Does Synthesized Lead V9 Reflect Left Atrial Activity During Atrial Fibrillation ?

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Abstract. *Previous studies have demonstrated right-sided precordial leads could reflect mostly right atrial (RA) activity, while posterior lead V9 could reflect mostly left atrial (LA) activity. 18 synthesized lead ECG enables us to extrapolate posterior leads V7-9 and right-sided precordial leads (V3R-V5R). Therefore, we conducted a preliminary study on whether synthesized leads are able to evaluate both atrial activities during atrial fibrillation. We recorded the standard 12-lead ECG, posterior leads V7–V9, right-sided precordial leads V3R–V5R and intracardiac electrograms (EGM) in the RA, LA and coronary sinus (CS) simultaneously from 1 male subject with paroxysmal AF before pulmonary vein isolation. The corresponding dominant frequency (DF) was estimated from the peak frequency of each lead's fibrillatory wave or EGM's FFT. The DFs in LA from EGMs in CS and LA (5.1 and 5.1 Hz) were consistent with that in lead V9 (5.1 Hz). Furthermore, that in synthesized lead V9 showed a close value (5.0 Hz). Furthermore, the DF in intracardiac RA (4.8 Hz) was close to that in V1 (4.8 Hz) and V3R-V5R. Synthesize lead V9 may evaluate the LA activity, and help in monitoring AF and identifying ablation sites through combining with the standard 12-lead ECG.*

Keywords: Atrial fibrillation, dominant frequency, frequency analysis, intracardiac electrogram, posterior lead

1. Introduction

Atrial fibrillation (AF) is the most popular cardiac arrhythmia, occurring in 1~2% of residents in Europe and United States [1]-[2], and in 0.56% in Japan [3]. Furthermore, the prevalence and incidence of AF increase with age, and reach about 10% in Europe and US and about 4.4% in Japan at 80 years' old.[1]-[3] AF is also an independent mortality predictor with a doubled death rate among AF subjects, and AF is the cause of 20% stroke.[2] The mechanism of AF is not completely confirmed but is usually attributed to focal mechanisms and multiple wavelets.[2] The main AF therapeutic methods are antiarrhythmic drug therapies including rate control and rhythm control [2], and cathode ablation.[2][4] Recent publications have also reported that significantly more atrial fibrillation (AF) patients after cathode ablations were free from any AF and symptomatic AF compared with AF patients underneath antiarrhythmic drug therapies. Furthermore, AF patients after cathode ablations have significantly better life quality at 12 and 24 months.[2] Therefore, catheter ablation is recommended as the first line therapy for atrial fibrillation (AF) patients with paroxysmal AF, with low CHA_2DS_2-VASc values, and without marked structural heart diseases.

Researches on frequency analysis of surface ECG and intracardiac electrograms have been conducted to discover the mechanism of AF and predict the resurrection of AF after cathode ablation.[5]-[7] Sanders et al. found that localized sites of high-frequency activity during AF may play roles in the maintenance of AF because ablation at these sites results in the prolongation of atrial fibrillation cycle length and termination of paroxysmal AF.[5] Mansour et al. concluded that left-to-right gradient of atrial frequencies supports the hypothesis that AF is the result of high-frequency periodic sources in the left atria.[6] Atienza et al. reported that

cathode ablation leading to elimination of left-to-right frequency predicts long-term SR maintenance in AF patients.[7]

Petutiu et al. found a strong correlation between V1 and right atrial EGM and between V9 and left atrial EGM, and therefore recording additional posterior ECG leads may noninvasively monitor right and left atrial events and interatrial frequency gradients.[8] Guillem et al. discovered that spectral analysis of body surface recordings during AF allows a noninvasive characterization of the global distribution of the atrial dominant frequency, and the identification of the atrium with the highest frequency noninvasively.[9]

Additional ECG leads such as posterior and right-sided precordial leads are not routine clinical tools for the diagnosis of AF, and the measurement of posterior leads is inconvenient and impractical in most situations. Wei has proposed an information redundancy method to derive posterior leads V7-9 from the standard 12 leads [10] and proved their usefulness in the diagnosis of right ventricular or posterior wall ischemia. In this paper, based on Wei's method, we conducted a preliminary study on whether synthesized posterior leads can also reflect left atrial activities during atrial fibrillation. Surface ECG and atrial electrograms were simultaneously recorded from an AF patient and the synthesized posterior and right precordial leads were synthesized from standard 12 leads. The f waves of surface leads were estimated by employing a QT-based method developed by our research team.[11] Then frequency analysis was conducted to get the dominant frequencies (DF) of f waves & atrial electrograms and their spatial distributions. Finally, the DFs obtained from the standard 12 leads, posterior leads, right-sided precordial leads, synthesized leads, and EGM were compared to unmask.

2. Subject and Methods

The surface ECG and intracardiac electrograms were recorded from a 49-year-old male paroxysmal AF subject before the performance of radiofrequency ablation. The 12 standard ECG and additional leads were simultaneously recorded together with His bundle, coronary sinus (CS), right atrial (RA), superior vena cava (SVC) electrograms. LA electrograms was measured by an ablation catheter. The body surface ECG was previously processed by a 0.05-100 Hz filter, and atrial electrograms were processed by a 30-150 Hz filter in the EP device. Powerline noise was removed by using a 50-60 Hz notch filter.

