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FREQUENCY ESTIMATION FOR ATRIAL FIBRILLATION FROM HUMAN STUDIES

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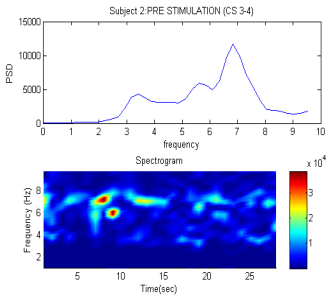
Graphical abstract



Abstract

Atrial Fibrillation (AF) is the most common disorder of the heart rhythms. There are about 2.3 million people in United States and 4.5 million people in the European Union with AF [1]. It is also one of the factors that may contribute to mortality and morbidity. Researchers who apply spectral techniques show that certain areas of the atria can have higher activation frequencies than other areas. Frequency analysis is used to measure changes in Dominant Frequency (DF). We access the electrical propagation inside the atria by spectrogram plotting and examining the effect of high frequency stimulation on human.

Keywords: Fequency estimation, atrial fibrillation, human studies

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1.0 INTRODUCTION

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 [2]. In this study, we hypotheses these ganglia by using high frequency stimulation produces changes in frequency. The stimulation is used to activate cardiac ganglia on the epicardium of the atria.

2.0 METHODOLOGY

For this study, we analysed intracardiac electrograms of 3 patients who were 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). The decapolar catheter was placed in the coronary sinus (Figure 1), which allows assessment of left atrial electrical activity. It is known that high frequency stimulation at selected endocardial sites can lead to stimulation of vagal tissue within autonomic ganglia [3]. The effect of vagal nerve stimulation can be seen as slowing of the ventricular rate, caused by atrioventricular conduction block. In this study, high frequency stimulation between 20 - 50 Hz at the proximal poles of the CS catheter (CS9-10 position) was delivered using a programmable cardiac stimulator used for electrophysiological studies. We defined a vagal response as production of atrioventricular block for at least 1s after applying high frequency stimulation over a 30 s period. Signals recorded on the CS1-2 and CS3-4 position during this period where a vagal response is seen, are then analysed using FFT and compared before, during and after stimulation.

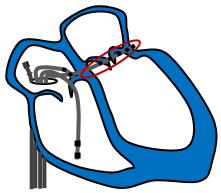


Figure 1 Catheter at coronary sinus (red circle)

Yoshihide Takahashi, *et al*., 2005 found that the optimal measurement site to get a repeated serial measurement is the coronary sinus (CS). The stability of the catheter during measurement is one of the reasons why the coronary sinus is a good place to record electrical activity in the left atrium.

The signals have been analysed using Fast Fourier Transform (FFT) analysis. After signal processing, an FFT was performed over 4096 points every one second from 30 second recordings. The maximum peak in the magnitude spectrum was defined as the dominant frequency (DF). The red colour shows the frequencies with high power while the blue colour corresponds to low power. The advantage of using a spectrogram is it allows us to see how the frequency changes along time.

The data have been taken from 3 patients. They are:

1) P1-VB (stimulation at 50 ms);
2) P2-CL (stimulation at 20 ms);
3) P3-TJ (stimulation at 40 ms).

The data have been analysed and spectra were produced for all the patients.

3.0 RESULTS AND DISCUSSION

3.1 Patient 1 (P1-VB)

The position for each bipolar (channel) labeled as:

- Channel 9: CS 1-2
- Channel 10: CS 3-4

The spectral plots for channel 9 and channel 10 are shown in Figure 2. The DF has been recorded for each of the channels during pre-stimulation, stimulation and post-stimulation conditions. The frequencies for atrial electrograms for CS 1-2 and CS 3-4 for P1-VB are shown in Table 1.

3.1.1 Pre-Stimulation Observation

According to P1-VB data, the DF during pre-stimulation is 6.35 Hz for channel 9 and 10. Besides, it is observed that channel 10 has dual spectrum peaks at 3.42 Hz and 6.35 Hz. The spectrograms also confirmed the situation based on the colour spectrum observed. The highest peak is observed at 6.35 Hz, but stating only the DF might be an oversimplification of the more complex activity here.

