Reconstruction of Respiratory Patterns from Electrocardiographic Signals

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Abstract: Presently there is lack of a reliable method for monitoring the respiratory cycles in the ambulatory patients. Knowledge of respiratory pattern is useful in many clinical situations. With the ECG signal being the most frequently monitored biomedical signal, it is essential to extract the respiratory waveform from ordinary ECG tracings. Such a technique would permit reliable detection of respiratory efforts in healthy and diseased patients.

In this paper we present the result of a pilot study in which the ECG signals from lead II (LL+ : RA-) and a modified chest lead I (V1+ : LA-) were used to derive the respiration waveforms from the mean electrical axis of the heart. The ECG derived respiratory patterns compared favorably with those obtained from airflow measurements.

INTRODUCTION

A comprehensive study of the current biomedical signal processing literature showed that it is possible to extract the respiratory signal from ordinary ECG tracings [1,2,3]. The changes in the impedance of the thoracic cavity influences the ECG signals recorded from the surface of the body. The respiration caused expansion and contraction of the chest results in the movement of chest electrodes. Short-term changes in thoracic impedance reflect the filling and emptying of the lungs, a phenomenon which is the basis of impedance plethysmography. The physical influence of respiration results in amplitude variations in the recorded ECG tracings. The respiratory influence modulates the direction of the mean electrical axis (MEA) of the heart. The diaphragmatic activity and the intercostal muscles cause expansion and contraction of the chest in 3-D space. This periodic or aperiodic movement affects the ECG signal in each lead differently. The frontal lead I will be primarily affected by the horizontal component while lead III will be primarily affected by the vertical component of the thoracic movements, but lead II will be least affected.

In this work, we used the ECG tracings from a set of nearly orthogonal leads to derive the respiratory components of the ECG signal. Here we present the result of processing the ECG signals from lead II and MCLI.

METHOD

The instrumentation used in this pilot study is shown in Figure 1. The data collection set up included four ECG leads namely, L1, L2, L3 and MCL1, thermistors (airflow measurements), chest and abdominal inductance plethysmographic bands. Analog signals from all the electrodes and transducers were first sent to the polygraph where preprocessing of the signals was performed. We only used the ECG recordings from L2 (lead II) and MCL1 for the purpose of this study. The respiratory signals were collected at a sampling rate of 10 Hz and the ECG signals were collected at a sampling rate of 500 Hz.

The ECG recording in the frontal plane lead is a projection of the cardiac Mean Electrical Axis on this plane, while the ECG signal in the chest leads (V1-V6) is a projection of the MEA on the transverse plane. The Z component as measured by Frank's lead system is the projection on the sagittal plane (Figure 2). The resultant of these three orthogonal projections provides the orientation of the MEA in 3-D space.

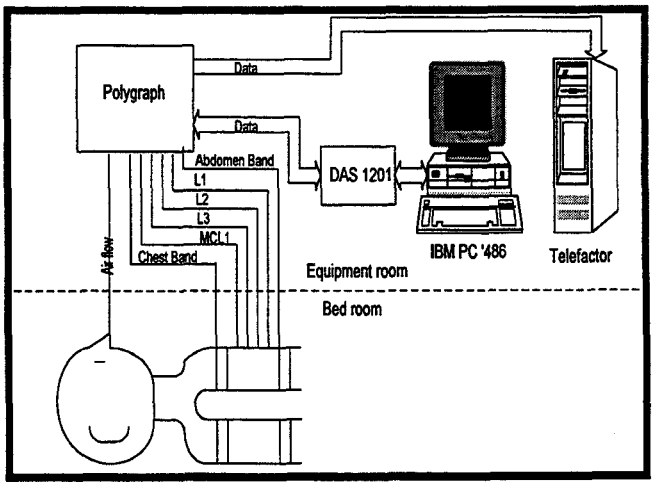

Figure 1. Schematic of the experimental setup

In routine monitoring and diagnostic electrocardiography only frontal and chest (precordial) leads are measured. Okada's algorithm [4] was used for QRS detection in Lead II and MCLI. The area under QRS complexes were calculated to obtain Ay and Ax (shaded areas under QRS complexes in Figure2). The orientation of MEA was calculated from lead II and MCLI as follows [2]:

$$\theta = \tan^{-1}(Ay/Ax)$$

where Ay is the area of the QRS complex in the frontal plane lead and Ax is the area of the QRS complex in the transverse plane lead.

