The Effect of Body Position on P-wave Axis

J Ng, AV Sahakian, S Swiryn

Northwestern University, Evanston, USA

Abstract

Changes in body position are known to change the electrical axis of the heart, resulting in changes in QRS amplitude, ST segment shifts, and T-wave inversions. We investigated the effect of body position changes on the frontal plane P-wave axis of ten healthy volunteers.

Subjects were monitored using three accelerometers recorded with two channels of ECG. Ten subjects followed a protocol of standing, sitting, walking, lying supine, and lying on the right and left sides for five minutes each. Median P-wave and QRS vectors in the frontal plane were computed.

With standing, sitting, right and left positions, P axis had mean shifts 10 +- 11 deg, 7 +- 12 deg, 2 +- 11 deg), and 12 +- 6 deg respectively when compared to the supine position. When compared to QRS shifts, P-wave shifts were larger with more variability and poorly correlated with QRS axis shifts.

1. Introduction

Changes in body position are known to change the electrical axis of the heart, resulting in changes in QRS amplitude, ST segment shifts, and T-wave inversions. Shifts can be attributed to the change of the position and orientation of the heart within the chest cavity, change in lung volume, and the change of electrode contact with the skin.

Because the anatomic location of the atria and its tethering to the great vessels differ from that of the ventricles and because of the change in sinus node pacemaker location with changes in rate, we hypothesized that the P-wave axis would shift differently with body position changes when compared with QRS complexes and T-waves. Therefore, the objective of our study was to examine the effect of body position on P-wave axis during ambulatory ECG monitoring and compare these results to the effect on QRS axis.

2. Background

In 1938, Sigler studied the effect of position changes on the electrical axis of the QRS and T-wave [1]. His study showed that out of 31 subjects with normal hearts, the standing position compared to recumbent produced QRS shifts in roughly two-thirds of those subjects. The T-wave showed shifts in ten of the subjects. It was noticed that electrical axis shifts often did not correspond to the expected anatomical axis shift of the heart. He and others hypothesized that changes in the ECG were due to the varying conduction caused by reorientation of various parts of the heart with its surroundings.

Dougherty examined the isolated effects of anatomic shifts of the heart with the electrical axis [2]. He found that each degree of anatomic shift and contribute to approximately three degrees of shift in the electrical axis.

3. Methods

3.1. Subjects

We recruited ten healthy subjects with no know cardiac problems. The healthy subjects consisted of eight males and two females, aged 24 – 31. The research project was approved by the Institutional Review Board of Evanston Northwestern Healthcare.

3.2. Equipment

Body position tracking using accelerometry has been shown to be highly reliable [3,4]. We demonstrated the ability of two accelerometers on the chest and one accelerometer on the left thigh to detect standing, sitting, walking and lying supine with at least 90% sensitivity for each position/activity during ambulatory ECG monitoring [5].

The accelerometers used were Analog Devices ADXL202 which are capacitive, micro-fabricated sensors that not only detect changes in velocity but also static gravity. A sensor pointing opposite to the ground would sense positive static acceleration therefore outputting a positive voltage. However, a sensor

0276-6547/01 $17.00 © 2001 IEEE

pointing toward the ground or pointing parallel to the ground would produce a negative or near-zero voltage, respectively. Therefore, the orientations of these sensors allow different body positions to be differentiated. Large fluctuations in the signal, especially from the thigh sensor, can imply ambulation or other motion. As shown in Figure 1, we have designated ChX as the accelerometer that points towards the subject's left and ChY as the accelerometer pointing towards the patient's head. On the thigh, ThZ points toward the left anterior thigh.

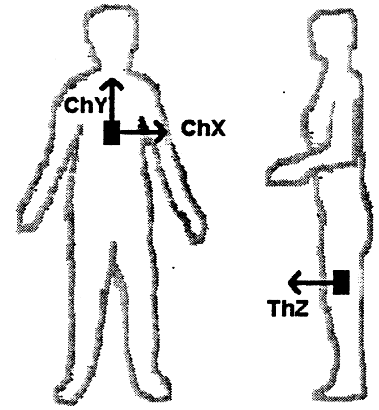

Figure 1. Orientation of three accelerometers.

The digital recorder is battery-powered and equipped with two differential channels for ECG and three single-ended channels for inputs from the position sensors. The ECG channels were set to have sample rates of 1kHz at 14 bits per sample with a 3.81μV resolution and have bandpass filters with a frequency range 0.05 – 400Hz. The three single-ended channels have a sample rate of 33Hz at 10 bits per sample. The data is stored on a CompactFlash memory card.

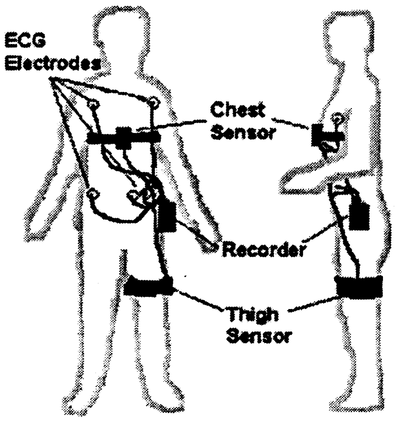

Figure 2. Diagram of equipment setup

3.3. Experimental Protocol

Each subject gave informed consent and then was fitted with the ECG/Body Position Recording System. After completing a one-minute test run, the subjects were asked to complete the half hour-long activity list shown in Table 1 to the best of their ability. The activity list was then repeated.

