Three-dimensional electroanatomical mapping of right periatriotomy tachycardias after interatrial defect correction

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Summary
Background. — Pericicatricial right intra-atrial reentrant tachycardias occur frequently in patients who have undergone surgical correction of an interatrial defect.
Aim. — To characterize the tachycardia circuits using three-dimensional electroanatomical mapping.
Methods. — Twelve tachycardias were analysed in 11 patients who had undergone surgical correction of an interatrial defect. Patients were divided into two groups: atrial flutter with typical sawtooth flutter waves in inferior leads, atrial tachycardia with clearly delimited P waves separated by an isoelectric line.
Results. — Seven tachycardias were classified as atrial flutter; three-dimensional mapping identified a pericricuspid circuit with inferior vena cava-tricuspid annulus isthmus involvement in all cases. All atrial flutters were terminated by linear ablation of this isthmus. Five tachycardias were classified as atrial tachycardia; three-dimensional mapping identified periatriotomy loops. All atrial tachycardias were ablated successfully between two scars or between a scar and an anatomical barrier.

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Conclusion. — Periatriotomy loops were always associated with an atrial tachycardia electrocardiogram pattern. Three-dimensional electroanatomical mapping appeared to be particularly useful for circuit identification and for ablation of these complex arrhythmias. © 2008 Elsevier Masson SAS. All rights reserved.

**MOTS CLÉS**
Flutter atrial ;
Ablation par cathéter ;
Congénital ;
Cartographie électroanatomique ;
Communications intracardiaques ;
Tachycardies incisionnelles

**Résumé**
Historique. — Les tachycardies par réentrées intra-atriales droites péricicatricielles compliquent fréquemment la chirurgie réparatrice des communications interauriculaires (CIA).
But de l’étude. — Caractériser les différents circuits d’arythmie par cartographie électroanatomique tridimensionnelle.
Méthodes. — Douze tachycardies ont été analysées chez 11 patients ayant bénéficié d’une cure chirurgicale de CIA. Ces tachycardies ont été séparées en deux groupes : celles ayant une allure flutterienne typique, avec un aspect en dents de scie dans les dérivations inférieures et celles ayant un aspect de tachycardie atriale, avec des ondes P discrètes, séparées par une ligne isoelectrique.
Résultats. — Sept tachycardies ont été qualifiées de fluttriennes ; la cartographie tridimensionnelle identifiant dans tous ces cas un circuit péricicatridial avec passage dans l’isthme cavotricuspide. Le traitement par ablation linéaire par radiofréquence de cet isthme a été efficace. Cinq arythmies ont été classées comme tachycardies atriales ; la cartographie mettant en évidence une macroréentrée autour de la cicatrice d’atriotomie. Ces dernières ont toutes été ablatées avec succès, soit entre deux zones cicatricielles, soit entre une cicatrice et une barrière anatomique.
Conclusion. — Les macroréentrées péricicatricielles droites étaient toutes associées à un électrocardiogramme de tachycardie atriale. La cartographie tridimensionnelle s’est révélée particulièrement utile pour l’identification des circuits et le traitement par radiofréquence de ces arythmies complexes.
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**Abbreviations**
AFI atrial flutter
AT atrial tachycardia
CS coronary sinus
ECG electrocardiogram
IAD interatrial defect
IART intra-atrial reentrant tachycardia
IVC inferior vena cava
RF radiofrequency
SVC superior vena cava
3-D three-dimensional
TA tricuspid annulus

**Introduction**

Right intra-atrial reentrant tachycardias (IARTs) are late arrhythmias that occur regularly after the surgical correction of an interatrial defect (IAD). The right atriotomy scar may be the central anatomical barrier around which the reentrant circuit can rotate. However, the inferior vena cava–tricuspid annulus (IVC–TA) isthmus is also involved frequently.

Electrocardiographical analysis of IARTs has been proposed as a means of classifying the type of tachycardia circuit [1–3]. We used a three-dimensional (3-D) electroanatomical mapping system (CARTO, Biosense Webster Inc., Diamond Bar, CA, USA) to better characterize the reentrant circuits and their correlation to the surface electrocardiogram (ECG) pattern.

**Methods**

**Patient selection**

Eleven consecutive patients who presented with atrial flutter (AFI) or atrial tachycardia (AT) on the surface ECG after IAD surgical correction underwent 3-D electroanatomical mapping and radiofrequency (RF) ablation using the CARTO system.

