Separating the Atrial and Ventricular Components in Atrial Fibrillation. Are 64 Leads Better than 12?

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Abstract

It is important to be able to separate the atrial activity from the dominant ventricular activity of the body surface ECG signals in atrial fibrillation so that the effect of therapies such as drug cardioversion and ablation can be adequately assessed. Principal Component Analysis (PCA) and Independent Component Analysis (ICA) are algorithms which can be used but their application has been limited to standard 12-lead ECG recordings. Our aim was to investigate whether better separation of the atrial and ventricular activities could be achieved using additional leads. We applied PCA and ICA to ECG recordings of 12 and 64 leads in 5 patients in atrial fibrillation. We measured and compared between the 12 lead and 64 lead analyses the amplitude of residual ventricular QRS which remained in the separated atrial activity and the dominant fibrillatory frequency. We found that there was little difference between 12 and 64 leads in separating the atrial and ventricular activity.

1. Introduction

1.1. The importance of being able to analyse the atrial signal

Atrial arrhythmias are the most common seen in clinical practice [1]. It is important to be able to separate the atrial activity from the dominant ventricular activity of the body surface ECG signals in atrial fibrillation so that the effect of therapies such as drug cardioversion and ablation can be adequately assessed [2,3]. Analysis of the body surface atrial signal presents a challenging problem because the atrial component of the electrocardiogram (ECG) is small and often obscured by the large ventricular component. PCA and ICA are algorithms which have been used to separate the atrial and ventricular activities of the multi-lead ECG [4,5] but there is often some residual ventricular activity remaining in the separated atrial signal. Applications of these algorithms have been limited to 12-lead recordings. Recently electrode positions other than those used for the standard 12-lead ECG have been thought to help reveal more of the atrial signal. Our aim was to assess whether these PCA and ICA algorithms were better able to separate the atrial signal from the mix of cardiac activites seen on the body surface using 64 leads compared to standard 12-lead recordings.

2. Methods

2.1. 12 lead and 64 lead BSP recordings

64-lead body surface potential data and standard limb leads were collected from 5 patients at the Freeman Hospital in AF and were recorded at a sample rate of 2048 Hz. The 12-lead ECG was derived from the limb leads and BSPM electrodes positioned closest to the standard 12-lead ECG precordial electrodes. BSPM was with respect to the Wilson Central Terminal. One second segments of the data were selected which contained one ventricular beat as well as the underlying fibrillating atrial signal. Electrode positions for the BSPM are illustrated in figure 1.

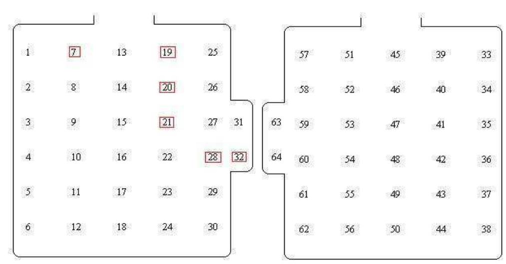

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Figure 1. The electrode positions for the 64 lead system. Electrodes used for derived 12-lead ECG shown in red squares.

2.2. Methods – separating the atrial and ventricular activities using PCA and ICA

PCA and ICA were applied to the 12-lead and 64-lead

BSP. The principal/ independent component with the largest atrial activity was selected from the separated ventricular and atrial components for comparison.

2.3. Comparison between 12 lead and 64 lead extracted atrial activities

In order to assess quantitatively the level of ventricular activity remaining in the extracted atrial component, we measured the amplitude of the QRS artefact in the extracted signal. Because the amplitude of the estimated atrial signals was different for 12 and 64 lead analysis, it was necessary to scale these signals so that the atrial components of these signals had the same amplitude. Fibrillation frequency is a key clinical parameter so we also compared the atrial fibrillantion frequency in the extracted atrial signals. The frequency spectra were extracted using Fourier analysis with a frequency resolution of 0.25Hz.