Table 1 Dominant frequency for P1-VB

Condition \ Channel	9 (CS 1-2) (Hz)	10 (CS 3-4) (Hz)
Pre-stimulation	6.35	3.42 / 6.35
Stimulation	6.59	6.59
Post-stimulation	6.10	6.10

3.1.2 During Stimulation Observation

There are increasing trends of DF during stimulation stage observed comparatively to Pre-stimulation. The stimulation produces an increase in the dominant frequency, which is an indication of stimulation of nearby autonomic ganglia.

3.1.3 Post Stimulation Observation

In short, all DF for Post stimulation are lower than pre-stimulation DF.

3.2 Patient 2 (P2-CL)

For patient P2-CL, the position for each bipolar (channel) recorded are labeled as:

- Channel 6: Coronary sinus 1-2;
- Channel 7: Coronary sinus 3-4;

The spectra for P2-CL are shown in Figure 3 and their dominant frequencies in Table 2.

3.2.1 Pre-Stimulation Observation

The DF at pre-stimulation is 6.84 Hz.

Table 2 Dominant frequency for P2-CL

Condition \ Channel	6(CS 1-2) (Hz)	7(CS3-4) (Hz)
Pre-stimulation	6.84	6.84
Stimulation	6.59	6.35
Post-stimulation	6.84	6.59

3.2.2 During Stimulation Observation

There is a declining trend of DF during stimulation period observed for all channels. There is 6.59 Hz for channel 6 and 6.35 Hz for channel 7.

