BRIEF REVIEW

SIGNIFICANCE OF VECTOCARDIOGRAM IN THE CARDIOLOGICAL DIAGNOSIS OF THE 21st CENTURY - 2006

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Abstract

Until the middle 80s, it was believed that the vectocardiogram presented a greater specificity, sensitivity and accuracy in comparison to the conventional electrocardiogram, in the diagnosis of the different heart diseases. However, more recent studies revealed that both methods present similar diagnostic abilities. The vectocardiogram still is superior to the electrocardiogram in very specific situations, such as in the evaluation of electrically inactive areas, in intraventricular conduction disorders combined and/or in association to inactive areas, in the identification and location of ventricular pre-excitation, in the differential diagnosis of patterns varying from normal of electrical axis deviation, in the evaluation of particular aspects of Brugada Syndrome, and in the estimation of the severity of some enlargements, among others.

With the advent of computerized vectocardiography, a technology that improves the determination of the onset and the end of loops, establishes a ratio between the length and width of the T waves and the spatial areas of the vectors; a future still promising is expected for this methodology.

In the fields of education and research, vectocardiography provided a better and more rational insight into the electrical phenomena that occur spatially, and represented an important impact on the progress of electrocardiography. Although a few medical centers still use the method as a routine, we hope that the use of this resource will not get lost over time, since vectocardiography still represents a source to enrich science by enabling a better morphological interpretation of the electrical phenomena of the heart.

Concept

The vectocardiogram is the spatial representation of electromotive forces generated during cardiac activity in the three spatial planes (horizontal, frontal and sagittal) [1]. **Figure 1**

An instantaneous electric dipole (difference of potential between two points, of equal magnitude and opposite charges) is formed each moment during ventricular

depolarization. The addition of all individual dipoles generates the resulting dipole of the cardiac electrical activity, moment to moment, represented by a vector.

Spatial vectocardiography is the form of electrocardiography that tries to describe the electromotive force developed by the heart each instant as a single vector, while all the successive instantaneous vectors have a common point of origin[2].

Vector: Measurement unit that has direction or orientation and module, magnitude and intensity, used in electrovectocardiography to represent the dipole of depolarization and repolarization. All vectors have an onset and an end called origin and end. Vulgar terms such as "tail" or "arrow" to refer to the origin or end of a vector must be avoided.

The size of a vector determines the magnitude, the orientation and the direction in the electric field represented by it, while the point of the vector always indicates its positive side (as was originally advocated by Einthoven). Therefore, vectocardiographic loops represent the position of all the instantaneous vectors, at each moment, during cardiac repolarization, obtaining different loops for the P, QRS, T and U waves[1].

Vectocardiography is based on the concept of the dipole as an approximation equivalent originated in the heart, and uses corrected orthogonal leads, which determine three spatial planes: frontal (FP), horizontal (HP) and left sagittal (LSP) or right sagittal (RSP). The term orthogonal originates in the fact that the axes of the three planes are perpendicular to each other, and corrected because technical devices of resistance and multiple connections that correct the deficient homogeneity of the electric field that surrounds the heart are used. These three corrected orthogonal leads of Frank's system, as well as the three planes determined by them, cross each other at a central point called E point, thus forming a 90º angle between each other.

Conventionally, the horizontal lead that stretches from left (0º) to right (+/- 180º) is called X orthogonal. The axis of the corrected X orthogonal lead corresponds approximately to the bipolar DI lead and the V_6 precordial lead. This lead forms the HP and the FP.

The vertical lead is known as the Y orthogonal lead, and it stretches from down (+90º) to the top (-90º) and it approximately corresponds to the unipolar aVF lead of ECG, which has its positive pole in +90º. It provides information about the infero-superior orientation of the vectors. The Y lead forms the FP and the LSP or the RSP.

Finally the axis of the sagittal orthogonal lead known as the Z axis, stretches from the back (+90º) to the front (-90º) or postero-anterior orientation, with its posterior part being positive and its anterior part being negative. The Z orthogonal lead corresponds approximately to the precordial V_2 lead of the conventional ECG and it forms the HP and the LSP or the RSP.

Figure 2 and 3

Advantages of the VCG compared to the ECG

1) The VCG provides three-dimensional information of the electric activity of the atria and the ventricles, showing in a clearer way than the ECG, the spatial orientation and the magnitude of the vectors at every moment[3].
2) The VCG has a greater sensitivity than the ECG in detecting atrial enlargements[4] and greater sensitivity and specificity than the ECG in the diagnosis of left ventricular enlargement (LVE).

