# Atrial electrogram discordance during baseline vs reinduced atrial fibrillation: Potential ramifications for ablation procedures

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**BACKGROUND** There are scant data comparing the electrogram (EGM) signal characteristics of atrial fibrillation (AF) at baseline vs electrically induced states during ablation procedures.

**OBJECTIVE** The purpose of this study was to use novel intracardiac signal analysis techniques to gain insights into the effects of catheter ablation and AF reinduction on AF EGMs in patients with persistent AF.

**METHODS** We collected left atrial EGMs in patients undergoing first ablation for persistent AF at 3 time intervals: (1) AF at baseline; (2) AF after pulmonary vein isolation (PVI); and (3) AF after post-PVI cardioversion and subsequent reinduction. We analyzed 2 EGM spectral characteristics: (1) dominant frequency and (2) spectral complexity; and 2 EGM morphologic characteristics: (1) morphology variation and (2) pattern repetitiveness.

**RESULTS** There were no differences in AF dominant frequency, dominant amplitude, spectral complexity, or metrics of EGM morphology or repetitiveness at baseline vs after PVI. However, dominant frequency, dominant amplitude, and spectral complexity differed significantly after direct current cardioversion and reinduction of AF.

**CONCLUSION** The frequency, spectral complexity, and local EGM morphologies of AF do not significantly change over the course of a PVI procedure in patients with persistent AF. However, reinduction of AF after direct current cardioversion results in different dominant frequency and spectral complexity, consistent with a change in the characteristics of the perpetuating source(s) of the newly induced AF. These data suggest that AF properties can vary significantly between baseline and reinduced AF, with potential clinical ramifications for outcomes of catheter ablation procedures.

**KEYWORDS** Atrial fibrillation; Electrogram analysis; Dominant frequency; Linear prediction

**ABBREVIATIONS** **AF** = atrial fibrillation; **CFAE** = complex fractionated atrial electrogram; **CoV** = coefficient of variation; **DA** = amplitude of dominant peak; **DC** = direct current; **DF** = dominant frequency; **ECG** = electrocardiogram; **EGM** = electrogram; **LA** = left atrium; **MP** = mean spectral profile; **PVI** = pulmonary vein isolation; **SP** = standard deviation of mean spectral profile

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## Introduction

Substrate-based electrogram (EGM) mapping and ablation of atrial fibrillation (AF) is often used along with pulmonary vein isolation (PVI) during AF catheter ablation procedures. Such mapping is based on various EGM characteristics, which include morphology (eg, complex fractionated atrial electrograms [CFAEs]) and/or activation patterns (eg, dominant frequency [DF], rotor-based targets). Reports of success rates using EGM-based techniques vary. Possible causes of discrepancies include lack of standardization of EGM collection as well as analytical methods.

Few clinical data exist regarding whether spectral or morphologic AF EGM characteristics differ when EGMs are collected at different time points during ablation procedures, including baseline, after PVI ablation, and when AF is converted to sinus rhythm and subsequently reinduced by electrical stimulation. It is clinically important to understand better the potential limitations of EGM-based treatment strategies during these procedures. For example, if AF DF values from a given site change over time, then frequency-based targeting of atrial sites may be neither rational nor effective.

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The aim of this study was to compare these quantitative parameters of atrial EGMs in patients with persistent AF (ie, at baseline, after PVI, and after direct current [DC] cardioversion and AF reinduction) in order to determine the effects of ablation and DC cardioversion on atrial electrical activation patterns and provide mechanistic insight into AF maintenance over the course of a catheter ablation procedure.

## Methods

### Study population

Intracardiac atrial EGMs were collected from a consecutive series of 35 adult patients at Columbia University Medical Center who underwent electrophysiologic study for persistent AF requiring treatment with radiofrequency ablation. The Institutional Review Board of Columbia University Medical Center approved EGM data collection and analysis.

### Electrophysiologic study

Patients underwent an initial evaluation, which included history, physical examination, ECG, and echocardiogram. All 35 patients had a history of persistent AF, and their baseline cardiac rhythm in the laboratory was AF. All membrane-active antiarrhythmic medications were held for at least 5 half-lives before the catheter ablation procedure, except for 1 patient who stopped amiodarone within 1 week before the procedure. Radiofrequency ablation consisted of PVI + linear ablations (cavotricuspid isthmus, left atrial [LA] roof, and/or mitral) ± CFAE ablation.

