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ScienceDirect

Journal of Electrocardiology 47 (2014) 430–437

JOURNAL OF Electrocardiology

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Olson method for locating and calculating the extent of transmural ischemic areas at risk of infarction

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Abstract

Objectives: The purpose of this study is to present a new and improved method for translating the electrocardiographic changes of acute myocardial ischemia into a display which reflects the location and extent of the ischemic area and the associated culprit coronary artery. This method could be automated to present a graphic image of the ischemic area in a manner understandable by all levels of caregivers; from emergency transport personnel to the consulting cardiologist.

Background: Current methods for the ECG diagnosis of ST elevated myocardial infarction (STEMI) are criteria driven, and complex, and beyond the interpretive capability of many caregivers. New methods are needed to accurately diagnose the presence of acute transmural myocardial ischemia in order to accelerate a patient's clinical "door to balloon time." The proposed new method could potentially provide the information needed to accomplish this objective.

Methods: The new method improves the precision of diagnosis and quantification of ischemia by normalizing the ST segment inputs from the standard 12 lead ECG, transforming these into a three dimensional vector representation of the ischemia at the electrical center of the heart. The myocardial areas likely to be involved in this ischemia are separately analyzed to assess the probability that they contributed to this event. The source of the ischemia is revealed as a specific region of the heart, and the likely location of the associated culprit coronary artery.

Seventy 12 lead ECGs from subjects with known single artery occlusion in one of the three main coronary arteries were selected to test this new method. Graphic plots of the distribution of ischemia as indicated by the method are consistent with the known occlusion. The analysis of the distribution of ischemic areas in the myocardium reveals that the relationships between leads with either ST elevation or ST depression, provide critical information improving the current method.

Keywords: Olsen method; ST elevated myocardial infarction; ECG

Introduction

In the contemporary management of acute coronary artery occlusion, intervention to restore arterial flow to ischemic myocardium is the highest priority. Emergency Medical Service (EMS) personnel and treating clinicians are guided in this process by information from the 12 lead electrocardiogram (ECG). Early and accurate identification of the location and extent of ischemic myocardium and relating this to the probable culprit artery are of great importance.

The currently accepted criteria for ST-segment Elevation Myocardial Infarction (STEMI) have made patient identification challenging. ST elevation in "at least 2 contiguous leads" is required for STEMI diagnosis [1]. However, conventional displays of the standard 12-lead ECG do not adequately present "contiguous leads". Only chest leads are displayed in their orderly sequence (V1 to V6), while the limb leads are not. The typically presented limb lead sequence permits only consideration of three pairs of contiguous leads: I and aVL, II and aVF, and aVF and III. A more logical orderly sequence of the limb leads would be:

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http://dx.doi.org/10.1016/j.jelectrocard.2014.04.005
0022-0736/

aVL, I, −aVR (inverted aVR), II, aVF, and III. [2–4]. By consideration of this "non-standard" ECG display, 5 contiguous lead pairs are identified in both the frontal and transverse planes.

Individual ECG leads, especially the chest leads, vary in distance from the heart, some having a greater amplitude effect than others. Such leads are said to have greater "lead strength" than others [5]. This is currently recognized in the required STEMI threshold values specified by the current ESC/AHA/ACCF/WHF standards [1], because threshold values for ST-segment elevation are 0.1 mV in all limb leads and in some chest leads, but greater in other chest leads.

These limitations of the standard 12 lead ECG can be overcome by the use of all available cardiac spatial information through a vectorcardiographic (VCG) approach [6]. The concept of using a vector, with magnitude and direction, to represent the electrical activity of the heart generated by a propagating wavefront was first explored by Wilson, et al. [7]. This was further advanced by Grant [8,9] who used vector concepts as a basis for interpreting ECG abnormalities, including the evolution of QRS, ST and T changes seen with myocardial infarction. Grant showed that it is possible to visualize vectorcardiographic information from inspection of standard ECG leads and clarified the usefulness of the evolution of QRS, ST segment and T vector relationships in determining the stage of evolution of the ischemia–infarction process.

