Different atrial regional patterns of activation
during atrial fibrillation:
is there any relationship with the anatomy?

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Summary. - Right atrial (RA) mapping has been recently more carefully examined in patients with idio-
pathic atrial fibrillation (AF) in order to improve radiofrequency (RF) catheter-mediated ablation lines to con-
trol recurrences. The aim of this study was to map right atrial activation during AF to analyze relationship
between anatomy and atrial activation for specific sites. Twenty-four patients with recurrent, drug-refractory,
paroxysmal AF underwent an extensive mapping of the RA before attempting RF linear lesion catheter ablation.
A typical pattern of atrial activation was recorded in all patients which was consistent with a more regular
activity on the trabeculated right atrium (type I AF) and a more fragmented and complex activation on the
posterior and the anterior septum (type II and III AF). This paper helps to understand the influence of the
anatomic barriers to atrial activation during atrial fibrillation.

Key words: atrial fibrillation, right atrium mapping.

Riassunto (Pattern regionali di attivazione atriale durante fibrillazione atriale: esiste una relazione con
l’anatomia?). - Lo studio sistematico dell’attivazione atriale durante fibrillazione atriale ha assunto un ruolo
fondamentale negli anni più recenti in rapporto allo sviluppo delle moderne tecniche di ablazione transcatetere.
In questo lavoro vengono analizzati patterns di attivazione atriale in relazione ad aree anatomiche definite cercando
di chiarire i rapporti tra anatomia ed elettrofisiologia, almeno quanto attiene all’atrio destro. Ventiquattro
pazienti consecutivi sono stati sottoposti a mappaggio estensivo dell’atrio destro prima di eseguire una procedura
di ablazione lineare. Un pattern tipico di attivazione atriale destra è stato registrato in tutti i pazienti nell’atrio
destro trabeculato. In tale area l’attivazione atriale era molto regolare (quasi un quadro di tachicardia atriale
rapida) consistente con un quadro di fibrillazione atriale di tipo I. Viceversa patterns diversi caratterizzati da una
variabile frammentazione dei potenziali sono stati registrati sul setto anteriore e nell’area posteroinferiore
(fibrillazione atriale di tipo II e III). Questo lavoro permette di comprendere meglio i rapporti tra elettrofisiologia
ed anatomia, chiarendo in particolare il significato di certune barriere anatomiche.

Parole chiave: fibrillazione atriale, mappaggio dell’atrio destro.

Introduction

Atrial fibrillation (AF) is a common arrhythmic
disorder affecting 0.5% of individuals 50 to 55 years
old to 8% over 70, and is usually associated to valvular
disease, coronary artery disease, heart failure,
hypertension, cardiomyopathies and hormonal diseases
but may occur in the absence of any other detectable
cardiac abnormality in at least 10% of the cases. The
electrophysiological mechanisms that initiate and
maintain AF may be multiple and cause different patterns
of AF [1, 2]. Electrophysiological mapping performed
during AF indicate that different patterns of atrial
activation in the same patient are related to the existence
of different migratory reentrant wavelets in both atria
[3-5]. In same way these patterns may be related to the
anatomy of the right and left atrium. Thus, in order to
study this possible relationship we performed a detailed
mapping of right atrial and coronary sinus (CS) activation
during AF.

Methods

Patients characteristics

A study population of 24 patients (male/female 22/2,
age 53 ± 11 years) referred to our institution for refractory
AF, underwent an extensive mapping of the right atrium
(RA) and CS before attempting linear lesions radio
frequency (RF) catheter ablation. The primary inclusion
criterion was a minimum of two symptomatic episodes of
AF per week for at least one year, defined as an AF that did not require pharmacological or electrical cardioversion to be terminated. Even though all patients had most of the episodes documented by an ECG since many years and they were aware of symptoms related to AF, they received a cardiac event recorder (King of Heart - Instromedix) for one month, and were asked to record at least one episode of spontaneous AF before being included in the study to prove the relationship between symptoms and AF. Duration and intensity of symptoms were simultaneously reported by the patients in a daily diary. Patients were also asked to discontinue any antiarrhythmic treatment during this month; if patients were having amiodarone, the treatment was stopped 4 months before inclusion. Pre-procedure cardiac event recorder documented symptomatic AF episodes and mean drug regimens are reported in Table 1.

Additional inclusion criteria were normal left ventricular function and atrial size by cardiac bi-dimensional color Doppler echocardiogram, absence of valvular or coronary artery disease, of hypertension or thyroid dysfunction.

All patients gave a written informed consent according to the protocol approved by the Ethics Committee.