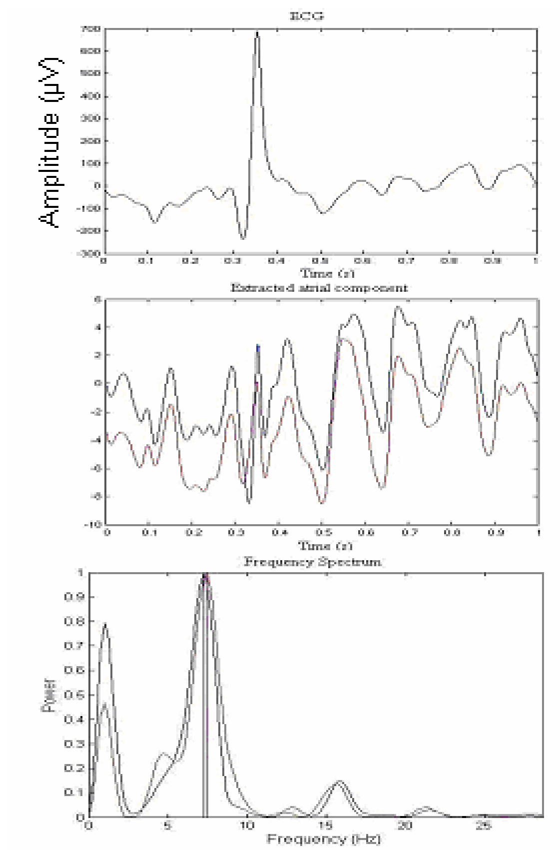

Figure 2. PCA analysis subject 1. ECG (top), extracted atrial component (middle), and frequency spectrum of the atrial component (bottom) for subject 1. Blue 12 lead, red 64 lead.

3. Results

For illustration presented in figures 2,3,4 and 5 are 2 of the results for both PCA and ICA for two cases. For each patient we present the PCA first and then the ICA results. The figures show V1, the extracted atrial components from 12 leads and 64 leads and their respective frequency spectra.

We also present the tables of the frequency analysis results (table 1) and the amplitude of residual QRS activity within the selected QRS segment of the components (table 2) for the 5 subjects.

For both 12 and 64 lead PCA and ICA the extracted atrial components are similar in shape and the amount of residual ventricular activity. The frequency spectra analysis also shows the similarity between 12 and 64 lead components.

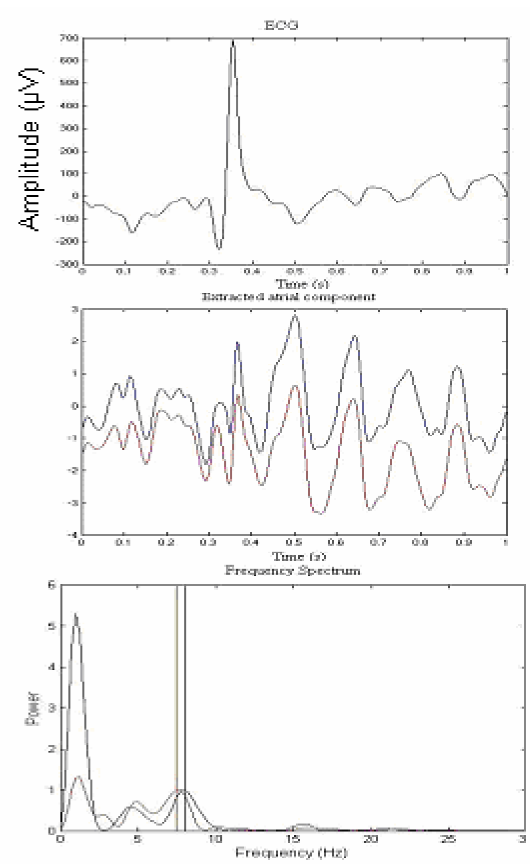

Figure 3. ICA analysis subject 1. ECG (top), extracted atrial component (middle), and frequency spectrum of the atrial component (bottom) for subject 1. Blue 12 lead, red 64 lead.

