Atrial mapping by basket catheter in patients with atrial fibrillation submitted to linear ablation

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Summary. - Recently non-pharmacological therapies for atrial fibrillation (AF) have been developed. The electrophysiological mechanisms of AF is thought to be the development of multiple reentrant wavelets circulating around anatomic barriers and variable regions of functional conduction block responsible of the perpetuation of the arrhythmia. Also the role of the triggering foci has been highlighted. To cure AF by means of non pharmacological therapy we may eliminate and/or modify the substrate. To better understand the mechanism underlying the AF and to choose the best ablation strategy is of fundamental importance to map the right and the left atrium during AF. Our experience shows that in chronic idiopathic AF disorganized atrial activity is observed at all atrial regions while in paroxysmal idiopathic AF the left septum and the right atrial posterior areas are highly disorganized while the lateral region shows more organized atrial electrical activity. Multipolar basket catheters are extremely useful in mapping right and left atrium in order to guide the best ablation strategy.

Key words: mapping, atrial fibrillation, electrophysiology.

Riassunto (Mappaggio mediante catetere basket in pazienti con fibrillazione atriale selezionati per ablazione con catetere lineare). - Terapie non farmacologiche per la fibrillazione atriale (FA) sono state recentemente sviluppate. I meccanismi elettrofisiologici della FA si pensa siano basati sullo sviluppo di onde di depolarizzazione circolanti attorno a barriere anatomiche o funzionali. Anche il ruolo di foci ectopici di trigger è stato ipotizzato. Per curare la FA mediante una terapia non farmacologica abbiamo eliminato e modificato il substrato. Per meglio comprendere il meccanismo alla base della FA e per scegliere la migliore strategia per l’ablazione è di fondamentale importanza mappare l’atrio destro e sinistro durante FA. La nostra esperienza mostra che nella FA cronica idiopatica tutte le regioni sono caratterizzate da attività atriale disorganizzata mentre in FA parossistica idiopatica il setto sinistro e l’area posteriore dell’atrio destro sono molto disorganizzate mentre le regioni laterali mostrano attività elettrica organizzata. I catetere basket multipolari sono estremamente utili per il mappaggio sia in atrio sinistro che destro al fine di scegliere la migliore strategia di ablazione.

Parole chiave: mappaggio, fibrillazione atriale, elettrofisiologia.

Introduction

Atrial fibrillation (AF) is the most common sustained arrhythmia and it is associated with significant morbidity and mortality. The therapeutic strategies proceed over two directions: restoration and maintenance of sinus rhythm with antiarrhythmic drugs or control of ventricular rate and anticoagulation therapy. Neither of these approaches is effective: side effects are associated with long-term antiarrhythmic therapy and anticoagulation carries the risk of potential bleeding complications. For these reasons non pharmacological therapies have been developed. In particular in the ’80s Cox developed the Maze procedure to cure the atrial fibrillation with a high rate of success [1].

Subsequently a more limited procedure consisting in a cryoablation of only posterior left atrium has been proposed with good results [2].

To avoid the cardiopulmonary by-pass and thoracotomy catheter-based radiofrequency ablation has been proposed with varying percentage of success.

To develop newer therapies for atrial fibrillation is crucial to understand its mechanisms. AF initiation has been related to the presence of several factors such as atrial extrasystoles, especially those with short coupling interval and with rapid firing rates due to ectopic foci localised most often in the pulmonary veins [3]. On the other side, short and dishomogeneous atrial refractoriness and intraatrial conduction disturbances constitute the substrate for the maintenance of AF [4]. These latter electrophysiological characteristics of the atrium favor the appearance and maintenance of the reentry mechanism consisting of multiple wavelets circulating around anatomic barriers and variable regions of functional conduction block allowing the perpetuation of AF. This hypothesis was first
proposed by Moe et al. [5] and then it was confirmed experimentally by Allessie et al. [6]. Their experimental data suggest that wavelets occurring during AF are not homogeneously distributed in the atria.

The non pharmacological treatment of AF may be obtained either eliminating the triggers or modifying the substrate. The former is achieved by ablating the ectopic foci initiating the arrhythmia or with the electrical disconnection of the pulmonary veins where most of the triggering foci are located. Modification of the substrate can be achieved with linear lesions aiming to the creation of new electrical barriers thus preventing the circulation and self perpetuation of the multiple fibrillatory wavelets. Therefore the knowledge of the electrophysiology of AF is crucial for the choice of the best treatment and the best ablation strategy depending on the regions that are critical for the appearance or maintenance of AF.

