectional block in the IVC-TA isthmus[19].

In accordance with this observation, the aim of this study was to verify whether in the long run the documentation of a clockwise block as demonstrated by local electrogram criteria during catheter ablation of AFl is an equivalent prognostic indicator to bidirectional multielectrode isthmus block criteria.

Methods

Study population. The study population consisted of 70 patients (41 males, 29 females, mean age 56 ± 10 years). Twenty-nine patients had cardiomyopathy (7 dilated cardiomyopathy, 5 ischemic cardiomyopathy, 8 hypertensive cardiomyopathy, 8 valvular heart disease, and 1 arrhythmogenic right ventricular dysplasia) while the remaining patients presented with AFl without structural heart disease.

All patients had episodes of typical counterclockwise AFl; 3 patients also had clockwise AFl and 7 patients presented with coexistent paroxysmal atrial fibrillation. Antiarrhythmic prophylaxis (at least two drugs) was ineffective in all patients. In all patients, thyroid function tests were within normal limits.

Electrophysiological study. All patients gave written informed consent. Antiarrhythmic drugs had been discontinued for at least 5 half-lives and no patient had received amiodarone in the preceding 6 months. The electrophysiological study was performed using an octapolar steerable catheter with a 2 mm interelectrode distance (Cordis-Webster Inc., Baldwin Park, CA, USA). The catheter was positioned in the coronary sinus (CS) via a right femoral vein approach and used for pacing from the proximal CS.

The ablation catheter was then introduced into the right atrium from the right femoral vein. In those patients who were in sinus rhythm we proceeded to ablation. In those patients who were in AFl we confirmed that the AFl was isthmus-dependent using the entrainment technique and then performed the ablation procedure.

Bipolar digitized endocardial atrial electrograms and surface ECG leads were simultaneously recorded (1 KHz sampling frequency, 30-500 Hz band-pass filters), displayed on a multichannel recorder and stored on magneto-optical disks (Cardiolab, Prucka Engineering Inc., Houston, TX, USA).

Ablation procedure. Radiofrequency (RF) ablation was performed with a generator EPT-1000 XP (EP Technologies, Mountain View, CA, USA) that delivered continuous unmodulated current at 500 KHz in a monopolar fashion and had a maximum power output of 150 W. RF lesions were delivered using an 8 mm tip electrode catheter (Blazer XP large curve, EP Technologies, Mountain View, CA, USA) in a temperature-guided mode (preset temperature of 60 to 70°C).

In sinus rhythm the procedure was performed while pacing from the proximal CS at twice the diastolic threshold at a cycle length of 600 ms.

Within the isthmus and close to the TA, the ablation catheter was initially positioned in such a way that a large ventricular potential and a small atrial electrogram were recorded (A/V ratio 0.1). The preset duration of the pulse was 60 s.

The ablation line was drawn in a posteroseptal position and the catheter was progressively drawn back under fluoroscopic guidance with sequential stops between each RF delivery in order to reach the IVC edge.

The endpoint of the procedure was the achievement of a complete clockwise isthmus block. We presumed complete block after having obtained a corridor with split atrial electrograms separated by an isoelectric interval along the ablation line. Complete block was then confirmed by analyzing, during CS pacing, the timing from the CS activity and the local atrial electrogram recorded on the ablation catheter in two positions: the first one just beyond the lesion line and the second one in a more posterolateral site on the IVC-TA isthmus. Clockwise block was considered present if the conduction time from the atrial electrogram closer to the lesion line was delayed in comparison with that measured in a more posterolateral position thus indicating counterclockwise activation of the isthmus during pacing from the CS (Fig. 1).

After interruption of the arrhythmia during RF delivery in patients with AFl at the time of the procedure or after the completion of the lesion line in patients in sinus rhythm, we mapped the line so as to find and eliminate any conduction gaps. Conduction gaps were defined as sites of recording of single or fragmented potentials between two sites with split electrograms[20].

In order to reduce the likelihood of early recurrence of isthmus conduction, the persistence of isthmus block was verified after 20 min.

