Atrial Fibrillation Dominant Frequency Changes during Ablation

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Abstract

Atrial fibrillation (AF) dominant frequency (DF) is thought to reflect the degree of organisation of underlying atrial activity (AA). Our aim was to assess the changes in DF stage by stage throughout AF ablation.

64-lead body surface ECG was undertaken in 4 patients during AF ablation procedures. After QRST subtraction, DF was obtained from spectral analysis of the lead exhibiting the largest AF component (A22). 28 recordings of 2 minute duration obtained between each ablation were analysed for within and between recording changes in DF.

Mean (SD) within recording DF difference was -0.023 (0.12) Hz. Mean (SD) between recording DF difference was -0.036(0.11) Hz. Within- and between- recording DF differences were not significant (Kruskal-Wallis ANOVA, p>0.05).

This study shows that the changes in DF due to ablation could not be distinguished from the natural variability of the DF as measured by the within recording variability.

1. Introduction

AF is the most common cardiac arrhythmia. It is distinguished by irregular electrical activity of the atria, and the fibrillating or trembling of the atrial muscle, instead of normal contraction. AF DF is thought to reflect the degree of organization of underlying atrial activity. DF increases with increased duration of AF and is generally higher in patients with permanent and persistent AF compared to paroxysmal cases. DF is known to decrease in response to anti-arrhythmic drugs and ablation treatment [1, 2]. Ablation has become a common treatment option for AF with the aim to restore sinus rhythm. An ablation procedure usually involves delivery of energy to create lesions at specific target sites within the atria, for example the pulmonary veins. Little is known about the anti-arrhythmic effect of individual lesion sites.

The aim of the present study is to assess the degree of DF change associated with specific lesion sites during ablation of AF.

2. Methods

2.1. Data recording method

Body surface potential mapping with 64-leads plus 3 bipolar limb leads was used to record electrical activity of the heart in 4 patients (3 male, 1 female, age 59±5 years, in paroxysmal AF), during cardiac ablation using the BioSemi® (BioSemi, Amsterdam, Netherlands) ActiveTwo™ recording system with a sample rate of 2048 Hz, 24-bit/sample.

The 64-lead ECG recording system consists of 8 flexible rubber strips (length of 43 cm) with 8 electrodes on each strip (each 45 mm apart). Electrodes from A1 to A32 were placed approximately parallel with one another on the torso from the level of the top of the sternum, down to the waist. Electrodes from B1 to B32 located in the other 4-strips were placed on the back, the same place and distance as the front strips, as shown in Figure 1.

Cardiac ablation in these patients was started by ablating the left lower Pulmonary Veins (PV), left upper PV, right lower PV, right upper PV, and septum.

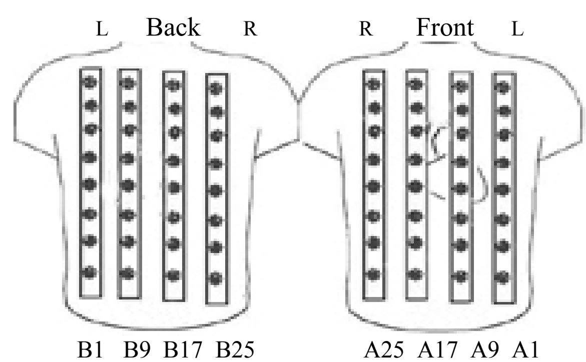

Figure 1. 64-lead electrode placement on the body surface. Front electrodes numbered from A1 to A32. A1-A8 (1st strip) left side of torso, A25-32 (4th strip) right side of the torso. Rear electrodes numbered from B1 to B32 were located as the front strips.

2.2. Data processing method

ECG data were processed offline. The ECG was down-sampled from 2048 Hz to 512 Hz and band-pass filtered (0.5 to 100 Hz) for baseline wander removal and high frequency noise suppression. ECG channel A22 was chosen in this study on AF analysis as its location on the torso is close to V1, where the atrial activity is generally prominent. The Wilson Central Terminal was computed and subtracted from the 64 channels to obtain 64 precordial leads. Beat detection was carried out by means of a proprietary threshold-based QRS detector. QRST cancellation was done by averaged-QRST template subtraction [3]. The QRST window was defined as the interval [RPEAK - 60ms, RPEAK + 310ms], where RPEAK represents the QRS fiducial point detected by the beat detection algorithm. Short-time Fourier Transform (STFT) spectrogram was adopted to compute time-frequency distribution (STFT-TFD) of atrial activity. A sliding Hamming window (50% overlap) was used. For each time slot (ΔW) of 8 s, atrial fibrillation (AF) dominant frequency (DFΔW) was identified in the AF window of interest (4-10 Hz), as the frequency corresponding to the highest local peak in the STFT TFD. For each recording DF was defined as the mean value of DFΔW. The choice of parameters for the STFT-TFD gives a frequency resolution of 0.125 Hz. The block-diagram in Figure 2 shows the ECG processing flow. Figures 3 to 5 show an example of ECG processing intermediate output. Figure 6 shows an example of STFT time-frequency distribution of AA signal.