Atrial activation during AF has been evaluated in some studies by high resolution epicardial mapping techniques but limited atrial regions (lateral walls) were analyzed, [6-9] while in other studies the analysis of atrial activation was performed with endocardial mapping in a limited number of sites [10, 11] or without simultaneous multisite mapping [3, 12] and populations not representative for clinical AF were evaluated [1, 7]. A wide spectrum of electrical activation patterns during AF was observed, although in general it was recognized that the regions more disorganized were found in the septum and posterior wall of both atria rather than in the lateral wall [10-12].

The use of multipolar catheters may allow a simultaneous recording from different regions permitting in such a way the analysis of different atrial activation patterns during AF. The “basket” catheters may play well this role since they are constituted of several electrodes positioned on flexible splines that expand when positioned in a heart chamber in order to fit its size and to be in contact with the atrial walls.

Basket catheters can also be used to recognise the electrical activity inside the pulmonary veins or to facilitate the detection of the origin of the ectopic foci. However considering its shape the basket catheter may be particularly useful to evaluate the electrical activation during AF in the right and left atrium (Figs 1 and 2) although its precise analysis is rather difficult due to the irregularity and the apparent continuous change of the atrial activation. Most of the few studies on mapping of AF have been performed in the right atrium since the procedure avoids the need of a transeptal puncture and the risks of systemic thromboembolism.

**Methods**

Based on these theoretical considerations we decided to map the right and the left atrium during AF in patients with paroxysmal and chronic idiopathic AF [13]. The procedure has been performed in a group of 30 patients (24 men, 6 women) with a mean age of 48.4 ± 10.4 years. Eighteen patients had history of frequent episodes of paroxysmal AF (> than 2 episodes/month) and 12 had a chronic AF defined as > 2 weeks in duration (AF mean duration 14 ± 12 months; range 3 weeks to 42 months). No difference in mean age and size of both atria was observed between patients with paroxysmal and chronic AF. All the patients underwent an electrophysiological study in a drug-free state.

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**Fig. 1.** - Fluoroscopic views of catheter position. Constellation catheter in the left atrium. Decapolar catheter in the coronary sinus. RAO: right anterior oblique view; LAO: left anterior oblique view; AP: postero-anterior view.
A multipolar catheter (Constellation catheter, EP Technologies, Inc.) was used to map the right atrium, and two decapolar catheters with 2 mm interelectrode distance and a 10 mm distance between each bipole were employed (Cordis-Webster, Inc.), one placed retrogradely along the left septum, and the other one inserted in the distal coronary sinus (CS) to map the region of the lateral wall (Fig. 2). The Constellation catheter carries 64 electrodes mounted on 8 flexible splines (8 electrodes per spline). Each spline is identified by a letter (A to H) and each pair of electrodes by a number, 1 being the most distal and 4 the most proximal on the spline.

The atrial activation analysis was simultaneously performed during AF at different atrial sites. In patients with paroxysmal AF the shortest duration of either spontaneous or induced episodes of AF chosen for the analysis was of at least 5 minutes. The period analyzed was chosen randomly excluding the first and the last minute of AF.

Four different types of analysis were performed:

a) AF intervals (FF) duration was measured at 10 sites; 7 in the right atrium: high lateral (RHL), low lateral (RLL), high posterior (RHP), low posterior (RLP), high septum (RHS), low septum (RLS), and anterior (RAN); and 3 in the left atrium: high septum (LHS), low septum (LLS), and epicardial lateral wall through the CS. We considered as different F-waves the presence of 2 distinct electrograms clearly separated by an isoelectric space of at least 50 ms. The choice of the limit of 50 ms for the shortest FF interval, which is similar to that used in other studies, and the simultaneous evaluation of the atrial electrograms at the sites adjacent to those analyzed aimed to reduce the interference of double or fragmented and long duration electrograms;

b) the AF classification suggested by Wells [14] was used to grade the higher or lower regularity of the atrial electrograms at the same sites of FF analysis for periods of 60 s. Type I represents discrete atrial electrograms separated by an isoelectric line free of perturbation; type II also shows discrete organized atrial electrograms, but with perturbed isoelectric lines; type III is characterized by absence of discrete atrial electrograms without clear isoelectric interval. The type IV which is characterized by type III alternating with type I or II, was not considered since the duration of type I, II, III at each site was expressed as a percentage of the total duration of the analyzed period;