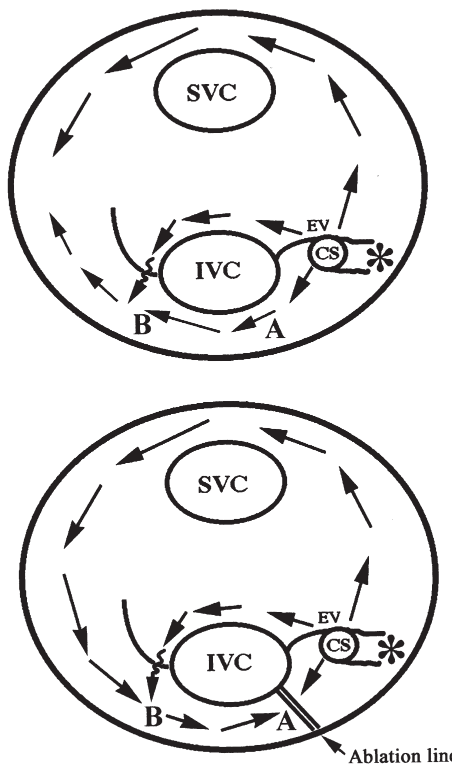

Figure 1. *Right atrium schema. The* upper panel *shows the sequence of atrial activation before isthmus ablation during pacing (*) from the coronary sinus os (CS). The atrial wavefront is able to circulate all around the inferior vena cava (IVC) orifice and timing in points A and B demonstrates its clockwise direction on the isthmus. The* lower panel *shows the sequence of atrial activation after isthmus ablation during pacing (*) from the CS. The atrial wavefront is blocked at the level of the ablation line while circulates through the posterior region of the IVC orifice. The timing in points A and B demonstrates a counterclockwise direction of the atrial wavefront on the isthmus. EV = Eustachian ridge; SVC = superior vena cava orifice.*

Results

At the time of the procedure, 43 patients were in sinus rhythm whereas 27 presented typical AFl with a mean cycle length of 235.7 ± 29 ms (range 210-310 ms). In all 27 patients with typical AFl, the entrainment technique showed that the IVC-TA isthmus formed part of the reentry circuit.

Ablation results. The ablation procedure was successfully performed in all patients. In the 27 patients with typical AFl at the time of the procedure, we observed that the arrhythmia was interrupted during RF delivery.

In all but 4 patients it was necessary to eliminate conduction gaps after completion of the line. The median of RF pulses was 10 (range 1-36). All the RF pulses were delivered along the same line. In some cases the delivery was repeated on the same site so as to obtain a transmural lesion with a local sign of block. No immediate or delayed complications occurred.

In all 70 patients the achievement of a complete isthmus block correlated with a splitting and consequently a sudden increase in the distance between the two atrial components recorded on the ablation catheter during RF energy delivery (Fig. 2).

Analyzing the atrial electrograms along the lesion line on the IVC-TA isthmus we have noted a strict correlation between the presence of a corridor of split electrograms with the achievement of a complete isthmus block (Fig. 3). The clockwise block presumed on the basis of these criteria was always confirmed by the counterclockwise activation of the isthmus mapped by means of the ablation catheter during pacing from the proximal CS (Fig. 4). The mean distance between the two components of split atrial electrograms after having demonstrated a complete block was 129 ± 31 ms (range 90-172 ms) and the mean conduction time between proximal CS activation and the latest isthmus atrial activity, just beyond the line, was 186 ± 31 ms (range 107-244 ms).

Early recurrence of isthmus conduction was seen in 17 out of 70 (24%) patients when the persistence of block was verified after 20 min. The recovery of isthmus conduction correlated with the disappearance of the corridor of split atrial electrograms and the appearance of isthmus activation in a clockwise fashion. Complete block was again achieved by means of repeat RF energy delivery employed so as to close the gaps of conduction along the line.

Follow-up. During a mean follow-up of 19.5 ± 4 months (range 11-21 months), 2 patients (2.8%) presented with recurrence of typical AFl and 2 others had

