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Is There any Difference in Cardiogoniometry Parameters of Ischemic and Nonischemic Cardiomyopathy in Patients with Left Bundle Branch Block?

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Background: Differentiating ischemic from nonischemic cardiomyopathy is important both prognostically and therapeutically, although it may be difficult clinically.
Objectives: We aimed to determine the diagnostic power of Cardiogoniometry (CGM) in the differentiation of the ischemic from the nonischemic etiology of left bundle branch block (LBBB).
Patients and Methods: We studied 37 patients with LBBB on the electrocardiogram (ECG) and left ventricular ejection fraction (LVEF) < 30%. All of them underwent coronary angiography, and 33 patients were included. Eighteen patients were categorized as the ischemic cardiomyopathy group, and 15 patients with normal coronary angiography were assigned to the nonischemic cardiomyopathy group. Then, CGM parameters were studied and compared between the two groups.
Results: Both ischemic and nonischemic cardiomyopathy groups were similar in age, LVEF, weight, height, and body mass index. Interestingly, there were no significant differences in the average value of the 40 CGM parameters that were analyzed in this study between the two study groups.
Conclusions: When LBBB is the underlying rhythm, CGM cannot differentiate ischemic from nonischemic patients with good accuracy. Large studies, however, are needed to confirm our results.

*Keywords:*Cardio Goniometry; Electrocardiogram; Left Bundle Branch Block; Ischemia; Coronary Angiography

1. Background

Differentiating ischemic from nonischemic cardiomyopathy is important both prognostically and therapeutically, although it may be difficult clinically (1). In two-thirds of patients with nonischemic cardiomyopathy, the resting regional wall motion is abnormal, while patients with ischemic cardiomyopathy may have uniform hyperkinesia (2). The surface electrocardiogram (ECG) can sometimes be used for the diagnosis of cardiac ischemia, but this tool is relatively not a sensitive method (2-5) and requires the ECG expertise of the reader as a crucial factor in its diagnostic yield. On the other hand, the automated interpretation of the ECG results has not gained popularity because of its unreliable results. The good news, however, is that advances in technology have provided cardiologists with improved therapeutic options for patients at risk of heart disease (3, 6-11).

Cardiogoniometry (CGM) is a noninvasive technique for the quantitative three-dimensional vectorial analysis of myocardial depolarization and repolarization. This method uses five electrodes in specific places and takes 12 seconds to obtain. CGM thereafter conducts a fully automated analysis and thus has the potential to determine whether or not underlying ischemia is present. This method can close the diagnostic gap in both stable coronary artery disease (CAD) and acute ischemic events (5). The main advantages of this system are three-dimensional recording and augmenting the ability of the physician to analyze the recordings more accurately. A recent study has shown that CGM can effectively differentiate patients with CAD from controls. By extracting parameters from the vector loop and subsequently applying regression analysis, the authors of that study successfully used CGM data to determine optimal parameter sets and achieve 65% sensitivity and 77% specificity based on over 50% stenosis by coronary angiography (5).

Schupbach et al. evaluated patients undergoing CGM immediately prior to elective coronary angiography; the diagnostic accuracy of CGM was 71% and it was significantly superior to plain ECG recordings (6).

2. Objectives

The purpose of the present study was to evaluate CGM techniques currently available for differentiating patients with cardiomyopathy and LBBB due to cardiac ischemia from patients with no underlying ischemia. The parameters that were evaluated as prognostic factors comprised resting ECG, premature ventricular contractions, QRS duration, damage scores, QT dispersion, and ST-segment and T-wave abnormalities. The T-wave alternans and late potentials identified on signal-averaged ECGs and heart rate variability were also considered.

3. Patients and Methods

This study enrolled 37 patients with the LBBB pattern on the ECG who were referred for coronary angiography. All the subjects underwent CGM at rest a few hours prior to catheterism. While in a supine position during the recording, the patients were asked to hold their breath for 12-15 seconds or if not possible, to perform shallow breathing to keep their thoracic excursions to a minimum. Standard CGM leads were implanted and protocols were observed. Past medical history was collected from clinical records and patient interviews.

Patients with atrial fibrillation as well as those with more than 3 ectopic beats during the CGM recording or poor quality CGM recording were excluded. Thirty-three patients remained in the study. Based on angiographic reports, the participants were categorized into two groups: patients with stenosis > 70% in at least one of the coronary arteries or previous documented myocardial infarction were assigned to the ischemic cardiomyopathy group and the others were allocated to the nonischemic cardiomyopathy group. Then, CGM parameters were selected and compared between these two groups.