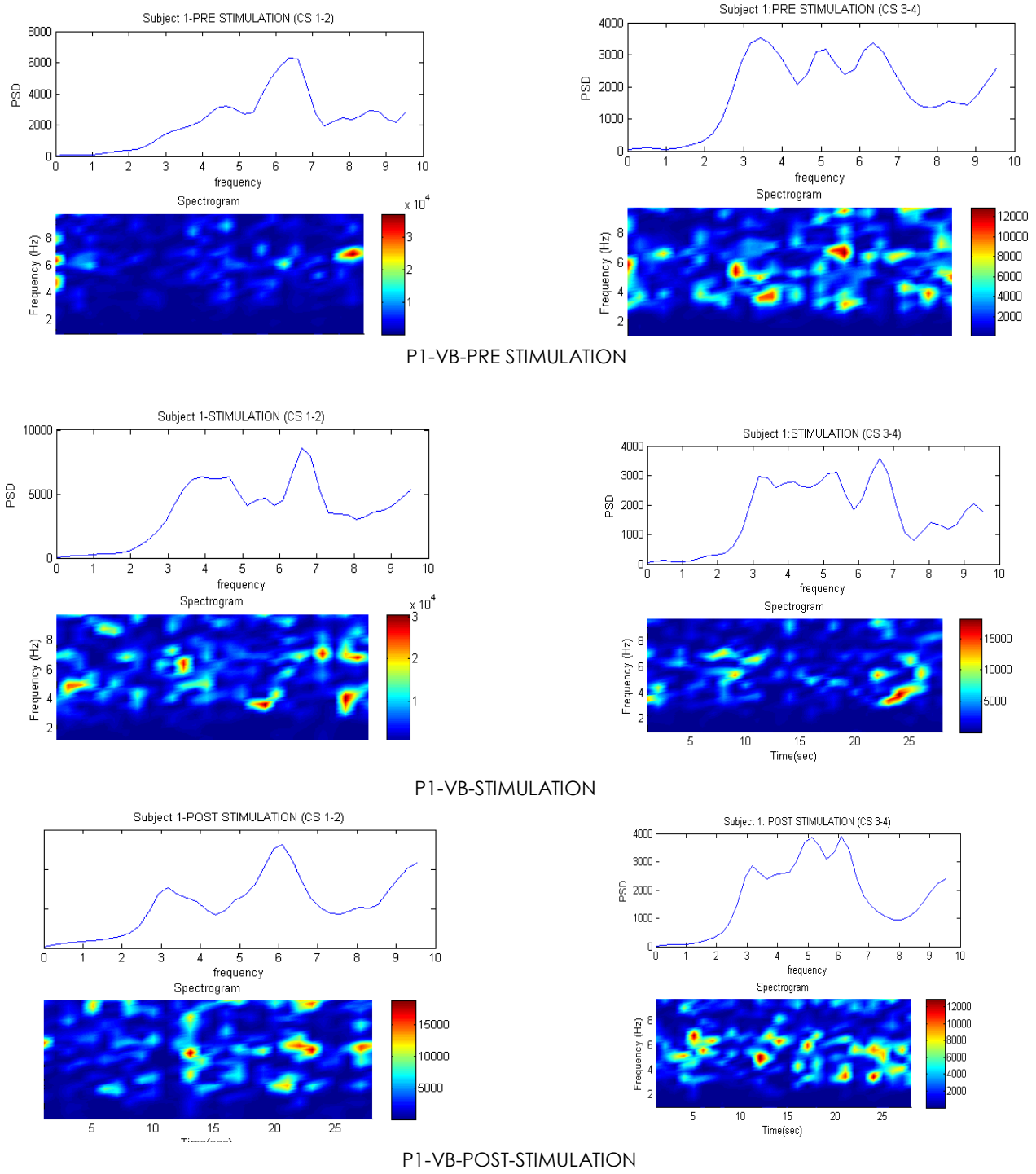
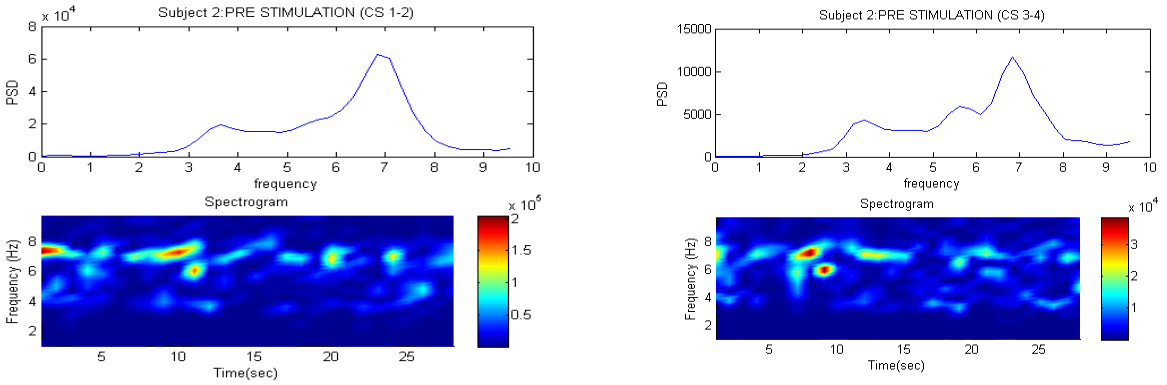
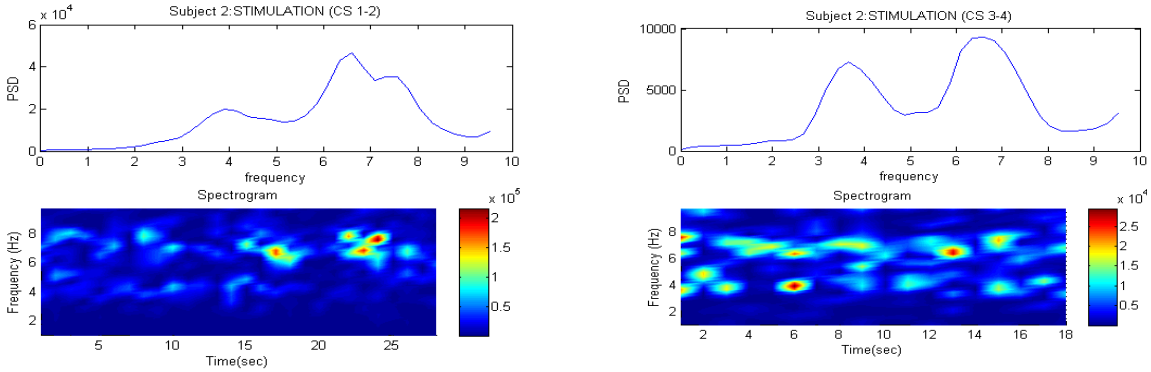