All patients gave informed consent for the procedures in accordance with conventional guidelines and the declaration of Helsinki.

**Definitions**

**Electrocardiographic patterns**

Two independent observers evaluated the 12-lead surface ECGs during tachycardia. AFI and AT were defined as follows (Fig. 1): AFI was diagnosed if there were clear, continuous sawtooth flutter waves on leads II, III and aVF, without isoelectric line or discrete identified P waves; AFI was further classified as type I AFI (common) if flutter waves were negative in inferior leads and positive in V1, or as type II AFI if flutter waves were positive in inferior leads and negative in V1; AT was diagnosed if there were discrete, positive P waves on leads II, III, and aVF, with a clear beginning and ending separated...
Figure 1. Standard lead ECG from a patient with AFI (left panel) and a patient with AT (right panel). Note the distinct features in the inferior leads: a sawtooth pattern in AFI and a discrete P wave in AT.

Three-dimensional electroanatomical mapping

CARTO mapping was used to localize the IART in each patient. The complete reentrant circuit was considered to be the spatially shortest route of unidirectional activation around the central barrier, covering more than 90% of the cycle length. We then distinguished two types of right atrial circuits: IVC–TA isthmus-dependent tachycardia, when the arrhythmia circuit included a unidirectional activation of this isthmus on activation and propagation maps, with a peritricuspid sequential depolarization; and pericicatricial tachycardia, when the arrhythmia circuit showed sequential activity around and/or between atrial scars on activation and propagation maps (in these cases, the IVC–TA isthmus was not included in the main circuit but was depolarized secondarily).

Electrophysiological study

All antiarrhythmic drugs were discontinued at least five half-lives before the electrophysiological study. An active fixation catheter was placed in a stable position in the right atrium and was used as the electrophysiological reference. After identification of anatomical landmarks (SVC, IVC, TA, and coronary sinus ostium), the CARTO system was used to construct the right atrial 3-D electroanatomical activation and propagation maps by sequential point acquisition as described previously [4]. Local activation times were determined automatically by the computer, and were checked manually and corrected if necessary. Scars were defined as areas of low voltage (< 0.1 mV) or electrically silent zones, and double potentials were defined as bipolar atrial electrograms separated by an isoelectric line. Mapping was stopped after recording of at least 90% of the tachycardia cycle length, with a sufficient density of points (especially in the IVC–TA isthmus) around the right atriotomy and the scar areas.

Radiofrequency ablation

Based on activation and propagation maps, patients underwent catheter ablation with a conventional RF generator (Stockert, Cordis-Webster Corp., Watertown, MA, USA). RF catheter ablation was performed with a temperature-controlled catheter (8 mm tip, Cordis–Webster Corp.), a target of 65 °C, a maximal power of 100 W, and sequential 60-second applications. Linear transection of the IVC–TA isthmus was performed in patients with IVC–TA isthmus-dependent tachycardia. In patients with pericicatricial tachycardia we determined the critical isthmus of the circuit and performed a line either between the inferior limit of the atriotomy and the IVC or between two scars. Success was defined as termination of the tachycardia with a subsequent lack of inducibility of the clinical tachycardia and confirmation of bidirectional complete block across the ablation line on new activation maps while pacing at both sides of the line.

Results

Patients

Eleven consecutive patients with recurrent atrial arrhythmias after corrective surgery for an IAD were included prospectively for analysis. The study population comprised four men and seven women, with a mean age of 51.8 years (range, 32–69 years). All patients had undergone surgical closure of ostium secundum atrial septal defect.

Twelve IARTs were identified in these patients (two different forms during the same procedure in one patient), all of which were located in the right atrium. Seven IARTs were classified as AFI and five as AT by ECG analysis as defined previously. 3-D electroanatomical mapping identified the tachycardia circuit, the central obstacle, and the protected zones of slow conduction in all cases. No complications were associated with the subsequent ablation procedures.
Figure 2. Activation map of a counterclockwise postoperative AFI in a posteroinferior view with a slight bottom rotation (depolarization front illustrated by a black arrow). The activation front is propagating through the IVC—TA isthmus where linear ablation was performed (red dots). A line of double potentials corresponding to the atriotomy scar is seen in the lateral wall of the right atrium (blue dots).

