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Jefferson Luiz Brum Marques
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José Marino Neto
Renato García Ojeda *Editors*

IX Latin American Congress on Biomedical Engineering and XXVIII Brazilian Congress on Biomedical Engineering

Proceedings of CLAIB and CBEB 2022, October 24–28, 2022, Florianópolis, Brazil—Volume 2: Biomedical Signal Processing and Micro- and Nanotechnologies

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Preface

The IX Latin American Congress on Biomedical Engineering and XXVIII Brazilian Congress on Biomedical Engineering (CLAIB&CBEB 2022) took place simultaneously on October 24–28, 2022, in Florianópolis-SC, Brazil, and were organised by the Institute of Biomedical Engineering of The Federal University of Santa Catarina (IEB-UFSC), the Regional Council of Biomedical Engineering for Latin America (CORAL) and the Brazilian Biomedical Engineering Society (SBEB). These events were held remotely for the most part, with a small set of conferences taking place in person on the premises of IEB-UFSC (Florianópolis, Brazil). They included 11 hands-on technical workshops for students, 26 keynote speakers and symposia, and 40 oral and poster presentation sessions attended by about a thousand participants, including undergraduate and graduate students, academic researchers, and public and private sector agents.

We are proud to present in this book a selection of papers presented at this event by researchers from all over the world, reporting recent and innovative findings and technological outcomes in the many areas of interest of biomedical engineering. These papers represent nearly 50% of those original contributions presented at the CLAIB&CBEB 2022. Their academic quality has been warranted by careful peer review coordinated by an expert scientific committee of leading Latin American senior researchers in biomedical engineering. The content is organised into four volumes and eleven chapters, covering the most relevant areas of scientific and technological developments within the broad spectrum of biomedical engineering interests. We are sure that the contributions presented in this book give a deep overview of the leading edge in your expertise and other areas.

On behalf of Scientific and Organising Committees, we thank authors, academic reviewers and sponsoring societies such as CORAL, SBEB, UFSC, FAPESC and IEB-UFSC for their contributions. Moreover, we encourage readers to enjoy this amazing piece of scientific literature as a breadth of knowledge in the biomedical engineering field.

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CLAIB&CBEB 2022 was organised by the Regional Council of Biomedical Engineering for Latin America (CORAL) and the Brazilian Biomedical Engineering Society (SBEB) in cooperation with the International Federation for Medical and Biological Engineering (IFMBE).

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Estimation of Heart Inclination Angle Using Posteroanterior Chest Radiograph and Comparison with Cardiac Axis Obtained from Synthesized Vectorcardiogram

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Abstract. In medical practice, it is common to perform electrocardiography exams and by mathematical transformations to obtain the vectorcardiogram. The vectorcardiogram provides important information for medical diagnosis, such as the angle of inclination of the heart. This article aims to present a methodology for estimating the QRS vector-related angle of the heart using a posteroanterior chest radiograph image. We used an open source image processing software (Icy software version 2.3.0.0, Institut Pasteur, France, 2021) to perform a manual measurement of the target angle by analyzing relevant morphological structures from the x-ray images and using some functions to help the user to measure it. 18 radiographic images were selected to measure the angle of the heart by two independent individuals. The measured angles were compared using the mean absolute error (MAE). We then computed the QRS peak elevation angles of the vectorcardiogram (VCG) of the 57 patients collected at Dante Pazzanese Institute of Cardiology. In addition, an individual was randomly selected to measure a set of 57 radiographic images of these same patients. We performed the statistical treatments and the results suggested that the proposed manual method may be an alternative, viable and fast approach to estimating the anatomical heart axis for the purpose of aiding in medical diagnosis. However, further comparisons with more data and information are needed to determine its validity and possible method improvements.

Keywords: Heart angle · vectorcardiogram · chest x-ray image

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1 Introduction

Commonly, at the Dante Pazzanese Institute of Cardiology, patients are submitted to routine tests such as electrocardiogram (ECG) and posteroanterior chest radiography. These exams are performed mainly due to their low cost, relative ease of execution and the delivery of information to support medical diagnosis.