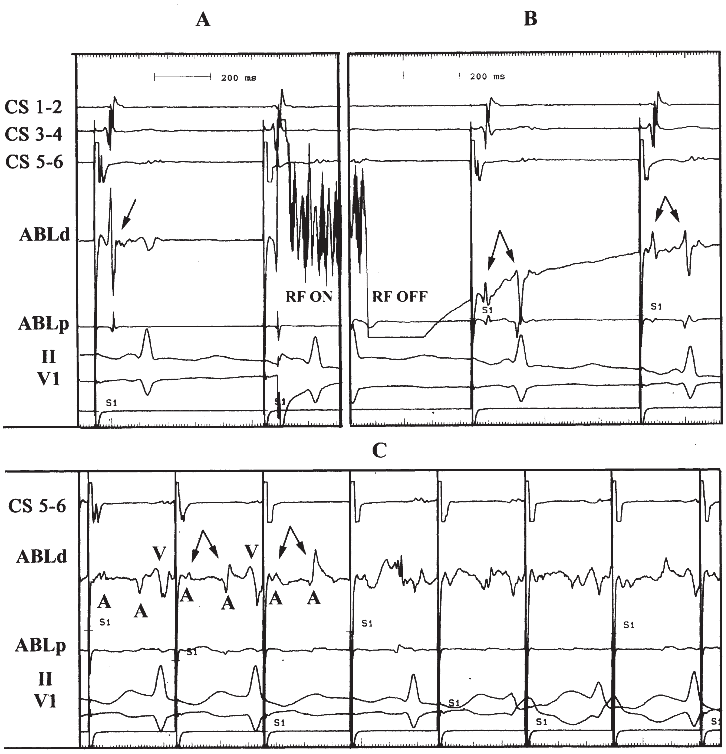

Figure 2. Panel A: *ablation site at the level of the edge of the inferior vena cava during pacing from the coronary sinus (CS 5-6) os. The* arrow *shows, on the ablation catheter recording, an atrial electrogram followed by a second low amplitude component before the delivery of radiofrequency (RF ON).* Panel B: *recordings from the previous ablation site at the level of the edge of the inferior vena cava after interruption of radiofrequency delivery (RF OFF). The* arrows *show a double atrial electrogram with a long isoelectrical interval between the two components.* Panel C: *same ablation recording site as* panel B *during incremental CS os pacing at the Wenckebach point of the atrioventricular node that unmasks the second component of the split atrial electrogram* (arrows). *A = atrial electrogram; ABLd = distal bipole ablation catheter recording; ABLp = proximal bipole ablation catheter recording; CS 5-6, 3-4, 1-2 = coronary sinus recording from the three pairs of electrodes; the catheter was positioned in such a way that the bipole 5-6 was at the os of the CS; V = ventricular electrogram.*

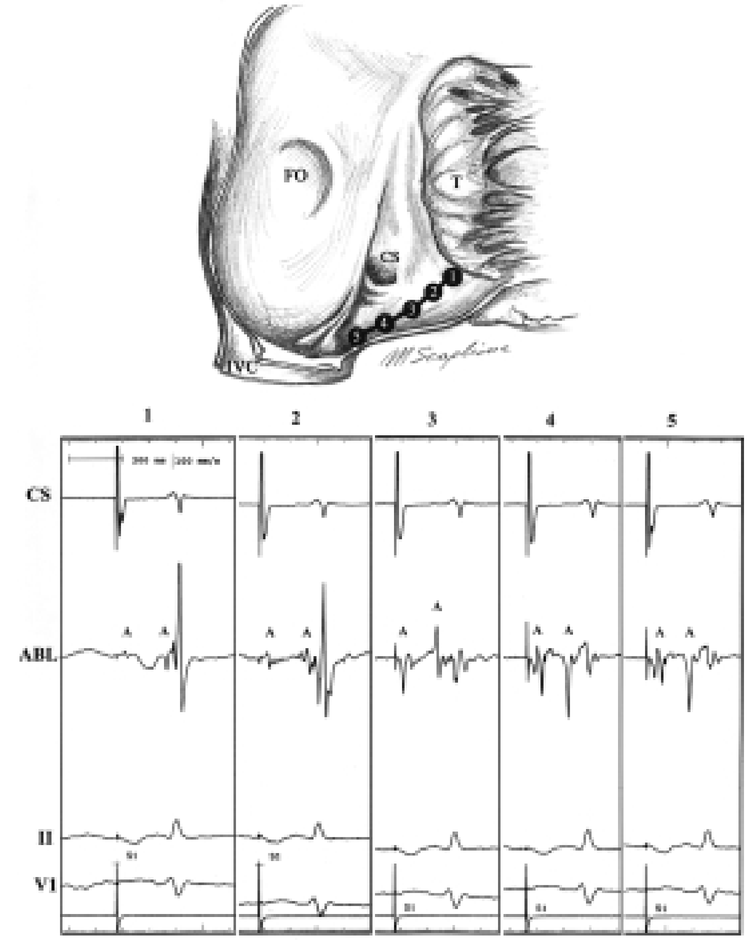

Figure 3. *Complete isthmus block: mapping of the ablation line.* Top: *schema of the right atrium in the right anterior oblique view. The* black circles *indicate the ablation line in a posteroseptal position along the isthmus. Each different numbered position of the line correlates with the* panels on the bottom *of the figure showing the endocardial and surface recordings at each site.* Panels 1-5: *endocardial and surface recordings at five different sites on the ablation line. Looking at the different sequential panels it is possible to appreciate a complete corridor of double atrial potentials (A) separated by an isoelectric interval correlating with complete isthmus block. ABL = distal bipole ablation catheter recording; FO = fossa ovalis; T = tricuspid valve leaflet. Other abbreviations as in figure 1.*

episodes of paroxysmal atrial fibrillation. The 2 patients with recurrence of typical AFl underwent a second procedure which confirmed the reappearance of conduction across the IVC-TA isthmus. These patients were submitted to successful ablation which resulted in the closure of the conduction gaps obtaining a complete corridor of double potentials.