**Table 1. - Population’s characteristics**

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Age expressed in years. F: female; M: male; TT: treatment. AF: atrial fibrillation.

**Catheters**

To map the RA, a 7F, twenty-pole catheter (Halo - Cordis Webster) with alternating 2- and 10-mm interelectrode distance (2-mm interpolar distance) was placed, via the right femoral vein, in the trabeculated RA to simultaneously record the right atrial free wall, the atrial roof and the anterior septum. A 10-pole catheter (USCI-Bard) was placed in the CS via the left subclavian vein for recording the LA and part of the inferoposterior atrial septum. A 4-pole catheter was inserted via the right femoral vein and positioned along the atrial septum in the region of the His bundle. In 4 patients, a monophasic action potential catheter (EP Technologies) was positioned on the anterior atrial septum close to the fossa ovalis.

**Electrograms recording**

Bipolar intracardiac electrograms filtered between 30 and 250 Hz were digitally recorded and stored on a Lab System 3.57 (Bard), simultaneously with a 2-lead surface ECG. Monophasic action potential recordings were filtered 0.001-2000 Hz.

Digital calipers were used to calculate atrial activation times in sinus rhythm. The AF cycle length (F-F intervals) was measured with the method described elsewhere [6]. Analysis of the amplitude and duration of the electrograms recorded by the ablation catheter was made at any site but the isthmus during sinus rhythm (SR), before and after the ablation to provide information on the efficacy of RF delivery.

During AF, the electrograms were continuously recorded from all bipoles along: a) the trabeculated RA; b) the smooth RA; and c) the CS. AF patterns were further analyzed to define the degree of organization with respect to specific atrial sites. We took note of any pattern of organization into typical atrial flutter or SR during the ablation procedure.

**Baseline electrophysiological study**

In all patients: a) a basal electrophysiological study (EPS) was performed in SR in all patients to exclude any other electrical disease which could be responsible for the episodes of AF; b) a bipolar electrode of the Halo catheter close to the right atrial auricula was chosen as pacing site. Stimuli were twice the diastolic threshold and 2-ms long.

**Definitions**

AF was defined as a rapid atrial rhythm (cycle length < 200 ms) with a characteristic surface ECG morphology, variability of the beat-to-beat cycle length (> 20 ms), and continuous changes in morphology and amplitude of recorded bipolar electrograms. Discrete atrial complexes, separated by an isoelectric baseline, with a constant activation sequence - either caudocranial or craniocaudal - were defined as type I AF [7]. Type II and type III AF
were defined on the basis of a variable degree of atrial electrograms fragmentation and in particular for type III lack of baseline isoelectric intervals. Episodes of AF lasting more than 30 seconds were defined as sustained.

Atrial flutter was defined as a typical macroreentrant atrial arrhythmia which was consistent with negative “F” waves in the inferior leads of the ECG and a counterclockwise right atrial endocardial activation. Clockwise right atrial activation with positive flutter waves in the inferior leads was defined as a typical uncommon atrial flutter [3].

Induction of atrial fibrillation

During the baseline EPS, AF was induced by programmed atrial stimulation in 96% of the patients. Soon after AF induction, the atrial activation was carefully analyzed to exclude patterns of activation consistent with focal AF or rapid atrial tachycardia as described by Jaïs [8]. Furthermore, bipolar recordings obtained from the trabeculated RA were compared to those recorded from the smooth RA and the CS. Analysis of the spontaneous event that initiate AF was not performed.

Results

The electrophysiological study

In all patients EPS showed the absence of other electrical diseases, including AVNRT, WPW and ectopic atrial tachycardia. Mean ativoventricular node effective refractory period was 270 ± 20 ms.

Atrial effective refractory period was not reached in 23/24 patients because of AF induction with a mean S2 of 200 ± 20 ms delivered during a standard drive of 600 ms. In 1 out of 24 patients AF was not inducible and atrial effective refractory period was 180 ms.

At the time of the baseline EPS, a total of 23 self-terminating episodes of sustained AF were induced during programmed atrial stimulation in all patients (i.e 1 AF episode per patient but for one in whom AF was not inducible).

No patient received electrical or pharmacological cardioversion. AF episodes duration ranged from three hours to two days.

Patterns of atrial activation during atrial fibrillation

A characteristic sequence of events was present in all 23 episodes of AF.