   Abbott-Smith et al., made vectocardiograms in 100 patients carriers of left ventricular enlargement (LVE) confirmed in the necropsy[5] and concluded that the VCG was capable of diagnosing 50% of the cases, with 11.7% of false positives. These figures point out a greater sensitivity of the VCG over the ECG in the diagnosis of LVE;
3) The VCG may clear doubts in the cases of suspicion of electrically inactive area in the septal or antero-septal wall of the left ventricle (LV), when the LVE of the systolic type is present, observed in ECG with QS pattern in V1;

V1 and V2 or V1, V2 and V3. In absence of electrically inactive area, the "dashes" of the initial 10 to 20 ms of the QRS loop, are recorded without delay, while in the presence of electrically inactive area, the dashes of the initial 40 ms are very close to each other[6].

4) The VCG presents a greater correlation with the echocardiogram, when compared with the ECG, in determining the left ventricular mass[7], and it appears as superior to ECG and echocardiogram in the diagnosis of chamber enlargement, associated to electrically inactive areas[8].
5) The VCG presents a greater diagnostic sensitivity in comparison to the ECG in acute myocardial infarction (AMI), when associated to left anterior fascicular block (LAFB). In the presence of AMI of the LV inferior wall, the VCG may bring additional information, which the ECG does not reveal, such as the association with LAFB[10].
6) The VCG presents a greater sensitivity and specificity than the ECG in the diagnosis of strict dorsal AMI, and it enables a more appropriate differentiation with other causes of prominent anterior forces, such as normal hearts with counterclockwise rotation of the longitudinal axis and shift to the right of the transition area in precordial leads, right ventricle enlargement, complete right bundle branch block (CRBBB), hypertrophic cardiomyopathy both in its obstructive and non-obstructive form (increase in the magnitude of the septal vector), diastolic enlargement of the left ventricle with dislocation of the transition area to the right, ventricular pre-excitation of the Wolff-Parkinson-White type with anomalous bundle, in a parallel way to posterior location (WPW type A), Duchenne-Erb myopathy or malignant in childhood and other causes[11; 12].
7) The VCG has more sensitivity than the ECG for the diagnosis of multiple infarctions, associated to LAFB[13].
8) The VCG has a greater accuracy than the ECG in the diagnosis of inferior infarction[10], however, about this topic, there is no consensus since there are studies that concluded that the VCG is not superior to the ECG in the diagnosis of isolated diaphragmatic infarction[14]. Edenbrandt et al, compared

the diagnostic value of both methods in 65 patients with inferior AMI proven by hemodynamic study and gammagraphy with Thallium 201. The authors observed that the sensitivity of the VCG was 69%, and the ECG was 43%, with this difference being statistically significant ($p<0.001$). In the control group, only three false positives occurred[15].

9) The method improves sensitivity in the diagnosis of inferior infarction extended to the LV anterior wall[16] (called deep septal infarction).
10) The VCG is of great significance for the diagnosis of the left septal fascicular block (LSFB)[17; 18; 19]. This type of left fascicular block was shown in numerous publications and, in an unexplainable way, the Anglo-Saxon literature does not acknowledge it.
11) The VCG is superior to the ECG in the cases of atypical CRBBB associated to LAFB (bifascicular block) called by Rosenbaum "standard masquerading bundle branch block". In these cases, in the presence of CRBBB associated to a high degree of LAFB, the DI lead presents small or non-existent s wave, with a pure R wave appearing in this lead, characteristic of CLBBB (pseudo CLBBB). This situation translates the presence of CRBBB associated to LAFB, LVE and block located in the left ventricle[20].

    In some cases, a CRBBB pattern is observed in the right precordial leads and CLBBB in the left precordial leads. This situation was called "masquerading bundle branch block". This pattern defines the presence of CRBBB associated to severe LVE, a block located in the antero-lateral wall of the left ventricle and usually LAFB[21].
12) The VCG is very useful to differentiate the rare CLBBB with extreme deviation of SAQRS to the right in the FP (to the right of +90º). According to the location of SAQRS in the FP, the CLBBB was divided into 4 types:
    1) CLBBB with SAQRS not deviated: between –30º and +60º. It represents 65% to 70% of the cases;
    2) CLBBB with SAQRS with extreme deviation to the left: beyond –30º. It represents 5% of the total;

3) CLBBB with SAQRS deviated to the right between +60º and +90º. It represents 4% of the total;
4) CLBBB with SAQRS presenting extreme deviation to the right: >+90º. This group represents less than 1% of the total of CLBBB and was called "paradoxical type" by Lepeschkin.