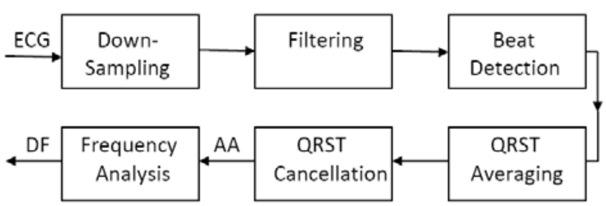

Figure 2. Signal processing block-diagram.

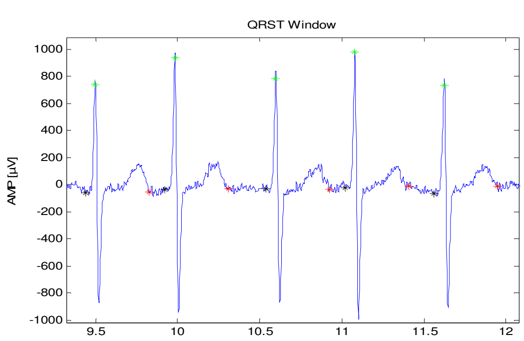

Figure 3. ECG excerpt from channel A22. QRS fiducial point (green asterisk), QRST onset (black asterisk), QRST offset (red asterisk).

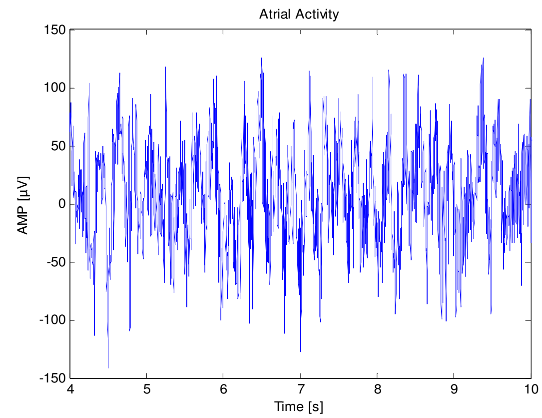

Figure 4. Atrial activity signal extracted from ECG channel A22, by QRST suppression.

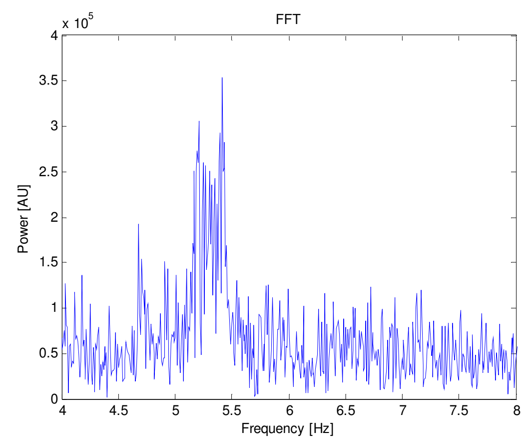

Figure 5. FFT for atrial activity channel A22.

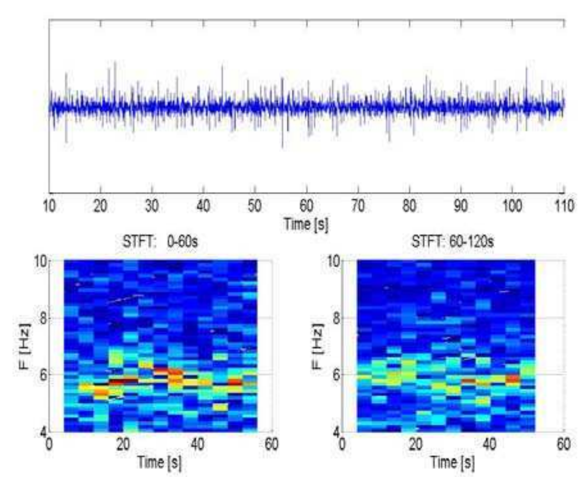

Figure 6. Atrial activity signal (top) and its STFT time-frequency distribution (bottom) for 1st minute of pre-ablation recording (left) and 2nd minute (right).

2.3. Data analysis method

Recordings of 2 minutes duration before and after each lesion were analysed. First, within recording differences in DF were quantified by calculating the difference between first and second minute within each recording. Second, changes in DF between pre- and post- ablation were calculated from the difference in the mean DF across pre and post ablation recordings. Mean and standard deviation (SD) were computed across all the recordings.

3. Results

Table 1 (a) and (b) show DF values for first minute and second minute of each recording. Table 1 (c) shows the difference of the first minute and second minute of each recording. Mean (SD) difference of DF within recording was -0.023 (0.12) Hz.

