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Evolution of Frequency Composition for Atrial Arrhythmias

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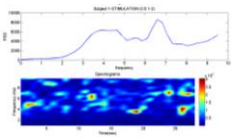
Graphical abstract



Abstract

In the United States of America, cardiac arrhythmias remain the leading cause of sudden death with more than 300,000 cases per year [1, 2]. The majority of sustained cardiac arrhythmias are atrial fibrillation and these contribute a major cause of stroke[3-6]. Irregular electrical pulses can be determined inside the atria. Frequency analysis is used to measure changes in the dominant frequency (DF). Welch method is used here to obtain the frequency spectrum of the signals. The 2D frequency strength plotting allows us to identify the evolution of the frequency composition of the signal with time. In physiological studies, we should see a general frequency increase during stimulation. That means the frequency at pre-stimulation should be lower than during stimulation and this should return to pre-stimulation state after simulation stops. The reason is that stimulation of the ganglia is supposed to promote atrial conduction in AF. The initiation and maintenance of AF is significantly enhanced by simultaneous parasympathetic stimulation In physiological studies, we should see a general frequency increase during stimulation. That means the frequency at pre-stimulation should be lower than during stimulation and this should return to pre-stimulation state after simulation stops. The reason is that stimulation of the ganglia is supposed to promote atrial conduction in AF. The initiation and maintenance of AF is significantly enhanced by simultaneous parasympathetic stimulation.

Keywords: Atrial arrhythmias; atrial fibrillation; electrocardiograms; frequency analysis

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1.0 INTRODUCTION

The commonest heart rhythm abnormality encountered in clinical practice is Atrial Fibrillation (AF). During AF, the atria contract very fast and irregularly. The mechanism of AF is still not fully understood but is thought to involve either multiple wavelets [7] propagating through the atria or focal high frequency re-entrant sources. This results in inefficient quivering of the atria instead of coordinated contraction. Consequently, the atria do not deliver blood into the ventricles effectively. This can result in stagnation of blood in the atria, giving rise to clot formation. A clot can travel into the arterial system and occlude circulation to the brain, resulting in an embolic stroke. Cardiac autonomic ganglia are nervous tissues, which can be found on the surface of the heart. They are thought to play an important role in initiation and maintenance of AF [8]. We hypothesize that stimulation of these ganglia will produce changes in the frequency spectrum of AF. The studies support the hypothesis that local cardiac autonomic ganglia in the fat pads (GP) at the margins of the PV antra, innervate PV myocardial sleeves and adjacent atrial myocardium, and can play a critical role in the initiation and maintenance of AF.

2.0 METHOD

For this study, we analyzed intracardiac electro grams of a patient who was in AF during routine electrophysiology study. All signals were recorded from a decapolar catheter (consisting of 5 bipole electrode positions starting at CS1-2 and ending at CS9-10) as shown in Figure 1. The decapolar catheter was placed in the coronary sinus, which allows assessment of left atrial electrical activity. High frequency (HF) electrical stimulation at 20 Hz was delivered from the proximal poles (position CS9-10) of the coronary sinus catheter to produce slowing of the ventricular heart rate, which is an indication of stimulation of nearby autonomic ganglia. Signals recorded from the distal poles (position CS1-2 and CS3-4) of the decapolar catheter were used for frequency domain analysis.

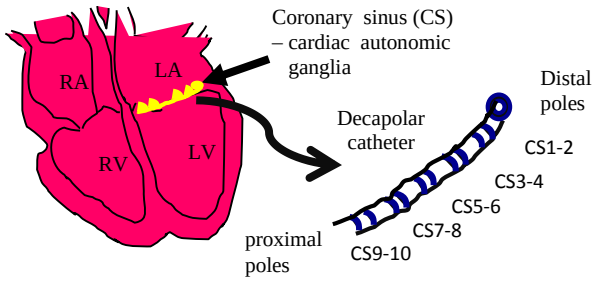


Figure 1 Intracardiac electro gram

2.1 Frequency Domain Analysis

The Fourier transform is a popular technique for digital signal processing for performing specified analysis[9]. During AF, frequency analysis is widely used to measure changes in the dominant frequency. Welch method is used here to estimate the frequency spectrum of the signals. The Fourier transform was calculated separately for each of the segments. The analysis was performed by taking the average of the segments, each with 2000 points sampled at 1000Hz, using a 4096-point FFT and an overlap of 50% with a hamming window. The equation for computing the averaged periodogram is:

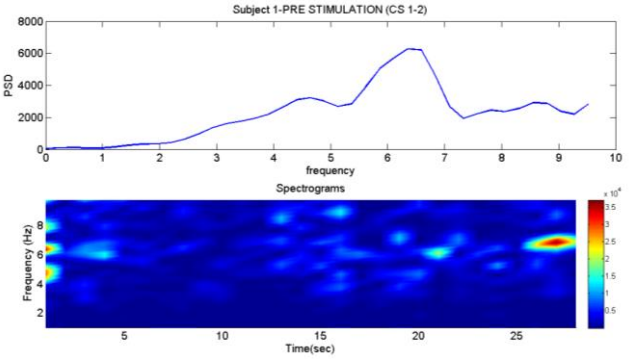
$$\hat{P}_W(f_k) = \frac{1}{M} \sum_{m=1}^{M} \hat{P}_m(f_k) \qquad 0 \le f_k \le f_s/2$$

where $\hat{P}_m(f_k)$ is the periodogram of the m[th] segment of data.