c) the morphology and sequence of atrial activation was evaluated along the right lateral (RL) and posterior wall (RP), along the right anterior wall (RAN), right (RS) and left septum (LS), and along the CS during the same 60 seconds of Wells’ analysis. This analysis was performed using all bipoles exploring each region. When we observed single potentials [15] separated by an isoelectric interval greater than 50 ms the atrial activity was considered organized. In the presence of double and/ or fragmented activation waves [15] the activation was considered disorganized;
d) in an attempt to summarize the spatial characteristics of electrical activity during AF in each patient, we classified the AF into 4 different patterns considering how many and which atrial regions showed a disorganized atrial activity. The regions considered were the RL, the RP, the CS and the septum (S). If the disorganization was confined to a part of the septum only, we considered the right and left septum separately. A region was considered disorganized when we observed fragmented electrograms and/or double potentials in at least two bipoles exploring the region and in more than 50% of the total time of analysis. Consequently the resultant pattern was the most prevalent one. The patterns are classified as follows: pattern A (Fig. 3) is defined by the presence of disorganized atrial activity only in one region, pattern B (Fig. 4) in two, pattern C in three and pattern D in all regions (Fig. 5). For each pattern we indicated the regions involved. This evaluation was performed during the same 60 s of Wells' analysis.

Results

This study showed that patients with paroxysmal AF showed longer FF intervals at all sites compared to patients with chronic AF. In patients with paroxysmal AF the FF intervals were significantly shorter at the right and left septum than at the right anterior and lateral wall. The patients with chronic AF had very short FF intervals in all locations with a significant reduction of the differences among different sites.

Types of Wells

The anterior and lateral right regions and the coronary sinus region presented a more prevalent type I AF while the septal region showed a predominant type III AF. Particularly the right anterior and the right lateral wall had a significantly higher incidence of organized activity (type I) compared to the left septum.

Fig. 3. - Examples of different patterns of atrial fibrillation. Pattern A. Left panel (A S): the atrial activation is regular in the lateral and posterior wall in the right atrium and in the coronary sinus, with a definite, single electrogram. The activation sequence is clearly craniocaudal in the right lateral wall. The septal region, both right (especially mid and low) and left, shows disorganized atrial activity with double, fragmented electrograms. Middle panel (A LS): the only disorganized area is the left septum. Right panel (A RP): atrial disorganization is evident in the right posterior wall while the other areas show organized activity. RAN: right anterior wall; RL: right lateral wall; RPL: right posterolateral wall; RP: right posterior wall; RPS: right postero-septal wall; RS: right septum; RAS: right antero-septal; LHS: left high septum; LMS: left mid septum; LLS: left low septum; DCS: distal coronary sinus; PCS: proximal coronary sinus; II: lead II ECG; S: both right and left septum; LS: left septum. Each pair of electrodes of the basket catheter is identified by a number: 1 is the most distal (superior) and 4 the most proximal (inferior) on the spline. At the bottom of each panel a 7 second ECG strip is showed; the space between vertical lines corresponds to the endocavitary signals.
Specifically, in paroxysmal AF the right lateral and anterior wall and the coronary sinus region showed a prevalent type I pattern that was present for more than 75% of the time analyzed. The septal region, mainly the left one, showed a more disorganized atrial activation with equal representation of type I, II, III pattern during the time period considered.

On the contrary in patients with chronic AF the prevalent patterns were type II and III at almost all sites. The right anterior and lateral wall showed a higher percentage of type I for the time considered but still for a less period of time in comparison with chronic AF.

**Regional activation sequences**

In paroxysmal AF the organized activity was mostly present in the RL and CS. In the RL craniocaudal activation was observed to greater extent than the caudocranial and indeterminable activation also, the right posterior wall had a prevalent craniocaudal direction. On the contrary, in the RS the caudocranial activation was present for longer periods than the craniocaudal sequence while the left septum did not exhibit a prevalent direction. The LS and RP had greater presence of disorganized electrograms than RL; also, the LS was significantly different compared with the CS. The RS had a significant presence of disorganized electrograms in comparison with RL.