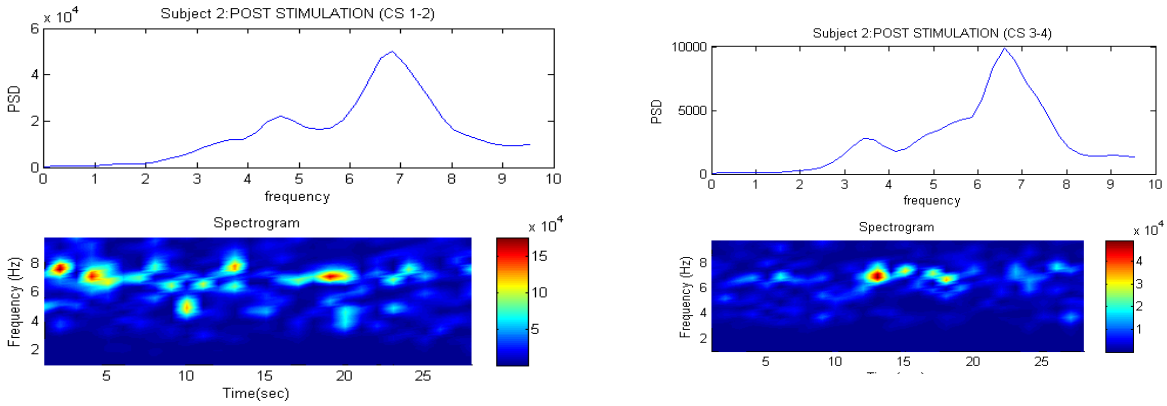
Figure 2 Spectrum and spectrogram for P1-VB (Pre stimulation, during simulation and post stimulation)



