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Sites of Focal Atrial Activity Characterized by Endocardial Mapping During Atrial Fibrillation

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OBJECTIVES The aim of the present study was to assess the feasibility of identifying sites of focal atrial activity by localized high-density endocardial mapping during atrial fibrillation (AF).

BACKGROUND Sites of focal activity in the left atrium have been demonstrated by epicardial mapping during AF.

METHODS Twenty-four patients (15 with paroxysmal, 3 with persistent, and 6 with permanent AF) underwent endocardial mapping during AF. A 20-pole catheter with five radiating spines was used to map both atria for 30 s in each of 10 pre-determined segments. A focal activity was defined as ≥3 atrial cycles with activation spreading from center to periphery of the mapping catheter. Catheter ablation was performed independent of the mapping results.

RESULTS Spontaneous focal activities were observed in 13 sites in the left atrium (9%; anterior 1, roof 2, posterior 6, inferior 4) in 12 patients (9 paroxysmal, 3 persistent). Focal activity was observed continuously (two sites) or intermittently (11 sites, median 5 episodes), and associated with shortening of the cycle length (from 183 ± 33 ms to 172 ± 29 ms; $p < 0.05$). The mean duration of an intermittent episode was 1.5 s (range 0.4 to 7.1 s). Atrial fibrillation terminated without ablation at the foci in all of 12 patients, but in 2 of them, re-initiated arrhythmia was successfully ablated at these foci. Nine of these 12 patients (75%) were arrhythmia-free without antiarrhythmic drugs during a follow-up period of 7.0 ± 3.1 months.

CONCLUSIONS Termination of AF without ablation at the sites of atrial focal activity suggests that this activity may be triggered by impulses originating from other regions, such as the pulmonary veins. (J Am Coll Cardiol 2006;47:2005–12) © 2006 by the American College of Cardiology Foundation

The importance of the pulmonary veins (PVs) in catheter ablation of atrial fibrillation (AF) is well recognized (1–5). Although the efficacy of catheter ablation is improved by additional modification of the atrial substrate (4–9), the mechanisms by which this is achieved are incompletely understood. Using epicardial activation mapping, Cox et al. (10) have demonstrated macro–re-entry during atrial fibrillation, interruption of which contributes to the efficacy of the Maze procedure. More recently, rapid focal activity in the left atrium (LA) and PVs has been demonstrated by epicardial mapping, implying a potential role for focal atrial activity in the maintenance of AF (11–14); however, the use of endocardial mapping to identify atrial foci during AF has not been reported. Additionally, the impact of PV isolation alone on such activity is unknown.

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The aim of the present study, therefore, was to identify and characterize atrial focal activity during AF, using a newly developed multispine catheter, and to investigate the relationship between the presence of focal atrial activity and the procedural and clinical outcomes of AF ablation.

METHODS

Study population. The present study comprised 24 patients with drug-refractory AF. Atrial fibrillation was paroxysmal in 15, persistent in 3, and permanent in 6. All antiarrhythmic drugs except amiodarone were discontinued at least five half-lives before ablation. Four patients with paroxysmal AF and two with permanent AF were taking amiodarone. Baseline characteristics of patients are shown in Table 1. All patients gave written informed consent.

Electrophysiological study. All patients had effective anticoagulation for at least one month, and transesophageal echocardiography was performed no more than 48 h before ablation to exclude thrombus in the LA. For the ablation procedure, a 6-F quadripolar catheter (Xtrem, ELA Medical, Montrouge, France) was positioned in the coronary sinus. Surface electrocardiogram and intracardiac electrograms were measured at a paper speed of 100 mm/s utilizing a digital amplifier/recording system (Bard Electrophysiology, Lowell, Massachusetts). A single bolus of 50 IU/kg of

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Abbreviations and Acronyms

AF = atrial fibrillation
LA = left atrium
PV = pulmonary vein
RA = right atrium
RF = radiofrequency
SVC = superior vena cava

heparin was administered after the trans-septal puncture and repeated only for procedures lasting more than 4 h.

