# Effect of linear ablation on spectral components of atrial fibrillation

Miki Yokokawa, MD,* Aman Chugh, MD,* Magnus Ulfarsson, PhD,† Hiroshi Takaki, MD, PhD,‡
Li Han, PhD,* Kentaro Yoshida, MD,* Masaru Sugimachi, MD, PhD,‡ Fred Morady, MD,
Hakan Oral, MD*

*From the *Division of Cardiovascular Medicine, University of Michigan, Ann Arbor, Michigan, †Department of Electrical and Computer Engineering, University of Iceland, Reykjavik, Iceland, and ‡Department of Cardiovascular Dynamics, National Cardiovascular Center Research Institute, Osaka, Japan.*

**BACKGROUND** Spectral components of atrial fibrillation (AF) other than the dominant frequency (DF) may represent macroreentrant circuits that coexist with higher-frequency sources during AF.

**OBJECTIVE** The purpose of this study was to determine whether spectral components of AF can be eliminated by targeted linear ablation.

**METHODS** Antral pulmonary vein isolation (APVI) and linear ablation were performed in 26 patients (age 60 ± 11 years) to eliminate long-standing persistent AF (duration 3 ± 2 years). Spectral analysis of atrial activation at multiple atrial sites was performed during AF, at baseline, after APVI, and immediately before and after liner ablation along the roof of the left atrium, mitral isthmus, and cavotricuspid isthmus. The prevalence and spatial distribution of spectral components of AF were examined before and after each step of ablation.

**RESULTS** Twelve (46%) of 26 patients had conversion of AF to atrial tachycardia (AT) during ablation. Mean cycle length of AT was 237 ± 25 ms. A spectral component of AF (3.7 ± 1.2 Hz) other than the DF (6.0 ± 0.9 Hz) was present in 74 (43%) of 173 baseline AF periodograms at multiple atrial sites. Following APVI, no difference in the prevalence of spectral components was seen (38% vs 43%, $P = .38$). However, linear ablation resulted in a significant decrease in the prevalence of spectral components (24% vs 43%, $P < .01$), but only when complete conduction block was achieved.

**CONCLUSION** Elimination of spectral components of AF by targeted linear ablation suggests that spectral components may indicate site-specific ATs that coexist with AF despite a lower frequency than the DF of AF.

**KEYWORDS** Atrial fibrillation; Atrial tachycardia; Catheter ablation; Spectral analysis

**ABBREVIATIONS** **AF** = atrial fibrillation; **APVI** = antral pulmonary vein isolation; **AT** = atrial tachycardia; **CFAE** = complex fractionated atrial electrogram; **CS** = coronary sinus; **DF** = dominant frequency; **LA** = left atrium; **PV** = pulmonary vein; **RA** = right atrium

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A study that analyzed the spectral characteristics of atrial fibrillation (AF) suggested that atrial tachycardias (ATs) to which AF converts during radiofrequency ablation may represent organized tachycardias that coexist with AF despite a lower frequency than the dominant frequency (DF) of AF.[1] If this were the case, targeted linear ablation might eliminate the lower-frequency components.

The purpose of this study was to determine whether linear ablation at sites frequently used by ATs eliminates specific spectral components of AF in patients with persistent AF.

## Methods

### Study subjects

The study consisted of 26 patients (23 men and 3 women; mean age 60 ± 11 years, range 35–77 years) with persistent AF who underwent radiofrequency catheter ablation. Mean left atrial (LA) diameter was 46 ± 6 mm, and left ventricular ejection fraction was 0.54 ± 0.09. AF was first diagnosed 8 ± 8 years before presentation and was persistent for 3 ± 2 years before ablation (range 1–7 years). Two patients had coronary artery disease. The clinical characteristics of the patients are listed in Table 1. Patients with a prior ablation procedure were excluded from the study.

### Electrophysiologic study

The study protocol was approved by the Institutional Review Board. All patients provided informed written consent. Antiarrhythmic drug therapy was discontinued ≥5 half-lives before electrophysiologic study, except for amiodarone, which was discontinued >8 weeks before the proce-

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**Address reprint requests and correspondence:** Dr. Hakan Oral, Cardiovascular Center, SPC 5853, 1500 East Medical Center Drive, Ann Arbor, Michigan 48109-5853. E-mail address: oralh@umich.edu. (Received May 17, 2010; accepted 2010.)

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**Table 1** Patient characteristics

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|---|---|
| Age (years) | 60 ± 11 |
| Gender (male/female) | 19/7 |
| Duration of atrial fibrillation (years) | 3 ± 2 |
| Left atrial diameter (mm) | 46 ± 6 |
| Left ventricular ejection fraction | 0.54 ± 0.09 |
| Coronary artery disease (%) | 2 (8) |

Values are given as mean ± SD.

dure. Electrophysiologic study was performed in the fasting state under conscious sedation using fentanyl and midazolam. Vascular access was obtained through a femoral vein. A decapolar catheter (E-Z Steer CS Decapolar, Biosense Webster, Diamond Bar, CA, USA) was positioned in the coronary sinus (CS). Immediately after the transseptal puncture, systemic anticoagulation was achieved with intravenous heparin, and the activated clotting time was maintained between 300 and 350 seconds throughout the procedure. The pulmonary veins (PVs) were mapped with a decapolar ring catheter (Lasso, Biosense Webster) advanced to the LA. Mapping and ablation were performed using a 3.5-mm open irrigation tip catheter (ThermoCool NaviStar, Biosense Webster). Bipolar electrograms were displayed and recorded at filter settings of 30 to 500 Hz during the procedure (EPMed Systems, West Berlin, NJ, USA). Electrograms were also recorded at 0.5 to 200 Hz for offline spectral analysis.