Discussion

Typical AFl is an arrhythmia with a well-defined macroreentrant circuit[21,22] and a critical isthmus bordered by the TA, the Eustachian ridge, the IVC orifice and the CS os represents the target site of the ablation procedure[1-3,10,11,14-18,23-27]. Nowadays, the achievement of a complete bidirectional block at the IVC-TA isthmus verified at multielectrode mapping has been considered the most reliable predictor of long-term success[14-18]. Some authors[15] described the possibility of obtaining an activation pattern compatible with incomplete and/or unidirectional block that correlates with recurrences during follow-up. It has been recently demonstrated however that after ablation the conduction across the posterior region of the IVC orifice may yield a pattern compatible with unidirectional incomplete block although a bidirectional block in the IVC-TA isthmus is present[19]. This phenomenon depends on the fact that, in the presence of complete isthmus block, the wavefront originating from the posterior region of the IVC orifice may activate the low lateral right atrium mimicking the persistence of isthmus conduction on the bipolar recordings exploring the activation in the low lateral right atrial wall. On the basis of this observation, it seems reasonable to assume that the isthmus is a single entity allowing only the presence or the absence of block that is consequently always bidirectional.

Because of this observation it becomes really important to find a reliable indicator of complete isthmus block, thus avoiding the possibility of a misdiagnosis due to the atrial activation pattern influenced by the specific anatomy of the low right atrium.

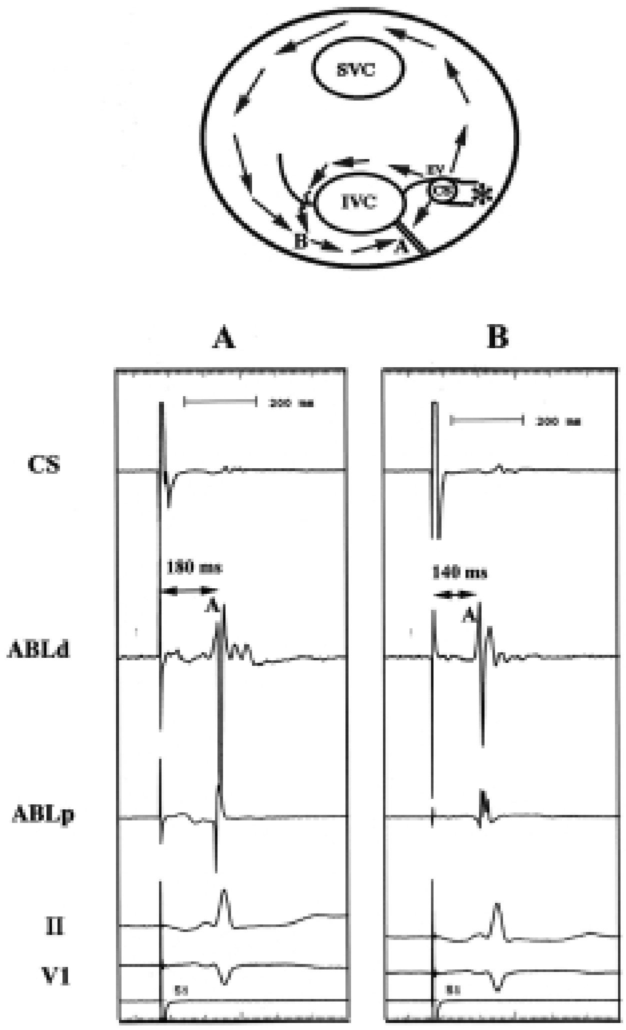

Figure 4. Top: *right atrium schema showing the sequence of atrial activation after isthmus ablation during pacing (*) from the CS. The atrial wavefront is blocked at the level of the ablation line while it circulates through the posterior region of the IVC orifice. The timing in points A and B demonstrates a counterclockwise direction of the atrial wavefront on the isthmus.* Panel A: *mapping site just beyond the ablation line (point A on schema) during CS pacing after having obtained a complete corridor of double potentials along the isthmus.* Panel B: *mapping site in a posterolateral position of the isthmus (point B on the schema) during CS pacing after having obtained a complete corridor of double potentials along the isthmus. Analysis of the timing intervals highlights the fact that the sequence of activation along this part of the isthmus has a counterclockwise direction during CS pacing. This signifies a complete conduction block in the posteroseptal position. Abbreviations as in figures 1 and 2.*

In order to verify this issue we validated the presence of clockwise block pacing from one site (i.e. the CS) using local electrogram-based criteria of isthmus block.