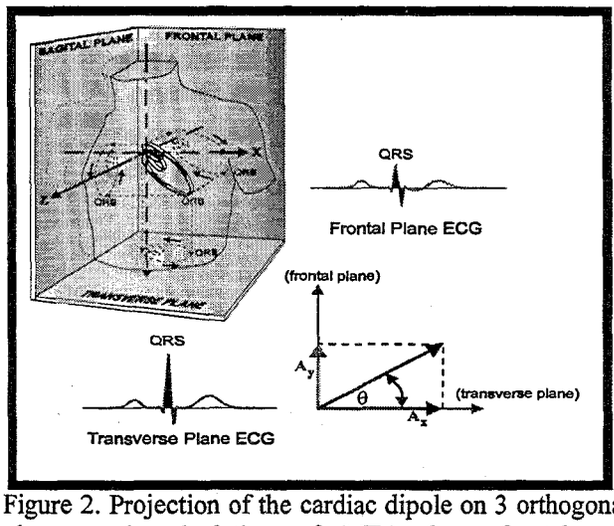

Figure 2. Projection of the cardiac dipole on 3 orthogonal planes and calculation of MEA from frontal and transverse ECG tracings.

RESULTS:

In Figure 3 panels 1&2, show the L2 and MCL1 signals, respectively. Panel 3 depicts the angle of Mean Electrical Axis calculated from the areas under QRS complexes in L2 and MCL1. Panel 4 shows the ECG Derived Respiration (EDR) signal interpolated from the data in panel 3 using the cubic spline method [5]. Panel 5 shows the respiration waveform obtained by airflow measurements. In panel 6, the cross-correlation between the EDR and the airflow measurements is shown. There was a mean cross-correlation of .738 ± .138 between the airflow and the EDR signals.

In our future studies different orthogonal ECG sets will be used to improve the mean cross-correlation of EDR and airflow signals.

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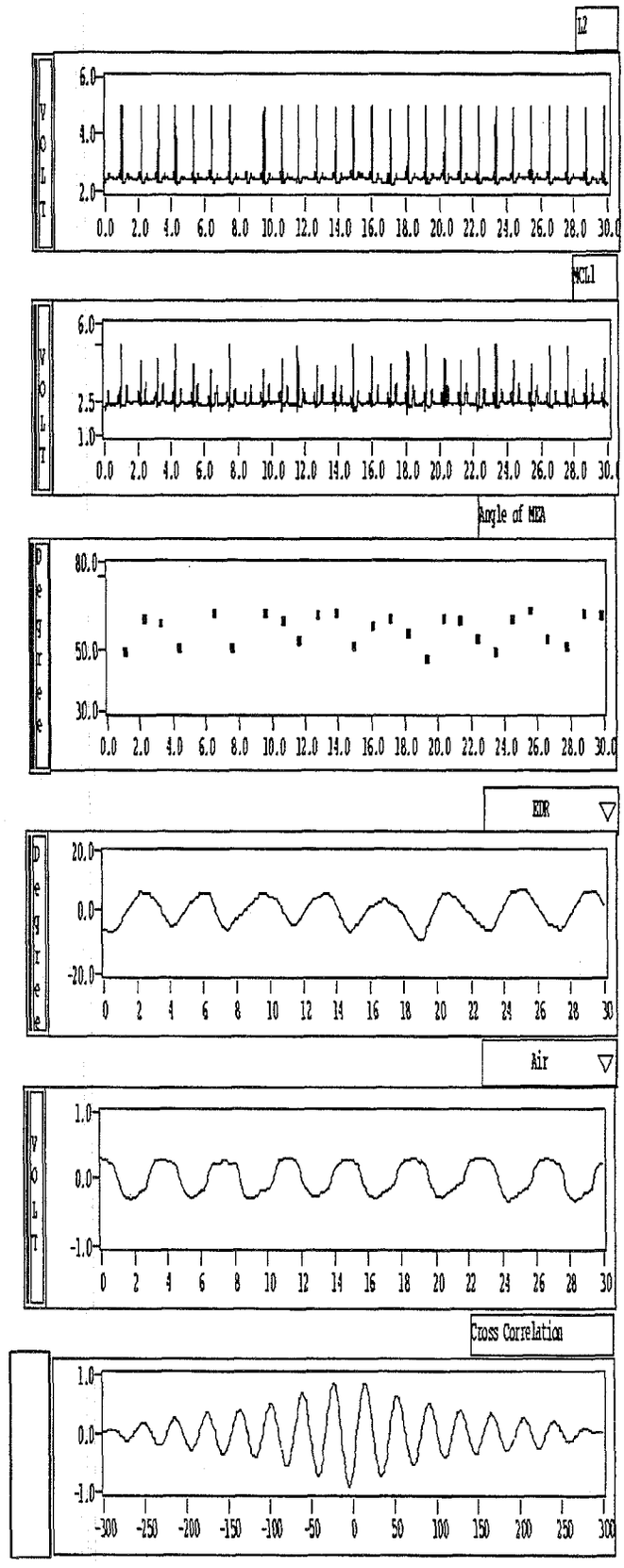

Figure 3. ECG leads L2 and MCL1, computed mean electrical axis, ECG derived respiration signal, airflow from thermistors, and cross correlation between EDR and airflow signal.