Figure 1 details the EGM sampling protocol for this study. All patients underwent PVI as the first step demonstrated by entry block or lack of any signals at all Lasso catheter poles. AF did not terminate by PVI in any of the 35 patients. All underwent DC cardioversion before any further ablation was performed. After 10 minutes of atrial pacing at a cycle length of 700 or 800 ms, during which time PVI was reconfirmed and hemodynamic parameters remained stable, AF reinduction was attempted using the following uniform protocol: LA burst pacing for at least 15 beats at each pacing cycle length, down from 300 ms to a minimum of 200 ms using interrupted pacing decrements of 10 ms.

Patients underwent EGM collection from the LA posterior wall at the following times: (1) before any ablation, including PVI; (2) after confirmation of PVI; and (3) after DC cardioversion and if at least 5 minutes of AF was reinduced (n = 9 patients). No linear ablation or CFAE ablation had been performed before DC cardioversion and AF reinduction.

### AF EGM measurements

The distal ablation pole of the mapping/ablation catheter (ThermoCool SF, Biosense Webster, Diamond Bar, CA) was used to record bipolar atrial EGMs from the same tagged site in the mid-posterior wall of the LA, outside electrically isolated antral areas, as identified by 3-dimensional mapping. Digitized bipolar posterior LA EGMs were collected in 8.4-second recording periods, filtered (30–500 Hz), sampled at 977 Hz, and stored on a digital recording system (CardioLab, GE, Milwaukee, WI).[1] A coronary sinus bipolar electrode (ie, CS3–4 or CS5–6) was used to record simultaneous EGMs for comparison of spectral characteristics at the 3 time periods. In addition, after QRS subtraction was performed, lead aVF was used to record simultaneous surface atrial waves at the 3 time periods.

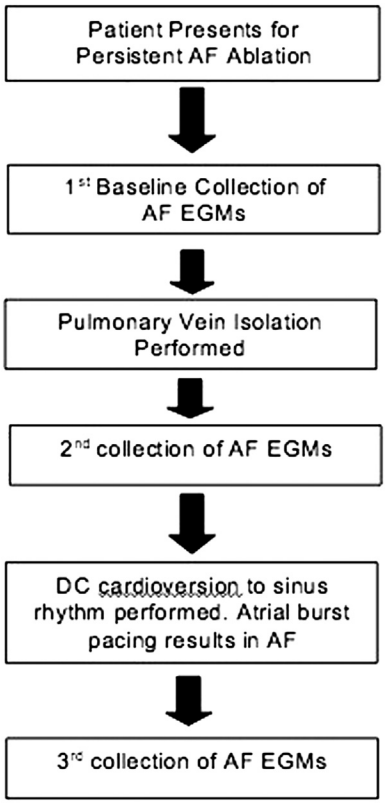


**Figure 1** Protocol for electrogram (EGM) sampling in atrial fibrillation (AF) patients.

### EGM characteristics

AF EGMs were analyzed for signal characteristics related to their frequency and morphology using previously validated techniques.[2,3] The DF is defined as the largest fundamental periodic component in the frequency range of interest (3–12 Hz). The amplitude of this dominant peak is defined as the dominant amplitude (DA). Therefore, the DA is the spectral magnitude of the largest fundamental peak in the frequency spectrum for the electrophysiologic range of interest. The frequency of this peak is the DF. The magnitude (ordinate) axis of the power spectrum is then normalized to a range of 0–1. The mean spectral profile (MP) is defined as the average level of the normalized spectrum. The standard deviation of the mean spectral profile is depicted as the SP.

Morphologic (EGM shape) characteristics were also measured by previously validated techniques.[4] Each EGM was characterized by detecting all EGM deflections and measuring peak amplitude, width, and upslope and downslope of each deflection, which were expressed as mean ± SD for all EGMs. The uniformity of amplitude peaks was expressed as the mean sum of absolute values of EGM