The electrocardiogram (ECG) records in waveforms the electrical potentials on the surface of the body generated by the electrical activity of the heart. Any variation in cardiac impulse transmission can cause abnormal electrical potentials and change the waveforms on the electrocardiogram. These abnormal electrical potentials can be related to structural changes in the heart that affect its activity or simply electrical abnormalities. For this reason, an ECG is important in diagnosing serious heart muscle abnormalities [1,2].

Another way to analyze the electrical activity of the heart is through the vectorcardiogram (VCG). The VCG is the vector representation of the electrical activities of the heart considering three mutually orthogonal axes (vertical, transversal, and sagittal). In the VCG, the electrical activity of the heart is described by three loops that represent the P wave, the QRS complex, and the T wave. The loop of the QRS complex is oval and faces the same direction as the cardiac axis of the heart. In the normal heart, the direction of the mean QRS vector is approximately 59° [1,3,4].

A way to get the VCG is through the mathematical transformation of the electrocardiogram. There are several different transformation methods, such as the quasi-orthogonal transform, the Inverse Dower Transform (IDT), P Least Square Value (PLSV) and Q Least Square Value (QLSV) Transformations, Mason-Likar (ML) and the Kors regression transform, the latter with relative better results than the others. The Kors regression method is a technique for constructing the cardiogram vector from the ECG, using a linear combination of eight conventional ECG leads [3,4]. Figure 1 shows the Kors transformation matrix derived by regression technique in order to minimize the mean error between the measured VCG and the transformed VCG [5].

Lead	I	II	V1	V2	V3	V4	V5	V6
X	0.38	–0.07	–0.13	0.05	–0.01	0.14	0.06	0.54
Y	–0.07	0.93	0.06	–0.02	–0.05	0.06	–0.17	0.13
Z	0.11	–0.23	–0.43	–0.06	–0.14	–0.20	–0.11	0.31

Fig. 1. Transformation coefficients of Kors regression method [5]

The joint use of the ECG and the VCG increases the precision in the diagnoses, but due to the difficulty in relation to the number of electrodes and their positioning, most of the time ECG is performed. However, VCG tests are more sensitive for detecting hypertrophy and ischemic heart disease. But the advent of mathematical transformation mitigated the difficulty of joint analysis of the two methods [4,6].

In the posteroanterior chest X-ray, the heart is located close to the frame, decreasing the cardiac magnification that can cause a false impression of increased heart volume. The chest X-ray is important in helping to diagnose cardiac diseases. With it, it is possible to identify structures and morphological changes, as occurs, for example, in the left ventricular aneurysm by identifying the aneurysmal dilatation resulting from a myocardial infarction [7].

Through X-ray it is possible to estimate the inclination of the anatomical axis of the heart and compare it with the electrical axis. Many times there is a strong correlation, especially in the anteroposterior and longitudinal axes (refer to the article), but some diseases can affect the heart's inclination and having different methodologies at hand can help in the medical diagnosis [8].

This article aims to present a methodology for estimating the QRS vector-related angle of the heart using a posteroanterior chest radiograph image. The measurement of heart inclination angle by the method proposed here is relevant as an additional source of information that complements traditional ECG/VCG exams for medical decision. We also computed the QRS peak elevation angles of the same patients' VCG and compared both angles. We emphasize that we did not find studies in the literature for estimating the inclination of the angle of the heart with a methodology similar to that proposed by this article.

2 Materials and Methods

Data were collected as part of a study by the Dante Pazzanese Institute of Cardiology, and this project was approved according to the *Certificado de Apresentação de Apreciação Ética* 76085317.5.3001.5185.

2.1 Manual Measurement of the Heart Angle

A set of posteroanterior X-ray images of patients from Dante Pazzanese Institute of Cardiology was used to measure the approximated angle of the QRS vector of the heart. An open-source image processing software (Icy software version 2.3.0.0, Institute Pasteur, France, 2021) was employed to manually calculate the angle.

The methodology to estimate the angle of the heart took into account the anatomy of the heart and its location inside the rib cage. In this study, the anatomy of the heart was important to recognize structural regions inside chest x-ray images to allow the definition of two points of interest, and be able to trace the reference line to estimate the angle of inclination of the heart. According to Fig. 2, the estimated points of interest for plotting the reference line were the ones located in the apex of the heart, and amides the superior vena cava (SVC) and the right atrium (RA).

To draw the reference line, we used some features of the image processing software to facilitate the identification of regions of interest. First, the contour