P2-CL-PRE STIMULATION

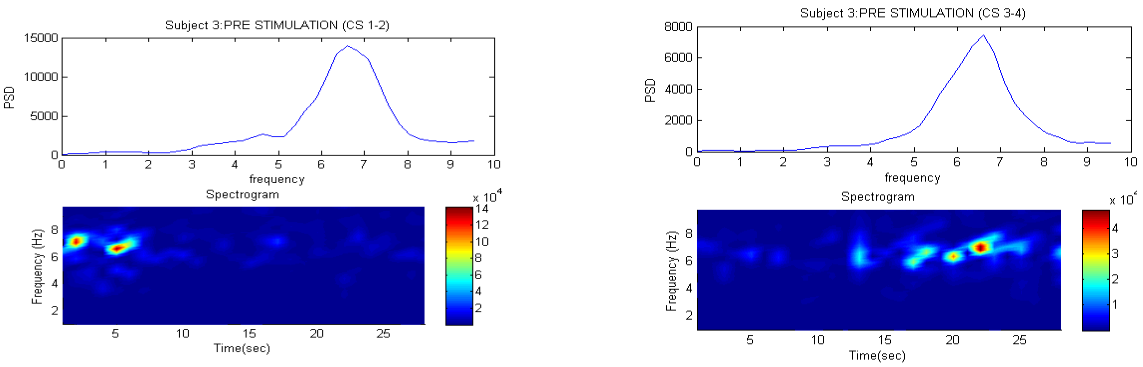


P2-CL-STIMULATION

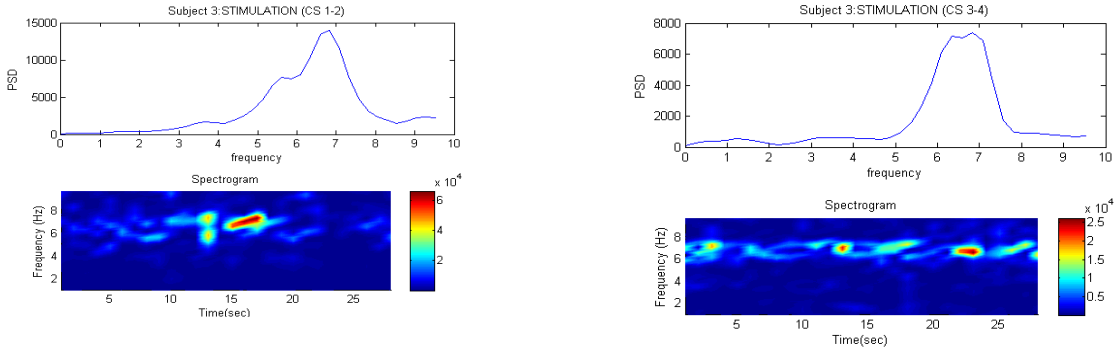


P2-CL-POST STIMULATION

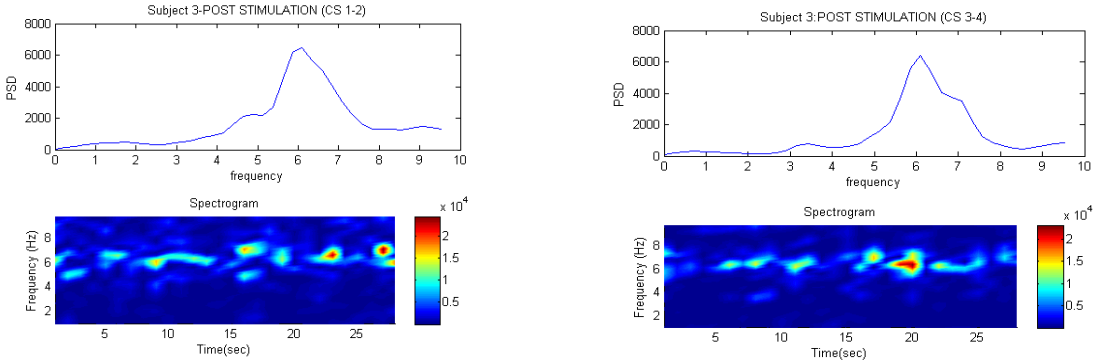
Figure 3 Spectrum and spectrogram for P2-CL (Pre stimulation, during simulation and post stimulation)



P3-TJ-PRE STIMULATION



P3-TJ-STIMULATION



P3-TJ-POST STIMULATION

Figure 4 Spectrum and spectrogram for P3-CL (Pre stimulation, during simulation and post stimulation)

3.2.3 Post Stimulation Observation

In brief, all data show an increase of DF from the state of stimulation to the state of post stimulation (6.59 to 6.84 Hz and 6.35 to 6.59 Hz) on channels 6 and 7.

3.3 Patient 3 (P2-TJ)

The position for each bipolar (channel) labeled is the same as P2-CL. The spectra for P3-TJ are shown in Figure 4 and their frequency in Table 3.

Table 3 Dominant frequency for P3-TJ

Channel / Condition	6 (CS 1-2) (Hz)	7 (CS 3-4) (Hz)
Pre-stimulation	6.59	6.59
Stimulation	6.84	6.84
Post-stimulation	6.10	6.10

3.3.1 Pre-Stimulation Observation

For P3-TJ, the DF during pre-stimulation is 6.59 Hz for channels 6 and 7

3.3.2 During Stimulation Observation

There are increasing trends of DF during stimulation period observed for channel 6 and 7.

3.3.3 Post Stimulation Observation

DF for Post stimulation is lower than DF for pre-stimulation.

4.0 CONCLUSION

From most human studies, the dominant frequency in AF is ranging between 4 Hz to 10 Hz [4, 5]. 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) [6, 7].

There is an expected behavior of DF value obtained for patients P1-VB and P3-TJ. However, in patient P2-CL, the DF during stimulation is less than pre-stimulation and post-stimulation. This is not the expected behavior. However, we observed the spectrum during stimulation is wide and shifting to the right. If we use 'center of gravity' approach for this spectrum, the DF estimation is obtained as shown in Table 4.

Table 4 Centre of gravity for P2-CL

Channel / Condition	6 (CS 1-2) (Hz)	7 (CS 3-4) (Hz)
Pre-stimulation	6.84	6.84
Stimulation	6.96	6.59
Post-stimulation	6.84	6.71

The center of gravity is the center value for a range of data. For this study, this approach is used to identify the center frequency of the spectrum. However, during stimulation, only channel 6 shows the DF (6.96 Hz) higher than pre stimulation (6.84 Hz) and post stimulation (6.84 Hz). Overall, the result for patient P2-CL does not conform to the theory.

Acknowledgement

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