This research has been permitted by the medical ethics committee of Tohoku University, Japan and was conducted based on the rules of the same committee.

We employed a QT-based method to extract f waves from surface ECG instead of the traditional average beat subtraction method. The details of the QT-based method were reported in our previous publication [11].

The surface ECG during AF can be expressed as a combination of ventricular activity atrial activity, and noise as follows,

$$x(t) = v(t) + a(t) + n(t), \quad (1)$$

where x, v, a, n, and t are ECG, ventricular activity, atrial activity (f wave), noise, and time, respectively.

Frequency analysis of f wave is conducted in a traditional way [11], where Fourier transform, a Hamming window (16.384 s) were used in this research. Furthermore, the value of FFT's amplitude is normalized to 0-1 in this research. DF is determined by the peak in the frequency bandwidth 4~9 Hz.

As atrial electrograms were previously processed by a bandpass filter, they were rectified in order to get the dominant frequency in 4-9 Hz. Then FFT with the same parameters as those

in the frequency analysis on f waves, was conducted to get dominant frequencies in the rectified atrial electrograms [11].

3. Results

Fig. 1 illustrates the locations of standard 12 lead ECG and additional leads including V7-9 and V3-5R. The derivation of right precordial and posterior leads is based on an information redundancy method proposed by Wei.[10] Fig. 2 illustrates frequency spectra of f waves extracted from V1 (blue curve) and V9 (red curve) leads. Table 1 shows the dominant frequencies estimated from surface ECG and atrial electrograms.

It is observed that there is a left-to-right atrial frequency difference as the DFs of RA distal and LA distal EGMs are 4.8 and 5.1 Hz, respectively. Furthermore, the DFs of additional leads were closer to those of synthesized additional leads. The DF of V1, 4.8 Hz was also lower than those of posterior leads and synthesized posterior leads (5.0~5.1 Hz).

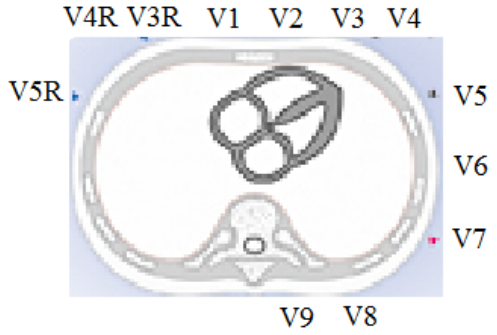

Fig. 1. Locations of standard 12 leads, right precordial leads, and posterior leads.

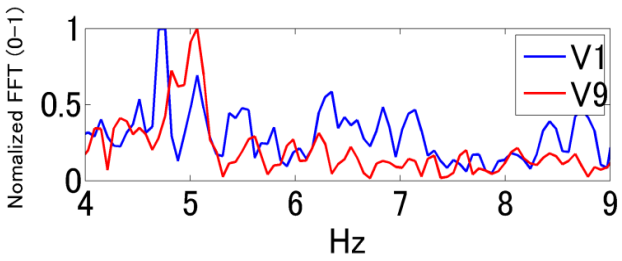

Fig. 2. Frequency spectra of f waves extracted from V1 (blue curve) and V9 (red curve) leads.

Table 1. Dominant frequencies estimated from surface ECG and atrial electrograms

Lead	DF (Hz)	Lead	DF (Hz)	Lead	DF (Hz)	Lead	DF (Hz)
I	5.2	V3R	4.8	synthesized V3R	4.9	RA dist.	5.5
II	5.0	V4R	4.8	synthesized V4R	4.8	RA prox.	4.8
III	5.0	V5R	4.8	synthesized V5R	4.8	CS dist.	5.0
aVL	5.0	V7	5.0	synthesized V7	5.0	CS prox.	5.1
aVF	5.0	V8	5.0	synthesized V8	5.0	LA dist.	5.1
V1	4.8	V9	5.1	synthesized V9	5.0	LA prox.	5.0

4. Discussion

Guillem et al. [9] have reported that it might be possible to localize the atrial fibrillation occurrence using surface ECG. Petrutiu et al.'s researches showed that a strong correlation between V1 and right atria and between V9 and left atria, and therefore recording additional posterior ECG leads may noninvasively monitor right and left atria events and interatrial frequency gradients [8]. As the measurement of posterior leads is inconvenient, we synthesized posterior leads from standard 12 lead to confirm whether synthesized posterior leads may reflect the electric activities of left atria. In this case, we observed that V9 and synthesized V9 leads had a similar DF to that of the left atrial EGMs, and V1 lead had a similar DF to that of the right atrial EGM. And there was a left-to-right atrial frequency difference, which was confirmed using the frequency analysis of left and right atrial EGMs. Therefore, synthesized V9 lead may be useful for noninvasively unmasking interatrial frequency difference. Of course, this should be further validated using more clinical data.

5. Conclusion

The result of the preliminary study demonstrated that DFs obtained from V1 & posterior and synthesized posterior leads may serve as non-invasive indexes to reflect the right and left atrial activities during AF, respectively. This may lead to a convenient noninvasive detecting for the responsible atrial chamber of AF maintenance before cathode ablation.

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