Feasibility of Separating the Atrial and Ventricular Components of the Electrocardiogram

AJ Haigh, A Murray, P Langley

Newcastle University, Newcastle upon Tyne, UK

Abstract

Our aim was to assess the feasibility of separating concurrent atrial and ventricular (AV) activities of the body surface signals using an algorithm in patients with heart block.

Principal Component Analysis (PCA) was applied to 12-lead ECG sections containing 'P wave on T wave' from two patients with complete heart block. The principal components containing the separated atrial activity were identified and the inverse transform applied to project the atrial activity back into the ECG leads. These extracted P waves were then compared with reference P waves occurring without ventricular activity.

The extracted and reference P waves were highly correlated (0.7 in patient 1, 0.8 patient 2).

PCA was able to separate the AV activities in heart block patients.

1. Introduction

Atrial arrhythmias are the most common arrhythmia seen in clinical practice [1]. Analysis of the body surface atrial signal presents a challenging problem because the atrial component of the ECG is small and often obscured by the large ventricular component. Analysis is therefore restricted to intervals where there is no concomitant ventricular activity. This is adequate for the assessment of atrial depolarisation in sinus rhythm for example, but there are many arrhythmias in which atrial depolarisation occurs simultaneously with ventricular depolarisation offer repolarisation. Slocum et al demonstrated the separation of AV activity in arrhythmias in which these activities were dissociated [2]. But the challenge remains for AV associated rhythms. More recently, interest in separating the atrial and ventricular components of the ECG has focused on atrial fibrillation and several algorithms have been demonstrated [3,4,5]. These algorithms fall into two categories: those which exploit the dissociation between the atrial and ventricular components, and those which exploit the concept that the AV activities are generated from different bioelectric sources.

The algorithms from the latter category offer the potential to separate AV activity regardless of the cardiac rhythm.

Our aim was to assess the feasibility of separating the concurrent atrial and ventricular activities of the body surface signal using such an algorithm in patients with heart block. The assessment of the feasibility of the technique in these patients is particularly was suitable because the ECGs of these patients exhibit periods of isolated AV activity, (ie the atrial activity is not obscured by the ventricular activity) and vice versa, when there are periods of simultaneous AV activity.

2. Methods

2.1. ECG data

12-lead ECGs of two patients of the Freeman Hospital with complete heart block were recorded at a sample rate of 500 Hz and amplitude resolution of 4.88 μV, and saved to a computer hard disk for subsequent off-line processing. For each patient, sections of ECG with atrial activity only, and atrial activity concomitant with ventricular activity, ie P waves on T waves, were selected by visual inspection of the ECG waveform. The P waves free of ventricular activity were the reference P waves which were compared with those extracted from the sections with simultaneous AV activity.

2.2. Principal Component Analysis

Principal Component Analysis (PCA) has been shown to separate the atrial and ventricular activities from the 12-lead ECGs of patients with atrial fibrillation [6] and was applied to the ECG sections with simultaneous AV activities to separate the atrial and ventricular components (figure 1). The principal component with the most dominant feature synchronous with the P wave in the ECG was selected as the one representing the atrial activity. The inverse PCA transform was applied to this, effectively projecting the separated atrial activity back into the ECG leads, facilitating direct comparison with the reference P waves.

ISSN 0276−6547 Computers in Cardiology 2006;33:393−396.

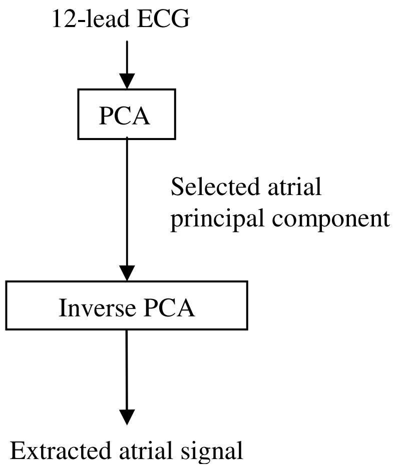

Figure 1. Stages of progress in obtaining the extracted atrial signal using the selected principal component

2.3. Comparison of extracted and reference P waves

To evaluate the algorithm we compared the P waves extracted by PCA to the reference P waves, and their correlation was calculated.

3. Results

Figures 2 and 3 show the 12-lead ECGs with concomitant atrial and ventricular activity for each patient. In both cases the P waves occurred after the peak of the T waves.

Figures 4 and 5 show the 12 principal components derived from the 12-lead ECGs. In each case the first principal component is dominated by ventricular repolarisation. For patient 1, principal component 3 was selected as the one to represent the atrial activity. For patient 2, principal component 2 was representative of the atrial activity.

Figures 6 and 7 show the contribution (PCA loadings) of each of the 12 leads of the ECG to each of the 12 principal components. Figures 8 and 9 show the selected principal component projected into lead V1 alongside the same lead containing the AV activity, and the reference P wave for that lead. The correlation between reference and extracted P waves is shown in table 1.