CLBBB with SAQRS located to the right of +90º in the FP, may have SAQRS located in the right inferior or right superior quadrant. Lepeschkin called them "paradoxical CLBBB" or type IV (SAQRS between +90º and +135º). We could add a type V when SAQRS is located to the right of +135º (CLBBB of congenital heart diseases). In these cases, the VCG is superior to ECG in determining the possible cause:

1) If CLBBB is associated to severe RVE;
2) If fascicular CLBBB (LAFB + LPFB) by a higher degree of block in the left posterior fascicle;
3) If the CLBBB is associated to lateral electrically inactive area.

13) The technique known as Continuing Vectocardiography Monitoring (CVM) carried out during elective angioplasty, proved to be a promising tool to detect patients with an increased risk of developing AMI related to the procedure. Guo et al[22], used the method in 169 patients, which started 5 minutes before the procedure and was interrupted 30 minutes after the first insufflation of the angioplasty balloon. Considering the ST segment elevation to determine the AMI, the sensitivity of the CVM to detect increased risk of acute myocardial infarction related to the procedure was 93%, the specificity was 56% and the negative predictive value 99%.

14) The VCG presents a greater diagnostic sensitivity than ECG to determine the severity of congenital aortic valve stenosis. Thus, the presence of the maximal vector in the horizontal plane to the left (LMSV) with a voltage greater than 4 mV, heading to the left and backward around –56º, represents a significant marker of severe aortic stenosis (left intraventricular pressure > 200 mmHg); the presence of the maximal vector to the left with a

voltage near 2.2 mV and around –19º, indicates mild congenital aortic stenosis[23].

15) In patients carriers of congenital pulmonary valve stenosis, the VCG has a good correlation between the value of the systolic pressure of the right ventricle and the presence of the maximal spatial vector to the right of the HP: "Maximal Spatial Voltage directed to the Right" (RMSV). Thus, a right intraventricular pressure >100 mmHg has a RMSV >2.3 mV[24].

16) The VCG is superior to the ECG to identify and locate the anomalous bundle in pre-excitation of the Wolff-Parkinson-White. The method presents a high sensitivity and accuracy. This fact is relevant to guide the electrophysiologist, pointing the most appropriate site to apply radiofrequency energy[25]. The diagnostic specificity is not increased when compared to an ECG in this case[3].

17) The VCG presents greater sensitivity and specificity than ECG in the diagnosis of end conduction delay by the fascicles of the right branch (blocks of the right branch: fascicular, zonal or of the free wall). The VCG enables to rule out or confirm the cases where the ECG presents a doubt when there is association of end delay through the right branch with electrically inactive areas, both of the inferior and the anterior walls[26].

18) The VCG optimizes the differential diagnosis of right fascicular blocks with left fascicular blocks[27].

19) The vectocardiogram is very useful in the diagnosis of Brugada syndrome when the ECG shows extreme deviation of SAQRS to the left in the FP (9.5% of the cases)[28]. We showed that in this entity, the extreme deviation of SAQRS to the left might be the consequence of LAFB and of end conduction delay through the superior or subpulmonary fascicle of the right branch, which goes through the right ventricle outflow tract, the area affected in this entity[29].

20) The VCG has a great value in the analysis of electrical modifications that are the consequence of septal percutaneous ablation of the obstructive form of severe hypertrophic cardiomyopathy, not responsive to drugs and with

incapacitating symptoms (functional class II and IV), by injection of absolute alcohol. The result of septal or antero-septal infarction generates a pattern of CRBBB in almost all cases, unlike myotomy/myectomy surgery, which promotes CLBBB in approximately 80% of the cases[30].

With the use of computerized VCG, obtaining and processing graphs is easier, and the problems of measuring the loops are eliminated, since it is possible to determine with greater accuracy, where each one begins and ends, establishing in a precise way, the ratio of length and width of T waves, and the estimation of the areas of the loops. In comparison with the traditional recording method, computerized VCG has a greater accuracy in measurement, besides a great processing velocity[31;32].