In chronic AF a significant increase of disorganized activity was observed in all regions compared to paroxysmal AF, especially in the left septum where was present 100% of the time considered. Only the right lateral wall was more organized with a 30% reduction of disorganized electrograms. No prevalent direction of activation has been noted at all sites.

**Patterns of atrial fibrillation**

Patients with paroxysmal AF generally showed a greater degree of regions with a relatively organized AF than in patients with chronic AF. In patients with paroxysmal AF, 4 showed pattern A (22%), 7 pattern B (39%), 7 pattern C (39%) and none pattern D. In two patients with pattern A a preferential involvement of RP was present, whereas the S and only the RS were involved in the other two. In the 7 patients with pattern B the regions showing mainly disorganized atrial activity were the RP and S in 3 patients, the RP and LS in other 3 patients, and the RL and LS in one patient. The 7 patients with pattern C had a prevalent disorganization of CS, RP and S in 5 and of CS, LS and RP in the other two. In only one patient the RL was disorganized.
In patients with chronic AF 7 had pattern D (59%), 4 pattern C (33%), one pattern B (8%) and none pattern A. In 3 patients with pattern C the regions with prevalent disorganization were the CS, RP and S. The only patient with pattern B had a long-lasting AF (14 months) and he showed disorganized electrograms exclusively in the LS and CS with an impressive organized activity in all right atrial regions.

Discussion

In the present study a significant difference in the electrical activity was found between chronic and paroxysmal AF. In fact, in chronic AF both a significant shortening of FF interval and an increase of atrial activity disorganization were observed at all atrial regions. In patients with paroxysmal AF the spatial differences were extremely pronounced, particularly the left septum and the right posterior areas were highly disorganized while the lateral region showed more organized atrial electrical activity. When the atrial activation showed an organized pattern, we generally found that the electrical activity in the right lateral wall had a craniocaudal sequence with a caudocranial activity in the right septum while the left septum showed a disorganized activity without a prevalent direction of activation.

In patients with paroxysmal AF a pattern with one or two disorganized areas always involving the septal or right posterior region (pattern A and B) was present in 61% of patients. In the remaining 39% there were three disorganized areas (pattern C). No patient had a completely disorganized electrical activity. In patients with chronic AF, 58% of patients showed a pattern D with a completely disorganized atrial electrical activity in all atrial regions analyzed. These findings are in agreement with the concept of atrial electrical remodelling. In fact, several experimental studies [16-19] demonstrated that prolonged pacing-induced AF favors its own maintenance with a shortening of FF intervals [16-18]. This can be attributed to the progressive decrease in atrial ERP [15-20] and conduction velocity [16, 17, 19]. Nevertheless, also in some patients (33%) with chronic AF we found mostly organized atrial activity in the right lateral wall. This could be, at least partially, explained by the anatomic characteristics of this region that is characterised by the presence of some electrical barriers such as the crista terminalis, the fossa ovalis, the direction of pectinate muscles.
Atrial mapping was performed by the use of bipolar recordings with a relatively large interelectrode distance. The use of unipolar recordings would have allowed more precise analysis of electrical activity. In addition, although the right atrium was mapped extensively using the basket catheter, the left atrium was mapped only in the septum and in the lateral region (through the CS) using two decapolar catheters. This is a limitation but the use of a second basket catheter or more multielectrode catheters in the left atrium to obtain more data might have caused additional risks of thromboembolic events or complications related to the transeptal approach.

### Study limitations

Some studies [3, 15, 21] have suggested that the characteristics of atrial electrograms may be important to identify regions critical for the induction or the maintenance of AF. Besides, it has been observed that selective lesions performed in regions responsible for the induction or in other regions with more disorganized atrial activity could be useful for AF ablation [10, 17]. Therefore, in order to achieve a greater possibility of success of radiofrequency ablation it is necessary to increase our knowledge about the spatial characteristics of atrial activity in different groups of patients affected by this arrhythmia, such as idiopathic AF or AF associated with valvular disease, hypertension, congestive heart failure or coronary heart disease. Our results showed that different patterns of electrical activity during AF may be present. In idiopathic AF the right posterior and the septal areas are the regions that generally demonstrated more disorganized atrial activity.

### Potential clinical relevance

Considering that each patient may show a different AF pattern, an extensive atrial mapping to choose different ablative strategies in the single patient seems very important. Multipolar catheters would provide useful information to detect the critical region in the perpetuation of AF and guide the radiofrequency ablation.

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### REFERENCES