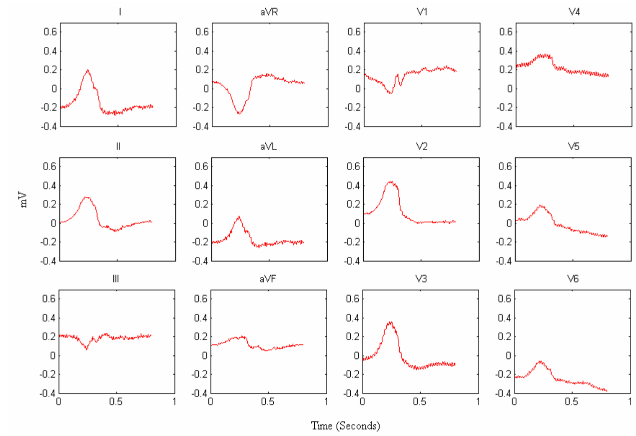

Figure 2. 12-lead ECG from patient 1 showing P wave on a T wave

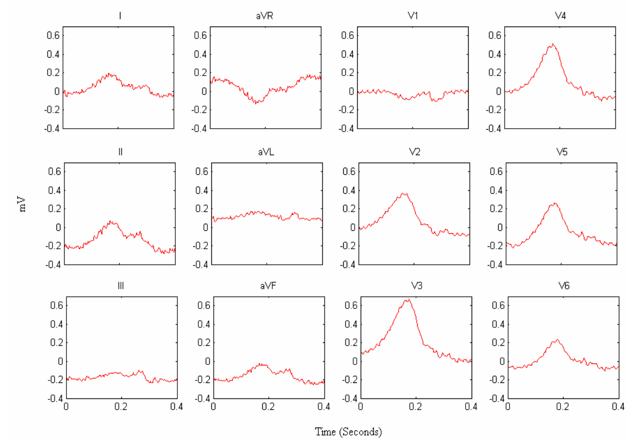

Figure 3. 12-lead ECG from patient 2 showing P wave on a T wave.

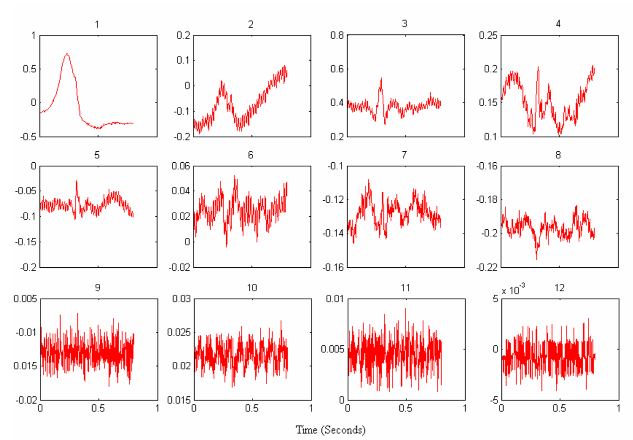

Figure 4. 12 principal components extracted from the 12-lead ECG of patient 1.

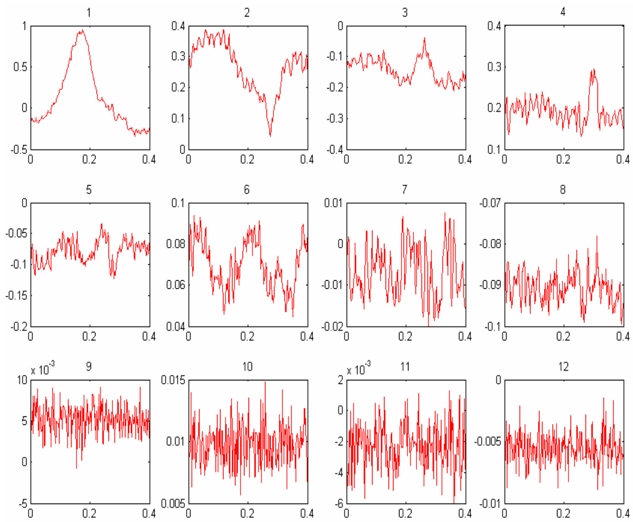

Figure 5. 12 Principal components extracted from the 12 - lead ECG of patient 2.

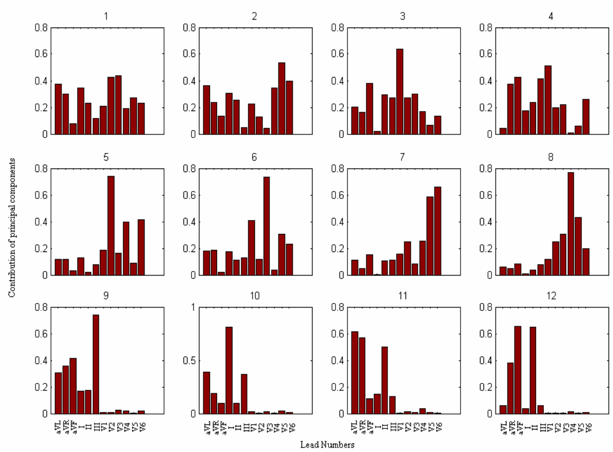

Figure 6. Contribution of each of the 12 leads of the ECG to the 12 principal components for patient 1.