In spite of the studies that show that the VCG and the 12-lead ECG have a very similar diagnostic capacity, when the ECG has a specialized interpretation[33], the VCG is still evolving and it will always have didactic usefulness to teach electrocardiology due to its three-dimensional representation, besides representing a simple and low-cost method, with great diagnostic value in different situations where conventional electrocardiographic recording is doubtful[34].

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Figure 1

P, QRS AND T – LOOPS OF VECTORCARDIOGRAM ON THREE PLANES

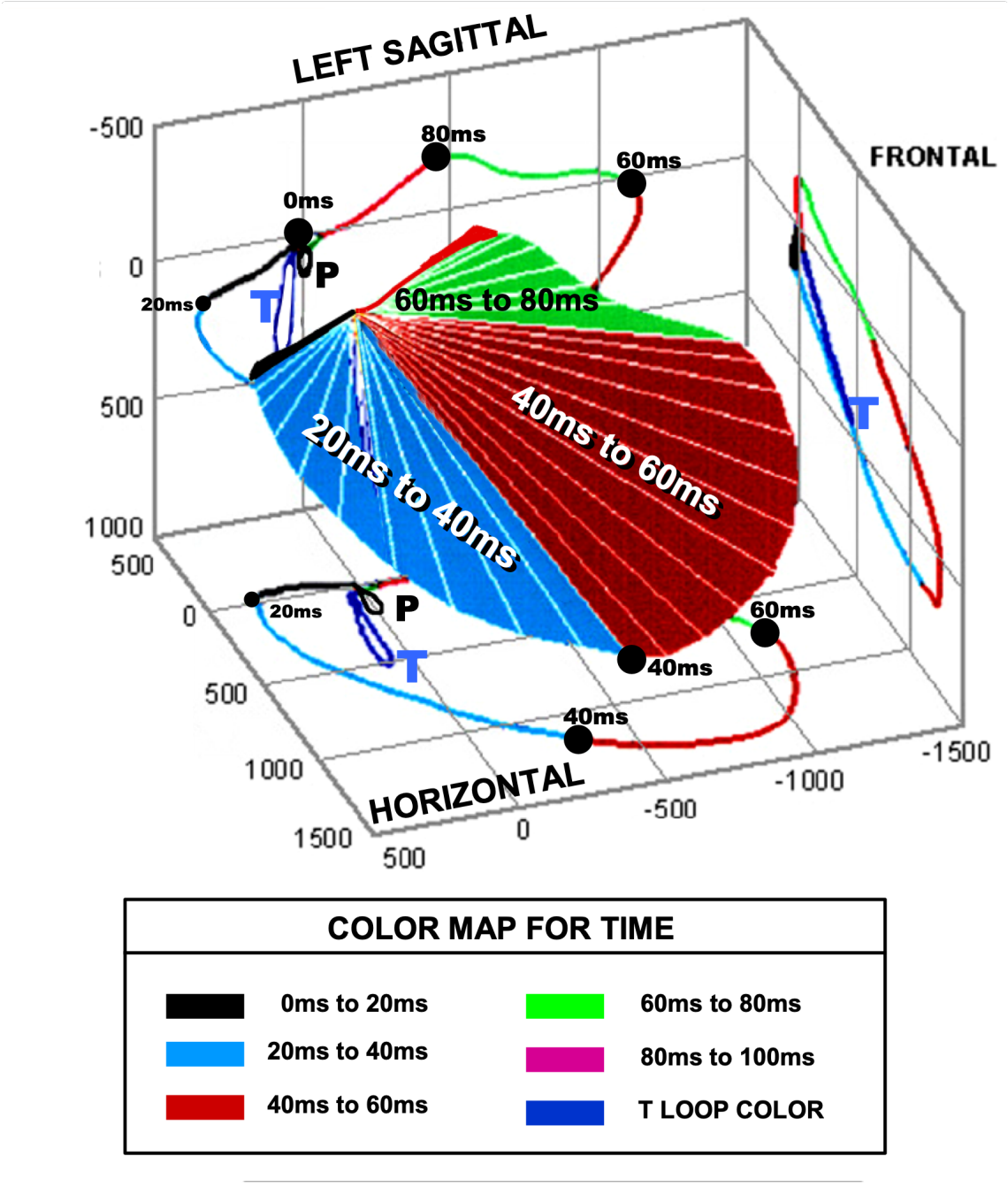

Figure 2

THE THREE ORTHOGONAL CORRECTED LEADS AND THE THREE PLANES ON VECTORCARDIOGRAPHY

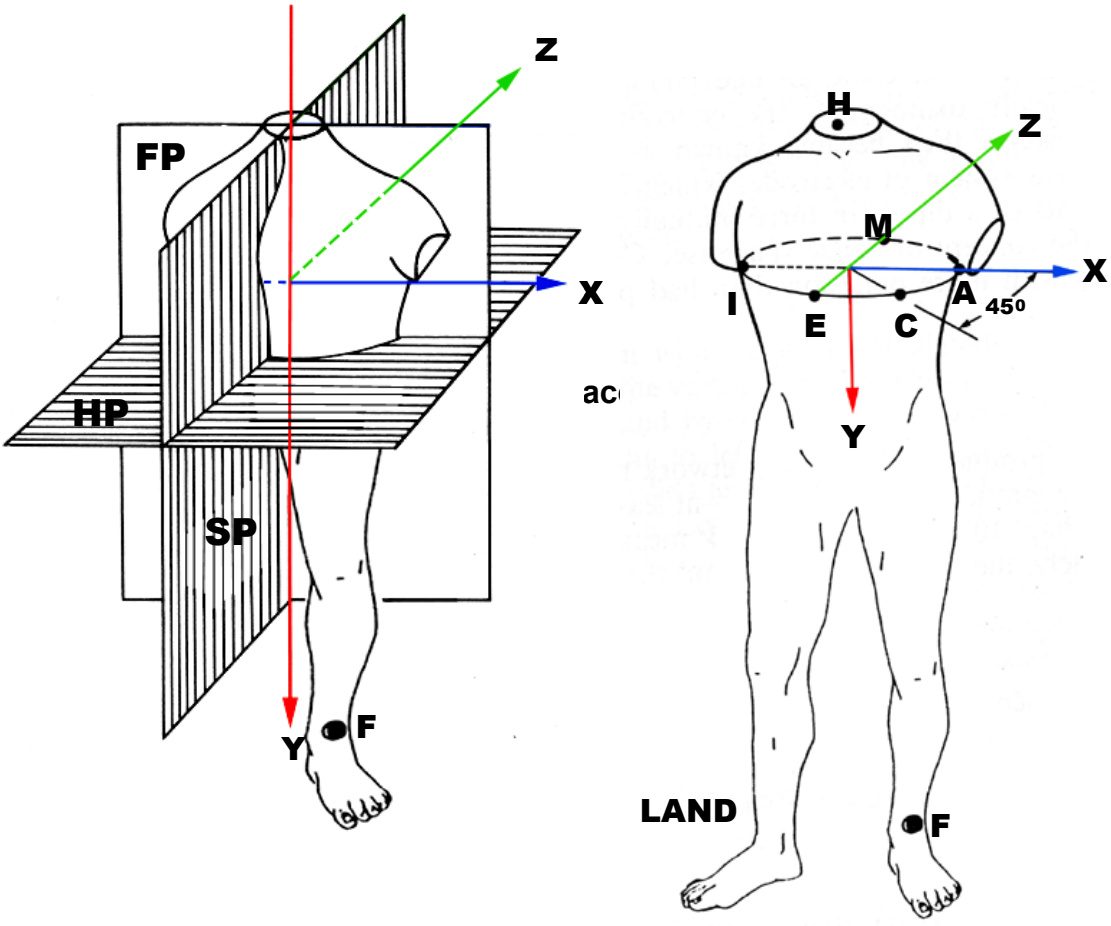

Figure 3

LOCATION OF ELECTRODES TO PERFORM VCG BY THE FRANK METHOD

Seven electrodes are applied on body surface, called H, F, I, C, A, E and M.

H: POSTERIOR REGION OF THE NECK.
F: LEFT LEG.
I: RIGHT MIDDLE AXILLARY'S LINE.
A: LEFT MIDDLE AXILLARY'S LINE.
C: LEFT MIDCLAVICULAR LINE.
E: MIDDLE LINE AND IN THE FRONT, ON THE CENTER OF THE STERNUM.
M: MIDDLE LINE AND BACK, ON THE CENTER OF THE COLUMN.