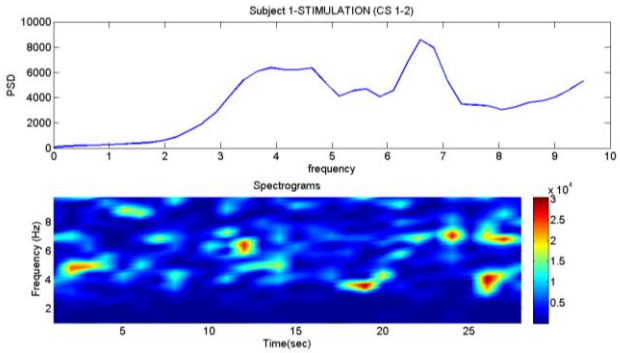
Dominant Frequency (DF) is a frequency of the signal when the power spectrum shows the maximum value. The general application of DF analysis is to estimate the atrial activation rates [10]. Researchers who apply spectral techniques show that AF has significant periodic elements with different degrees of regularity. It has also been shown that certain areas of the atria can have higher activation frequencies than other areas. This condition may be drivers that preserve AF and could be targets of ablation therapy [11-17]. DF was obtained from the FFT analysis. In general, all the DF values obtained are within the range of 6.10–6.84 Hz and this is in agreement with the results obtained by Ropella [18].

■3.0 RESULTS AND DISCUSSION

The AF data have been analyzed and spectra were produced for these two patients. The average spectrum and the spectrograms obtained from the first patient are shown in Figure 2.



(a)



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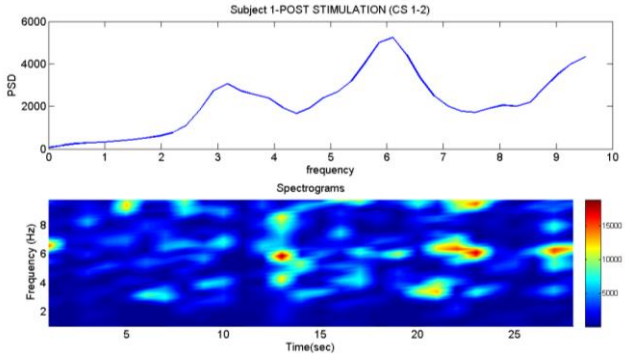

(c)

Figure 2 Power spectrum and 3D spectrogram for patient 1, (a) pre-HF stimulation (b) During HF stimulation and (c) post-HF stimulation

The DF has been recorded at coronary sinus (CS1-2) for pre-HF stimulation, during HF stimulation and post-HF stimulation. The frequencies from coronary sinus positions for patient 1 and patient 2 are shown in Table 1.

Table 1 Dominant Frequency for Patient 1 and Patient 2

	DF (CS1-2), Hz	
Conditions	**Patient 1**	**Patient 2**
Pre-HF stimulation	6.35	6.59
During HF Stimulation	6.59	6.84
Post-HF stimulation	6.10	6.10

DF at Pre-HF Stimulation for patient 1 is 6.35 Hz and 6.59 Hz for patient 2. 3D diagram confirmed the situation based on the color-coded spectrogram observed. There are increasing trends of DF (6.59 Hz for patient 1 and 6.84 Hz for patient 2) during stimulation stage observed for this channel comparatively to Pre-stimulation. The values of all DF for post stimulation are lower than that of pre-stimulation DF that is 6.10 Hz (for both patients).

From most human studies, the dominant frequency in AF is between 4 Hz to 10 Hz [17, 18]. It is more commonly around 6 Hz to 7 Hz. In physiological studies, we should see a general frequency increase during stimulation. That means the frequency at pre-stimulation should be lower than during stimulation and this should return to pre-stimulation state after simulation stops. The reason is that stimulation of the ganglia is supposed to promote atrial conduction in AF. The initiation and maintenance of AF is

significantly enhanced by simultaneous parasympathetic stimulation (shortening the refractory period of the atria) [19,20]. An increase in the DF during HF stimulation suggests that the autonomic ganglia can influence the rate of atrial depolarization during AF, possibly by altering electrophysiological properties of the atria (e.g. shortening tissue refractory period).

■4.0 CONCLUSIONS

As of this stage, using frequency domain analysis, the 2D frequency strength plotting is achieved. The plotted diagram allows us to identify the evolution of the frequency composition of the signal along time. We have shown that the DF of AF can be influenced by stimulation of autonomic ganglia (frequency increase during stimulation procedure), suggesting a possible role in the maintenance of AF and hence supporting the idea that these ganglia should be targets for ablation in the treatment of AF.

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