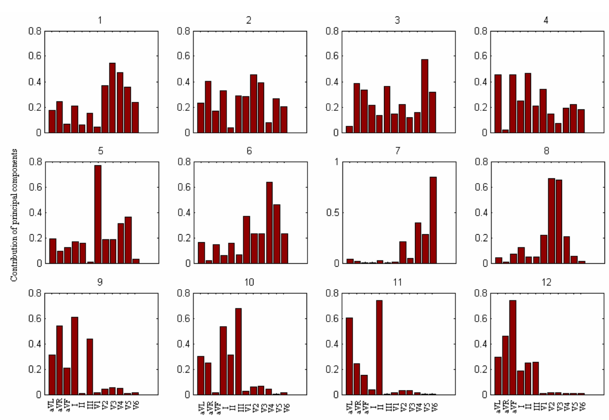

Figure 7. Contribution of each of the 12 leads of the ECG to the 12 principal components for patient 2.

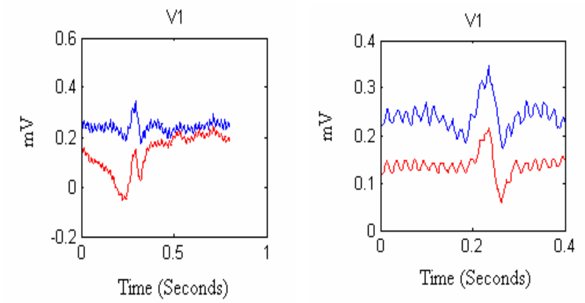

Figure 8. On the left, the extracted P wave signal (top) and the P wave on the T wave for patient 1. On the right, a comparison of the extracted P wave (top) to a separate reference P wave (bottom).

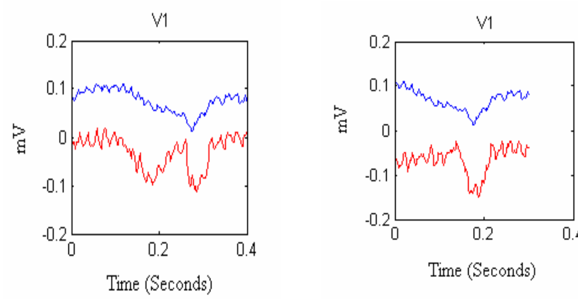

Figure 9. On the left, the extracted P wave signal (top) and the P wave on the T wave for patient 2. On the right, a comparison of the extracted P wave (top) to a separate reference P wave (bottom).

Table 1. Correlation between extracted and reference P waves.

	Patient 1	Patient 2
Correlation	0.7	0.8

4. Discussion and conclusions

We have shown that PCA is able to separate the atrial and ventricular components from the 12-lead ECG in heart block patients. For this to be achievable the bioelectric sources generating the body surface atrial and ventricular signals must be uncorrelated. This is due to the fundamental requirement that the principal components are orthogonal. We chose to analyse P on T waves. This study will be extended to see if atrial activity can be separated during ventricular depolarisation. The algorithm is not restricted to rhythms with AV dissociation.

Acknowledgements

A Haigh and P Langley are funded by EPSRC.

References

[1] Fuster V, Ryden Lem Asinger RW, et al: ACC/AHA/ESC Guidelines for the management of patients with atrial fibrillation: Executive summary A report of the American college of Cardiology/ American Heart Association task force on practice guidelines and the European Society of Cardiology. Circulation 2001; 104(17): 2118-50.

[2] Slocum J, Sahakian A, Swiryn S. Diagnosis of atrial fibrillation from surface ECGs based on computer detected atrial activity. J Electrocardiol 1992; 25:1-8.

[3] Stridh M, Sornmo L. Spatiotemperal QRST cancellation techniques for analysis of atrial fibrillation. IEEE Trans Biomed Eng 2001; 48: 105-11.

[4] Reita JJ, Millet-Roig J, Zarxöso V, et al. Atrial fibrillation, atrial flutter and normal sinus rhythm discrimination by means of blind source separation and spectral parameters extraction. Computers in Cardiology 200; 29: 25-28.

[5] Langley P, Stridh M, Reita JJ, Sornmo L, Millet-Roig J, Murray A. Comparison of atrial rhythm atrial frequency from the 12-lead electrocardiogram in atrial fibrillation. Computers in Cardiology 2002; 29: 29-32.

[6] Raine D, Langley P, Murray A, Danuwille A, Bourke JP. Surface atrial frequency analysis in patients with atrial fibrillation: assessing the effects of linear left atrial ablation. J Cardiovasc Electrophsiol 16;8: 838-844.

Address for correspondence

A Haigh
Medical Physics Dept.
Freeman Hospital
Newcastle upon Tyne
UK
a.j.haigh@ncl.ac.uk