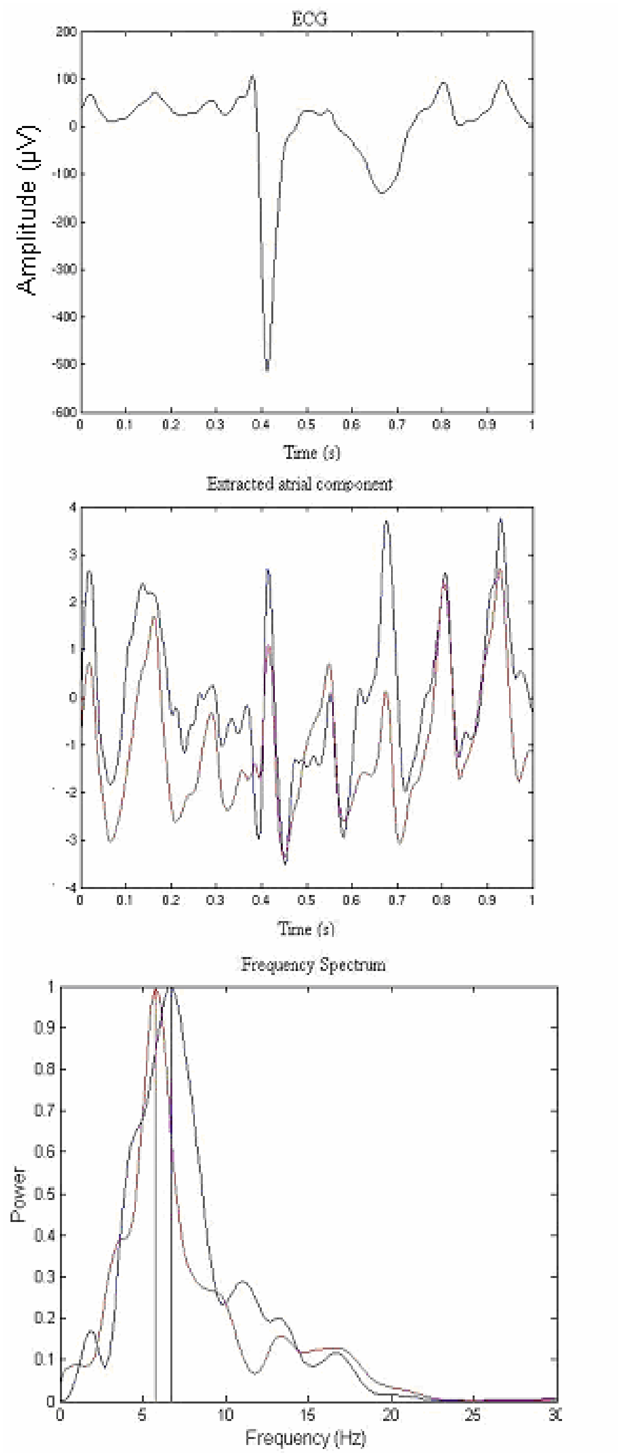

Figure 4. PCA analysis subject 5. ECG (top), extracted atrial component (middle), and frequency spectrum of the atrial component (bottom) for subject 5. Blue 12 lead, red 64 lead.