Trabeculated right atrium and atrial roof. - In 23 patients, along the trabeculated RA and the roof, a pattern of organized AF (type I) was noted, characterized by discrete atrial electrograms, separated by an isoelectric baseline, with a continuous switching between clockwise and counterclockwise activation. Each activation sequence lasted a mean of 7 ± 5 cycles, and a longer FF interval or a pause preceded every single change of sequence (Fig. 1). The mean AF cycle length was slightly shorter during clockwise than during counterclockwise activation: 156 ± 31 vs 163 ± 24 ms (statistically not significant p < 0.91). A minimum of 100 AF cycles were analyzed with the method described elsewhere [6]. No attempt to entrain this local activity was ever made.

Anterior septum. - In the majority of patients, simultaneous recordings from the anterior atrial septum, above the catheter positioned in the region of the His bundle, showed fractionated electrograms consistent with a disorganized activation pattern. Measurements of cycle length of atrial signals in this area were not reliable because of the variability of the isoelectric baseline and the presence of split potentials, but cycle length appeared qualitatively shorter than that recorded in the right atrial free wall.

Postero-inferior septum and coronary sinus. - The atrial activation in the inferior septum and CS was rather disorganized, neither synchronized with the activation sequence of the trabeculated RA nor with that of the anterior septum. Furthermore, the activation pattern showed fractionated electrograms and variability of the isoelectric baseline similar to that recorded in the septum (Fig. 2).

Discussion

Patients enrolled in this study had frequent, highly symptomatic episodes of drug-resistant paroxysmal AF. This population does represent a very specific group in which AF was most likely caused by an isolated electrical abnormality.

The right atrial activation during atrial fibrillation

Trabeculated right atrium and atrial roof. - A remarkably stereotypical pattern of endocardial activation was observed in all patients along the trabeculated RA and the roof, characterized by discrete atrial electrograms, separated by an isoelectric baseline, with a continuous alternation between clockwise and counterclockwise activation. This particular sequence of events was already described [9], and could be due to different anisotropic conduction properties and anatomical barriers such as the crista terminalis and the Eustachian ridge [10].

As Lesh [11] and Gaita et al. [5] reported a similar pattern of organized AF, we can reasonably assume that anatomical barriers may favor “streaming” of excitation along the trabeculated RA. The degree of transverse coupling along the crista terminalis may reduce the
invasion of multiple wavelets coming from the septum and posterior wall, whereas clockwise or counter-clockwise rotation might be explained by a variable line of functional block along the right atrial free wall [12]. According to Gaita this area might be somehow protected against the appearance of multiple wavelets, but, in our opinion, it may not be a simple bystander and may influence the activation of the inferior septum and, through the CS, the LA around the mitral valve annulus. In fact depending on the cycle lengths of the arrhythmia and the relative electrophysiological properties of both the smooth RA and the left, a fast atrial flutter can short local atrial effective refractory period to a value that lead to AF.

Anterior septum. - As previously demonstrated by other authors [5, 13], this study confirms that in the majority of patients, the anterior atrial septum shows more fractionated electrograms.

The reduced AF organization in this area may be related to the presence of multiple simultaneous inputs from the posterior-inferior septum and the LA, via Bachmann’s bundle.

Postero-inferior septum and coronary sinus. - The atrial activation in the inferior septum was rather disorganized, neither synchronized with the activation sequence of the trabeculated RA nor with that of the anterior septum. Finally, a variable degree of organization was found in the CS, indicating that its activation during AF may be largely affected by the proximity of the Eustachian ridge, the isthmus and the mitral valve annulus, as demonstrated by other authors [3, 4].

The isthmus. - The atrial activation at the isthmus was synchronized with the activation sequence of the trabeculated RA, but not with that of the anterior septum and the posterior septum. Some degree of relationship was detected with the CS. This pattern of organization of AF at the isthmus may be explained by his particular non-uniform muscular trabeculated pattern which usually results in an area of slow conduction. The non uniformity is particularly conspicuous in the area immediately inferior to the CS and provides connections along the os [14].

Fig. 1. - "Washing-machine phenomenon". From top to bottom: surface ECG lead I. AL2-AL3 identify the lateral wall of the right atrium; AR4-AR6 the atrium’s roof; AS7-AS8 the anterior septum; MS9-MS12 the lower septum. His prox corresponds to the His tracing. The coronary sinus is visualized from CS1 to CS5. The electrograms recorded by the Halo catheter (AL2-MS12) show the change from clockwise to counterclockwise activation. The arrow indicates the longer interval that precedes the change of sequence.
Study limitations

The LA was mapped only through the CS, although a more complete study of AF activation could have been performed with a multipolar catheter placed in the LA to complete the information on its activation.

Conclusions

In agreement with other studies, our results show that the anatomy may condition the atrial activation pattern by creating natural variable functional lines of block. In particular, RA anatomy, more complex and embriologically different, results to several simultaneous patterns of AF activation.

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REFERENCES