Catheter navigation and ablation were performed with guidance from an electroanatomic mapping system (CARTO, Biosense Webster). Radiofrequency energy was delivered at a maximum power of 20 to 25 W at a flow rate of 17 mL/min near the PVs, along the posterior wall, and within the CS and at a maximum power of 35 W at a flow rate of 30 mL/min elsewhere in the atria. Maximum temperature was set at 48°C.

## Study protocol and ablation strategy

All patients presented to the laboratory in AF, and ablation was performed during AF. First, antral pulmonary vein isolation (APVI) was performed to isolate all PVs and resulted in termination of AF in 1 of 26 patients. Therefore, the study protocol was completed in the remaining 25 patients who remained in AF after APVI. In these 25 patients, linear ablation along the LA roof and mitral isthmus was performed (Figure 1). At the discretion of the operator, complex fractionated atrial electrograms (CFAEs) were targeted in 20 (80%) of 25 patients. CFAE ablation was performed before linear ablation in 12 (60%) of 20 patients and after liner ablation in 8 (40%) of 20 patients. Linear ablation along the cavotricuspid isthmus was performed in 5 patients who had a history of typical atrial flutter. Whenever AF converted to an AT, entrainment and activation mapping were performed to guide ablation of the AT. Sinus rhythm was restored by transthoracic cardioversion in patients who remained in AF after ablation. After sinus rhythm was restored, conduction block across the LA roof, mitral isthmus, and cavotricuspid isthmus lines was assessed.[2–4] If necessary, additional ablation was performed to achieve complete block.

Prior to ablation, all PVs were mapped with a decapolar ring catheter. Electrograms then were recorded for ≥30 seconds at ≥2 different locations (tagged on the map; Figure 1) at each of the following sites: (1) LA roof, (2) mitral isthmus, (3) LA appendage, (4) LA septum, (5) CS, (6) cavotricuspid isthmus, and (7) right atrial (RA) appendage. Caution was exercised to create linear lesions ≥5 mm from the sampling sites. Sampling was performed at baseline, after APVI, (and also after CFAE ablation when applicable), and immediately before and immediately after linear ablation without any CFAE ablation between the two sampling times.

## Digital signal processing and data analysis

Electrograms were processed offline in the MatLab environment (MathWorks, Inc., Natick, MA, USA) using custom software as described previously.[1] In brief, first digitized bipolar electrograms sampled for ≥30 seconds at 2,000 Hz underwent preprocessing steps of bandpass filtering at 40 to 250 Hz, rectification, and low-pass filtering at 20 Hz. Then the discrete Fourier transform of the prepro-

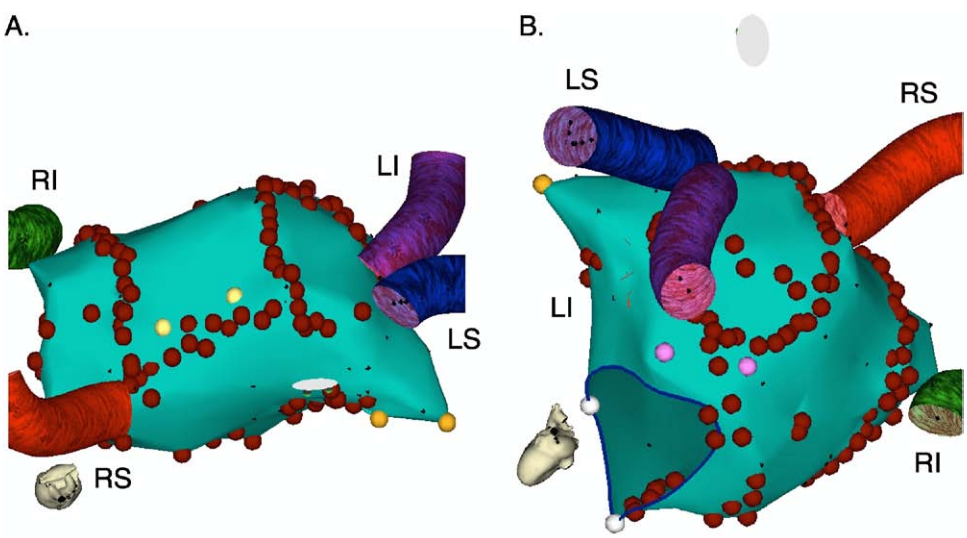


**Figure 1** Antral pulmonary vein isolation and linear ablation. Shown is the three-dimensional reconstruction of the left atrium and pulmonary veins during ablation of atrial fibrillation (**A:** craniocaudal projection; **B:** left posterior oblique projection). Electrograms were recorded for ≥30 seconds at ≥2 different positions at each atrial site. *Red tags* indicate ablation sites. *Yellow tags* and *pink tags* indicate sampling sites. LI = left inferior; LS = left superior; RI = right inferior; RS = right superior.