Table 1. Activity List

Position/Activity	**Duration**
Standing	5 mins.
Sitting	5 mins.
Walking	5 mins.
Supine	5 mins.
Lying right	5 mins.
Lying left	5 mins.
Total	**30 mins.**

In addition to being monitored by the recording system, a human observer manually recorded times of body position changes for validation.

4. Analysis

Following each experiment, the memory card was removed from the recorder and data is loaded into a host computer where it was analysed

The three accelerometer signals were first decoded into body position as shown in Figure 3. This was accomplished through the setting of threshold values for the expected accelerations at each body position. Having the body position information allowed correlation with the QRS and P-wave axis.

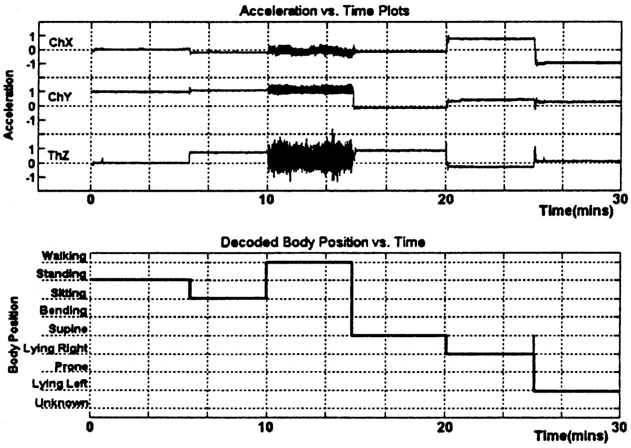

Figure 3. Decoding Acceleration Plots to Body Position

We computed the median QRS and P-wave vectors in the frontal plane using Pipbergers's half area method [6,7]. This was accomplished by first finding the onsets and offsets of the P-waves and QRS-complexes signal averaged over five beats, then by adding the area of the triangles formed by adjacent vectors.

We compared the magnitudes and angles of the P-wave and QRS median vectors for the different body positions. Figure 4 shows an example of body position compared with QRS median vectors. From top to bottom the three graphs show body position vs. time, QRS median vector magnitude vs. time, QRS median vector angle vs. time. Below the graphs are typical QRS loops for each body position/activity.

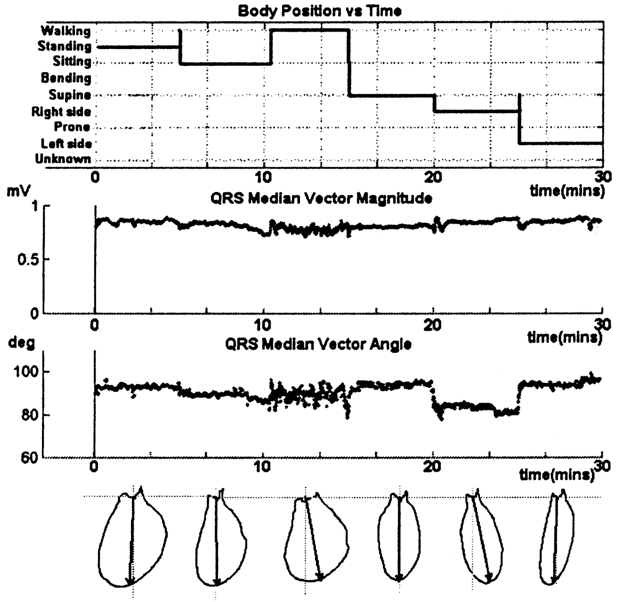

Figure 4. Comparison of body position with QRS median vectors.

5. Results

P-wave and QRS shifts of the standing, sitting, lying right and lying left position were computed with the supine position as a reference. Walking was not analyzed because of the poor signal due to motion artifacts. For the ten subjects in the supine position, the P-wave median vector angle ranged from 35 to 78 deg (mean 64 ± 13 deg) while the QRS median vector angle ranged from 65 to 96 deg (mean 82 ± 10 deg).

Figure 5 displays the mean degrees of axis shift relative to supine for the ten subjects shown as the dark vectors and their standard deviation represented by the gray area. The left column contains the P-wave shifts for standing, sitting, lying right, and lying left and the right column contains the corresponding QRS shifts. The shifts of the P-axis were of greater magnitude than those of the QRS axis especially for the lying left and standing positions.