We decided to perform the procedure by pacing from the CS os such that after having produced a lesion line in a posteroseptal position on the isthmus we could analyze the activation sequence along the isthmus and hence confirm the presence of complete block.

The first electrophysiological criterion, i.e. the presence of a corridor of double potentials which, in turn, is an expression of a local block was always confirmed by mapping two sites on the isthmus with the ablation catheter: one just beyond the line in a posterior and another one in a posterolateral position while pacing from the CS. The measurements of the conduction times from these two sites confirmed a counterclockwise activation of the isthmus only in the presence of a corridor of split atrial potentials separated by an isoelectric line. Such a corridor indicates complete isthmus block. This precise and direct correlation of isthmus mapping with local signs of block along the lesion line may be explained because the isthmus is a strip of atrium "protected" by electrical obstacles where, in the presence of a posteroseptal lesion, the conduction across the posterior region of the IVC cannot lead to a misdiagnosis of the presence of a complete block during pacing from the CS os (Fig. 1). In fact, other studies using local electrogram criteria of block[28] demonstrated the possibility of a misdiagnosis or misunderstanding of isthmus block in some patients (15%) when indirect mapping criteria based on CS os and right septum timing during pacing from the low lateral right atrium are used. Moreover, it is also possible that when the conduction across the posterior region of the IVC activates the CS and the septal region it may be suggestive of the persistence of counterclockwise isthmus conduction despite the presence of complete block as we have demonstrated in the clockwise direction[19]. Furthermore, the same authors[28] concluded that isthmus block might be present despite the presence of sites without two completely separated atrial electrograms and/or of sites with fragmented atrial activity along the lesion line. In contrast to this observation, in our study the appearance of complete clockwise isthmus block correlated always and only with the sudden increase in the distance between the local double atrial potentials obtained with the preceding RF deliveries and with the presence of a corridor of split atrial potentials along the line with a long distance between the two atrial components (mean 129 ms). The presence of fragmented or double but very close atrial potentials in some areas of the lesion line always correlated with the absence of subsequent criteria of isthmus block. A critical delay between the two split atrial components in the corridor indicating the achievement of a complete block was not found although it was always > 90 ms.

Another important finding deriving from the present study is that using an 8 mm tip catheter together with a 150 W generator we were able to obtain a complete isthmus block in all patients without complications.

In a minority of patients the number of RF pulses required to obtain our goal was quite high, because of the isthmus morphology determined by the presence of muscular ridges and of the terminal portion of the pectinate muscles or because RF pulses on the same site had to be delivered repeatedly in order to obtain a transmural lesion.

The possibility of obtaining such a very high success rate is highly important since with conventional ablation catheters it is not always possible to achieve a complete bidirectional isthmus block[29]. The precise reason for the resistance to conventional RF ablation is unclear: it might be due to a thicker than usual isthmus myocardium or to a particular site topography or even to the edema associated with the RF lesion that renders complete necrosis in the deeper layers difficult[30,31]. All these problems may be overcome by using more powerful ablation catheters (larger tip electrode, more watts, irrigated catheters, etc.) which permit the infliction of larger and deeper lesions[29,32-34]. In our experience, the use of an 8 mm tip catheter and the possibility of delivering high energy were very useful in the presence of anatomical variants or in the thicker portion of the isthmus.

Despite the achievement of a high rate of acute success we must stress the importance of verifying the persistence of isthmus block for at least 20 min, in order to eliminate early recurrences of isthmus conduction[28,35]. In fact, the reappearance of isthmus conduction within 20 min was observed in 24% of patients. The closure of these residual conduction gaps was associated with a very low long-term recurrence rate.

In conclusion, the achievement of clockwise isthmus block strictly correlates with a corridor of double potentials separated by an isoelectric interval along the lesion line and with the demonstration of counterclockwise activation of the isthmus during CS pacing. This unidirectional assessment of block using local electrogram criteria appears to be sufficient for the prediction of the acute and long-term success in typical AFl ablation. In addition, isthmus ablation using an 8 mm tip catheter with a 150 W generator resulted in a 100% acute success rate with a low recurrence rate during follow-up. The feasibility of isthmus ablation using this simplified two-catheter approach may reduce the cost of the procedure while maintaining the same long-term success rate as the standard method.

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