**Tachycardias with atrial flutter ECG criteria**

Seven tachycardias were classified as AFl by two independent ECG analyses, six of which fulfilled the diagnostic criteria for type I AFl and one for type II AFl. Cycle lengths ranged from 240 to 335 ms, with a mean cycle length of 279 ms.

3-D mapping was able to identify the involvement of the IVC—TA isthmus in all cases. The main circus movement was turning around the tricuspid annulus with some complex participation of the scar areas (Fig. 2). A counterclockwise rotation was identified in the six patients with type I AFl, and a clockwise depolarization sequence was identified in the patient with type II AFl.

Sequential linear ablation of the IVC—TA isthmus terminated the clinical tachycardia in all patients, with a mean of 11.7 RF pulses (range, 8—18 pulses) required to create a complete isthmus block.

**Tachycardias with atrial tachycardia ECG criteria**

Five tachycardias were classified as AT by ECG analysis. Cycle lengths ranged from 220 to 310 ms, with a mean cycle length of 275 ms.

3-D electroanatomical mapping was able to identify a pericicatricial loop in all cases, without primary participation of the IVC—TA isthmus (Fig. 3).

One tachycardia was terminated by a radiofrequency line between two identified scars and four were terminated by linear ablation between the inferior limit of the atriotomy to the IVC, using a mean of 15.8 RF pulses (range, 14—18 pulses).

**Discussion**

Right IART is a frequent late complication after surgical closure of an IAD [5,6]; it is often drug resistant, and RF catheter ablation has been shown to be an effective and safe technique for terminating the tachycardia and preventing recurrence [7,8]. A successful procedure is based on a
clear understanding of the depolarization front in the right atrium.

The conventional electrophysiological approach is based on entrainment pacing to determine protected zones of slow conduction in the circuit, with concealed fusion determination and postspacing interval analysis during tachycardia [9,10]. Arrhythmia termination by RF current delivery is obtained by targeting the critical isthmus of slow conduction [11–15].

More recently, 3-D electroanatomical mapping has been shown to be useful in localizing the IART circuit. Correlation between determination of the arrhythmia circuit by conventional entrainment techniques and by CARTO mapping appears to be excellent [16–19]. Entrainment pacing may still be helpful in confirming the reentry mechanism and determining the best site for ablation [20]. With the CARTO system, the arrhythmia loop is represented by a colour-coded activation map covering the whole cycle length. The isthmuses are localized directly between scar areas and/or between scar areas and anatomical barriers such as the IVC, SVC or TA. The protected conduction corridors are visualized directly by activation, propagation and voltage maps. The scar of atriotomy is identified readily as a vertical lateral line of double potentials on the right atrial free wall, anterior to the crista terminals. Activation around the atriotomy is analyzed carefully, especially between its inferior margin and the IVC, as well as the IVC–TA isthmus participation.

Two main atrial loops are usually reported in patients presenting with incisional tachycardias after IAD surgical correction. The depolarization front may rotate around the scar of atriotomy with no primary participation of the IVC–TA isthmus [13,14]. On the contrary, the activation front may involve the IVC–TA isthmus as a critical component of the circuit. The latter can account for greater than 70% of postoperative atrial tachycardia [21]. Dual loop IART (figure-of-eight circuit type) can also exist in this population [22].

Different electrocardiographic features of atrial arrhythmias have been described in men after an operation for congenital heart disease, and in an animal model [23,24]. In our series we have confirmed that the usual sawtooth flutter waves on inferior leads (defined as type I and type II AFI) were always associated with a macro reentrant circuit that included the IVC–TA isthmus, making it the critical zone for linear ablation. By comparison, discrete P waves on inferior leads separated by an isoelectric line, or at least with a clear beginning and ending, and without any sawtooth pattern (defined as AT), were always related to a more or less complex pericatricial loop. In these cases, tachycardia was terminated by creating a line of block either from the surgical scar to the IVC or between two atrial scars. None of our patients with AT pattern had primary involvement of the IVC–TA isthmus.

In conclusion, we found that pericatricial loops were always associated with an AT surface ECG pattern. The use of a 3-D mapping system appeared to be particularly useful in guiding RF ablation in these complex arrhythmias.

**Conflict of interest**

None declared.

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**References**