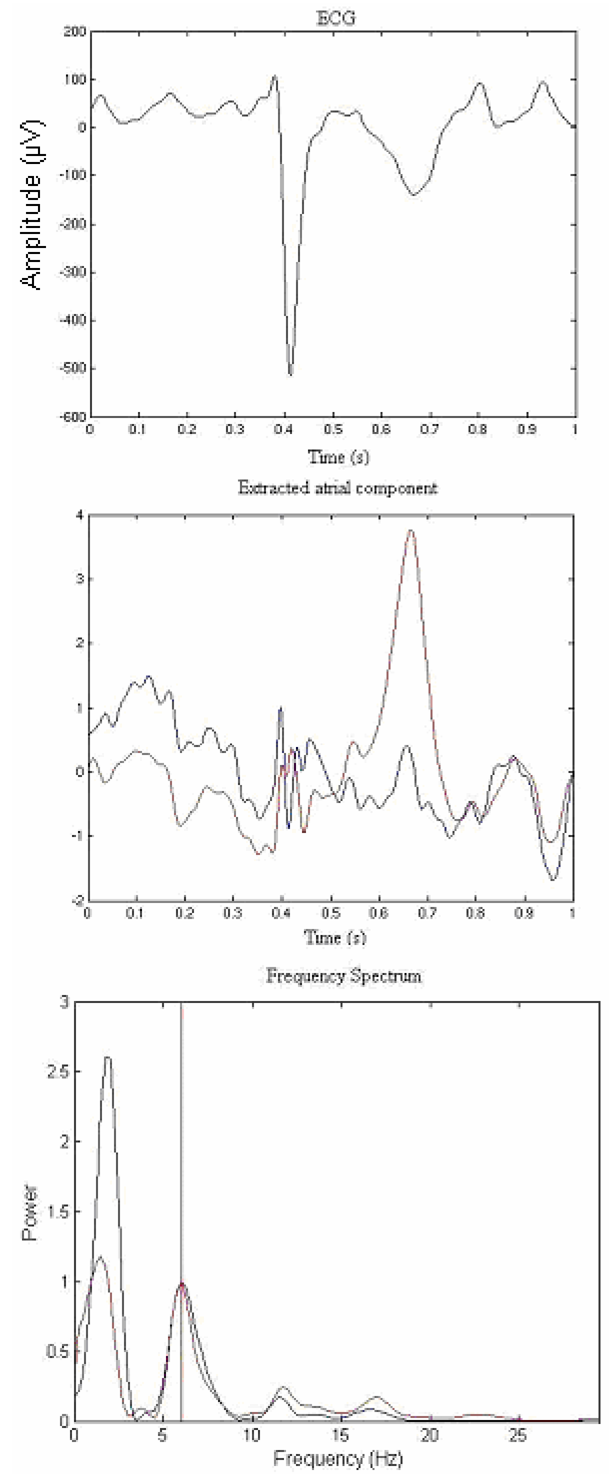

Figure 5. ICA analysis subject 5. ECG (top), extracted atrial component (middle), and frequency spectrum of the atrial component (bottom) for subject 5. Blue 12 lead, red 64 lead.

PCA frequency analysis

	Subjects				
	S1	S2	S3	S4	S5
12 lead	7.25	5.75	8.75	7.75	6.75
64 lead	7.5	5.75	8.75	7.75	6.25

ICA frequency analysis

	Subjects				
	S1	S2	S3	S4	S5
12 lead	8	6	8.75	7.5	6.75
64 lead	7.75	6	8.75	7.5	6.75

Mean of PCA and ICA

	PCA	ICA
12 lead	7.25	7.4
64 lead	7.2	7.35

Table 1. Comparison of fibrillatory frequency (Hz).

PCA

	Subjects				
	S1	S2	S3	S4	S5
12 lead	0.798	0.404	0.887	0.414	0.912
64 lead	0.529	0.309	1.027	0.854	0.281

ICA

	Subjects				
	S1	S2	S3	S4	S5
12 lead	1.777	2.945	2.535	1.211	1.638
64 lead	2.084	1.904	3.01	1.999	1.465

Mean of PCA and ICA

	PCA	ICA
12 lead	0.683	2.019
64 lead	0.599	2.091

Table 2. Comparison of amplitude of residual QRS (μV).

4. Discussion and conclusions

From the results presented above there appears to be no significant difference in the ability of ICA or PCA to separate the atrial and ventricular components dependant on the number of signals taken from the body surface. In both PCA and ICA of 12 and 64 leads the amount of residual ventricular activity remaining is similar and the frequency spectra shows similar values for both. The T wave residual was not measured, as identifying the residual can sometimes be difficult.

In this work we have selected only the main atrial component, further inspection of the components of 64 leads may reveal additional features of atrial fibrillation not seen in 12 leads.

Acknowledgements

A Haigh and P Langley are funded by EPSRC.

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