Study protocol. A 20-pole multispine catheter (PentaRay, Biosense Webster, Diamond Bar, California) was utilized for endocardial two-dimensional mapping (Fig. 1). This catheter has five spines, with four electrodes on each spine. Each electrode measures 1 mm, with an interelectrode spacing of 2-6-2 mm. A mapping area has a diameter of 35 mm if all spines are optimally applied to the atrial endocardium. Using this catheter, high-density mapping was performed within the LA and the right atrium (RA) during spontaneous or induced AF in each of the following sites for 30 s: anterior LA, LA roof, posterior LA, inferior LA, lateral LA, LA septum, anterior RA, lateral RA, posterior RA, and RA septum. For patients with a diagnosis of paroxysmal AF who were in sinus rhythm at the beginning of the procedure, AF was induced before commencement of mapping by burst pacing from the coronary sinus, LA, or RA.

Wave front propagation was categorized as follows: 1) passive activation—consistent propagation of a single wave front sweeping across the mapping area during three or more consecutive beats (Fig. 2); 2) chaotic activation—beat-to-beat variable activation pattern, or highly fragmented or split potentials without a consistent activation sequence (Fig. 3); and 3) centrifugal activation—a single wave front emanating from the center of a mapping area during three or more consecutive beats. Centrifugal activation was defined as the earliest endocardial activation occurring on the innermost bipoles of all spines and propagating simultaneously to the outermost bipole of all spines of the mapping catheter (Fig. 4). This activation pattern was considered to demonstrate focal activity originating from within the area encompassed by the catheter spines.

The dominant activation pattern was defined as the pattern occupying the greatest proportion of the 30-s mapping window. In those regions showing intermittent centrifugal activation, the duration of centrifugal activation and cycle length during the episode were determined. In addition, the duration of activity in the mapping area, defined as the interval from the onset of earliest activity to the end of the latest activity among bipoles of the mapping catheter, was determined during centrifugal activation. If no atrial electrograms could be recorded on three or more bipoles, the activation pattern was not evaluated at that site and the mapping catheter was moved to the next recording site. All endocardial mapping data were analyzed offline by a single investigator who was blinded to ablation outcomes.

Catheter ablation. After two-dimensional mapping of six sites in the LA, all patients underwent catheter ablation during ongoing AF with use of a 3.5-mm, irrigated-tip catheter (Biosense Webster). Ablation was performed independent of the mapping results.

For paroxysmal AF, isolation of each pulmonary vein was first performed guided by a 10-pole circumferential catheter. Radiofrequency (RF) energy was delivered at 1 cm proximal to the PV ostium or at the rim of the ostium with a delivered power of 30 or 25 W, respectively. If ipsilateral PVs were located closely or a common ostium was observed, RF lesions for each PV were connected and these two PVs were isolated en bloc. The ablation catheter was dragged every 30 to 60 s with continuous RF energy delivery. The end point was circumferential elimination or dissociation of PV potential. Inducibility of AF was tested after completion of PV isolation by burst pacing from the LA, RA, and coronary sinus. If AF was inducible or persisting ≥10 min, modification of the atrial substrate was performed, including linear ablation (connecting both superior PVs [roof line] and/or from the postero-lateral mitral annulus to the left inferior PV [mitral isthmus line]), ablation targeting fractionated or short cycle-length activity in the LA (atrial ablation), and disconnection of the superior vena cava (SVC) (9). The end point of linear lesions was bi-directional block confirmed during sinus rhythm.

Table 1. Patients' Baseline Characteristics

	Paroxysmal AF (n = 15)	Persistent/Permanent AF (n = 9)	p Value
Age (yrs)	54 ± 11	52 ± 10	NS
Gender (male/female)	12/3	8/1	NS
AF duration (months)	66 ± 62	92 ± 55	NS
Persistent AF duration (months)	—	16 ± 33	
Structural heart disease	0	2 (LV hypertrophy 1, ischemic heart disease 1)	NS
LA			
Parasternal (mm)	37 ± 7	46 ± 5	<0.01
Longitudinal (mm)	53 ± 9	61 ± 10	0.06
Transverse (mm)	39 ± 5	43 ± 7	NS
LVEF (%)	70 ± 8	69 ± 13	NS

AF = atrial fibrillation; LA = left atrium; LV = left ventricle; LVEF = left ventricular ejection fraction.