The later work of Frank, who studied models of the human torso with a fixed dipole current source placed at its electrical center to determine the surface response at varying planes and levels on the body surface [10,11], demonstrated that previous assumptions representing the body as an equilateral triangle with the heart's electrical activity arising in the triangle's center are not accurate. These studies also provided a mathematical basis for the design of orthogonal X, Y, and Z leads used for recording of the VCG. In addition, as demonstrated by Frank [10,11], Burger [12], and others, there is considerable distortion of the electrical axes of recorded ECG leads with reference to the bony landmarks, and commonly accepted angular relationships among leads.

The Olson Method is based on the principles of the VCG: the electromotive forces producing the ECG can be represented at each instant of the cardiac cycle by a single sum vector originating at the electrical center of the heart. The Olson Method also recognizes the validity of the principles presented by Frank and others, establishing a mathematical basis for transmission of these forces to points on the body surface.

The purposes of this paper are to describe the Olson Method of estimating myocardial location and extent of transmural ischemia due to acute occlusion of one of the major coronary arteries, and to illustrate the performance of the Olson method in a patient population with known documentation of coronary site occlusion.

Methods

Steps in implementation of Olson method

There are 3 steps by which the ischemia information in the 12-lead ECG is transformed to be used in the Olson Method: Step 1: conversion of ST-segment information to corrected ischemic vectors at the electrical center of the heart; Step 2: division of the left ventricular (LV) myocardium into segments, and establishing a theoretical vector for uniform transmural ischemia in each segment; Step 3: determination of the contribution of each myocardial segment to the ischemic vector described in Step 1.

Step 1: The Olson Method uses ST-segment information in each of the 12 leads to identify the presence of a "current of ischemia", i.e. the deviation of the ST segment at the J point, measured relative to the level of the PR segment immediately before QRS onset. For each lead, the recorded value, in μV, is multiplied by a set of three conversion values, which convert the ECG lead deviation to X, Y, and Z amplitudes on three orthogonal axes at the electrical center of the heart. These conversion values were calculated by the first author from information in Frank's published image surface diagrams [10]. The result is a single vector at the heart's electrical center for each lead, corrected for differing lead strengths and lead axes and with a common orthogonal reference system.

In theory, the corrected central ischemic vector from one lead should be approximately the same as that for any other lead. The Olson method utilizes all 12 leads, because the ST measurements are approximations, and because it is reasoned that errors are minimized by using all leads instead of one or a smaller subset of ST vectors.

Step 2 establishes a reference system by which the LV myocardium is divided into logical areas which could be involved in an ischemic process. One or more of these areas are identified as the likely generator of the ischemic forces responsible for the subject's ST segment deviation, and the ischemic vectors converted from them. For this purpose the Olson Method utilizes the 12 segment LV model, developed and used by Selvester in his classic studies of myocardial infarction size and location [13].

This model uses a modified Mercator projection of the LV (Fig. 1), which divides this chamber into four anatomic walls: septal, anterior, lateral, and inferior. Each wall is further divided into three regions from base to apex: basal,

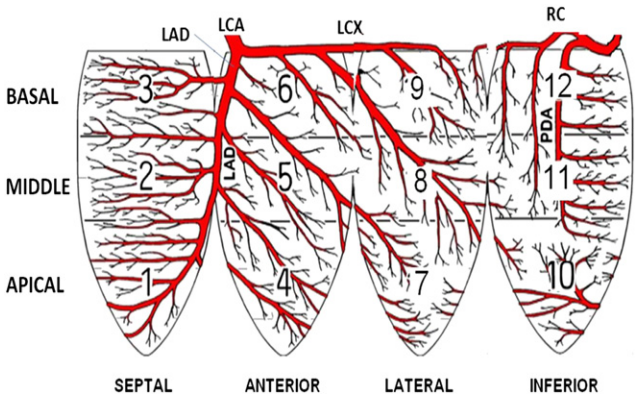

Fig. 1. The Selvester 12 segment model including the four LV walls and their three levels is displayed as a Mercator view. A typical distribution of the three major coronary arteries and the distributions of their branches is superimposed. A number is assigned to each segment; progressing from apex to base in each wall, and from septal to anterior to lateral to inferior walls.