Table 2 (a) shows DF values for 2 minute recordings for each subject, (b) shows difference of DF before and after each ablation for 2 minute recordings for each subject. Mean (SD) of DF between recording differences were -0.036 (0.11) Hz.

Figure 7 shows box plot of DF for pre and post ablation recordings. Kruskal-Wallis test indicated no significant difference (alpha = 0.05).

Table 1. (a) and (b) DF (Hz) for first and second minute recordings for each subject. R1 is first recording before ablation, R2 is the second recording after ablation, R3 is third recording before second ablation and so on as is described in the data recording method. The numbers of recordings for all patients are not the same, as in some cases AF has been terminated earlier. (c) Difference of DF between first minute and second minute of recordings in each subject.

(a)

Patient / 1^{st} min Rec	1	2	3	4
R1	7.06	5.06	6.06	5.56
R2	6.68	5.56	6.25	5.68
R3	6.68	6.00	6.25	5.87
R4	6.87	5.18	6.12	5.56
R5	6.31	5.37	6.06	-
R6	7.12	4.78	6.18	-
R7	6.75	-	6.06	-
R8	6.93	-	6.12	-
R9	6.68	-	-	-
R10	6.31	-	-	-

(b)

Patient / 2^{nd} min Rec	1	2	3	4
R1	6.75	5.12	6.37	5.81
R2	7.00	5.62	6.06	5.75
R3	6.75	6.00	6.12	5.93
R4	6.56	5.25	6.12	5.87
R5	6.56	5.37	5.25	-
R6	7.12	5.00	6.12	-
R7	6.87	-	6.31	-
R8	6.93	-	6.31	-
R9	5.56	-	-	-
R10	6.37	-	-	-

(c)

Patient / 1^{st}min–2^{nd} min	1	2	3	4
R1	0.31	-0.06	-0.31	-0.25
R2	-0.32	-0.06	0.19	-0.07
R3	-0.07	0	0.13	-0.06
R4	0.31	-0.07	0	-0.31
R5	-0.25	0	0.81	-
R6	0	-0.22	0.06	-
R7	-0.12	-	-0.25	-
R8	0	-	-0.19	-
R9	1.12	-	-	-
R10	-0.06	-	-	-

Table 2. (a) DF (Hz) for the entire 2 minute recordings. (b) Difference of DF before and after each ablation.

(a)

Patient / 2 min Rec	1	2	3	4
R1	7.06	5.06	6.25	5.68
R2	7.00	5.62	6.18	5.68
R3	6.87	5.62	6.18	5.87
R4	6.87	6.00	6.12	5.74
R5	6.68	5.37	6.06	-
R6	7.12	5.00	6.12	-
R7	6.75	-	6.12	-
R8	6.93	-	6.12	-
R9	6.68	-	-	-
R10	6.31	-	-	-

(b)

Patient / Pre-post	1	2	3	4
R1-R2	0.06	-0.56	0.07	0
R3-R4	0	-0.38	0.06	0.13
R5-R6	-0.44	0.37	-0.06	-
R7-R8	-0.18	-	0	-
R9-R10	0.37	-	-	-

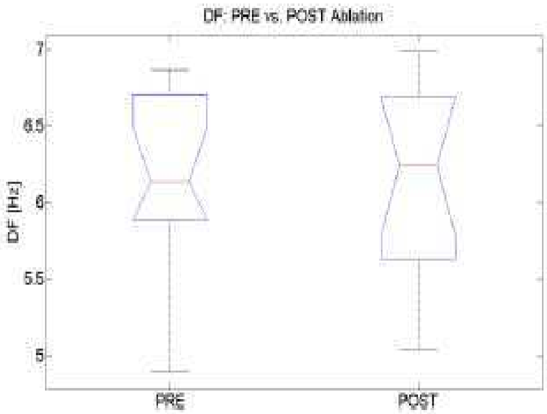

Figure 7. Box plot of DF pre and post ablation.

4. Discussion and conclusions

In this study 2 minute ECG recordings from 4 subjects were considered with the goal of analysing dominant frequency changes in atrial activity during cardiac ablation.

Mean (SD) within recording DF difference (1st vs. 2nd minute) was -0.023 (0.12) Hz. Kruskal-Wallis analysis of variance showed no significant difference (p>0.05).

DF is known to decrease in response to anti-arrhythmic drugs and ablation treatment [1, 2]. However, according to this study, Mean (SD) between recording DF difference was -0.036(0.11) Hz, which was found not significant (Kruskal-Wallis, p>0.05).

This preliminary study on a small number of subjects suggests that, in our subjects, ablation had very little effect on the DF of AF. Further work will quantify the DF changes due to ablation in a greater number of subjects and seek to establish whether changes in DF are predictive of ablation success.

References

[1] Raine D, Langley P, Murray A, Dunuwillw A, Bourke JP. Surface atrial frequency analysis in patients with atrial fibrillation: A tool for evaluating the effects of intervention. J Cardiovasc Electrophysiol 2004; 15: 1021-1026.

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