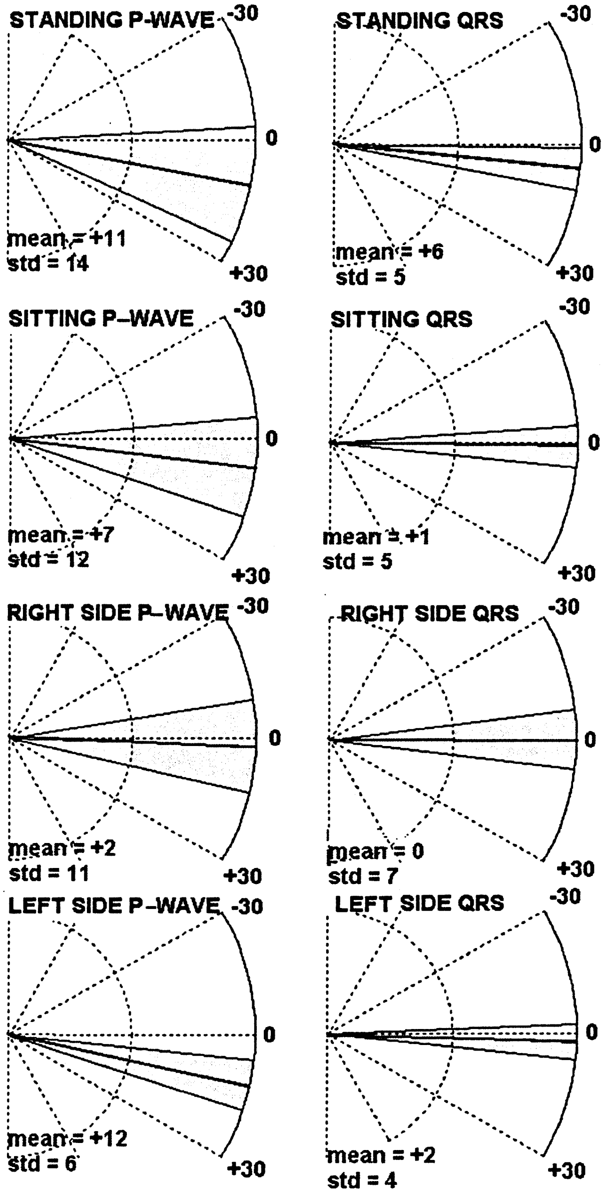

Figure 5. P-wave and QRS axis shifts for four body positions relative to supine (mean of 10 subjects).

The P-wave and QRS vector shifts were correlated with each other for each position. Shifts from supine to standing, sitting, lying right, and lying left had correlation coefficients of 0.03, 0.04, 0.87, and 0.13. Only the lying right position had any significant correlation.

6. Discussion

The results show larger P-wave shifts during changes in body position than that of the QRS complex. The tethering to the great vessels would imply less freedom of movement of the atria. However, the P-waves' lower amplitude compared to the QRS could contribute to greater errors during the calculation of the half-area median vectors. Boineau et al. [8] has shown that the location of the sinus node pacemaker shifts anatomically with sinus rate. This, too, could have contributed to our findings.

The relative lack correlation of the QRS and P-wave during the change of positions was also surprising. This suggests that orientation and position of the heart within the chest cavity may not be the main contributor of electrical axis shift in the P-wave.

7. Conclusions

We have shown that compared to QRS axis shifts, P-wave shifts are of greater magnitude, have greater variability between subjects, and are poorly correlated with QRS axis shifts.

Further studies of ECG with body position are possible using this technology, even in unsupervised, ambulatory patients.

Acknowledgements

This project was made possible by grants from the O'Shaunessey Foundation and the Dr. Scholl Foundation. Special thanks goes to Dr. Dae-Joon Ahn, for his contributions to this project.

References

[1] Siegler L, Electrocardiographic changes occurring with alterations of posture from recumbent to standing positions. Am. Heart J., 1938, 15:146-157.
[2] Dougherty J, Changes in the frontal QRS axis with changes in the anatomic position of the heart. J. Electrocardiol., 1970, 3:299-308.
[3] Fahrenberg J, Foerster F, Smeja M, Müller W, Assessment of posture and motion by multichannel piezoresistive accelerometer recordings. Psychophysiology, 1997, 34:607-612.
[4] Foerster F, Smeja M, Fahrenberg J, Detection of posture and motion by accelerometry: a validation study in ambulatory monitoring. Computers in Human Behavior, 1999, 15:571-583.
[5] Ng J, Sahakian AV, Swiryn S, Sensing and documentation of body position during ambulatory ECG monitoring. Computers in Cardiology, 2000, 27:77-80.
[6] Pipberger HV, Evaluation of Quantitative Methods for Obtaining Mean Spatial QRS Vectors. Circulation, 1957, 16: 926.
[7] Ball MF, Pipberger HV, The Normal Spatial QRS-T angle of the orthogonal vectorcardiogram. Am Heart J, 1958, 56:611-615.
[8] Boineau JP, Schuessler RB, Hackel et al.,Widespread distribution and rate differentiation of the atrial pacemaker complex. Am. J. Physio., 1980, 239:H406-H415.

Address for correspondence

Alan V. Sahakian, Ph.D.
Northwestern University
Department of Electrical and Computer Engineering
2145 Sheridan Rd.
Evanston, IL 60208
USA
sahakian@ece.northwestern.edu