3.1. Principle Cardiogoniometry

The principles of CGM have been published in detail elsewhere (6). In brief, by using four electrodes, the frontal and oblique sagittal plane (OSP) of the heart is defined. The X-axis, which has an anteroposterior (values with positive signs have a posterior location) orientation, and Y-axis, which has a left-oblique-sagittal basoapical (values with positive signs pointing to the apex) orientation, construct the OSP plane. The Z-axis is perpendicular to the X and Y axes. (Values with negative signs point up.) The Y and Z axes construct the frontal plane. The projection of the heart vector into each of these two orthogonal planes is done via three electrodes. Using the vector projections in the two orthogonal planes, the spatial display of electrical heart activity can be reconstructed for every millisecond. The degrees of longitude (angle alpha) define how far the vector is anterior or posterior to the frontal plane (YZ-plane). When a vector lies in the Y-axis and points to the apex, this angle is + 90°. Latitude (angle beta) defines how far the vector lies above or below the OSP (XY-plane). If a vector points to below the OSP, the angle beta will have a positive value and it will be negative if the vector is assigned to above the OSP. The phi angle is defined as the angle between the maximal vectors of the R-loop and the T-loop.

The analysis of all these data is fully automated by the CGM device and more than 300 parameters are calculated. These parameters can be divided into the following main classes: potential angles; time course; amplitude; shapes and eccentricities direction of vectors; potential distributions; and beat-to-beat variability for each P, R, and ST-T loop.

3.2. Statistical Analysis

The data were analyzed using SPSS (version 22) and the independent t-test or the Mann-Whitney U-test. A P value < 0.05 was considered significant.

4. Results

Thirty-three patients remained in the study after the implementation of the exclusion criteria. Fifteen patients had a normal coronary angiography, so they were assigned to the nonischemic cardiomyopathy group. The other 18 patients were categorized as the ischemic cardiomyopathy group. Where 61.9% of the ischemic group patients were male, only 38.1% of those in the nonischemic group were male. Both ischemic and nonischemic cardiomyopathy groups were similar in age, LVEF, weight, height, and body mass index. The baseline clinical features of the study population are summarized in Table 1. Totally, 40 CGM parameters were analyzed in this study (Table 2), and there were no significant differences in the average values of any of the parameters between the two study groups (Table 3).

Table 1. Baseline Characteristics of the Patients in the Two Groups [a]

	Nonischemic Cardiomyopathy	Ischemic Cardiomyopathy	P Value
Age, y	58	65	0.548
LVEF, %	21.2	25.8	0.297
Male, %	38.1	61.9	0.467
Wight, kg	74.3	69.8	0.278
Height, cm	162.7	165.0	0.483
BMI, kg/m^2	27.6	26.2	0.448

[a] Abbreviations: LVEF: Left Ventricular Ejection Fraction, BMI: Body Mass Index.

Table 2. CGM Parameters Description

Parameter number	Parameter	Description
P9	SD Rvmax [a]	Standard deviation of maximal spatial velocity of the R-loop for all measured
P12	SD Tvmax [a]	Standard deviation of maximal spatial velocity of the T-loop for all measured
P19	Median Rvmax/ Tvmax	Median ratio of the maximal spatial velocity of the R-loop over the maximal spatial velocity of the T-loop
P20	Mean Rvmax/Tvmax	Mean ratio of the maximal spatial velocity of the R-loop over the maximal spatial velocity of the T-loop
P46	Median alfaRmax	Median angle alpha of the maximal vector of the R-loop
P47	Mean alfaRmax	Mean angle alpha of the maximal vector of the R-loop
P48	SD alfaRmax	Standard deviation of the angle alfa of the maximal vector of the R-loop for all measured heart beats
P49	Median betaRmax	Median angle beta of the maximal vector of the R-loop
P50	Mean betaRmax	Mean angle beta of the maximal vector of the R-loop
P51	SD betaRmax	Standard deviation of the angle beta of the maximal vector of the R-loop for all measured heart beats
p64	Median alfaTmax	Median angle alpha of the maximal vector of the T-loop
p65	Mean alfaTmax	Mean angle alpha of the maximal vector of the T-loop
p66	SD alfaTmax	Standard deviation of the angle alfa of the maximal vector of the T-loop for all measured heart beats
P67	Median betaTmax	Median angle beta of the maximal vector of the T-loop
P68	Mean betaTmax	Mean angle beta of the maximal vector of the T-loop
P69	SD betaTmax	Standard deviation of the angle beta of the maximal vector of the T-loop for all measured heart beats
P70	Median phi	Median angle phi for all measured heart beats
P71	Mean phi	Mean angle phi for all measured heart beats
P72	SD phi	Standard deviation of the angle phi for all measured heart beats
P85	Median Rmax/Tmax	Median ratio of the potential sum at R maximum and T maximum
P86	Mean Rmax/Tmax	Mean ratio of the potential sum at R maximum and T
P87	SD Rmax/Tmax	Standard deviation of the potential sum at R maximum and T for all measured heart beats
P106	Median Rexc	Mean of the variable “eccentricity”, which describes the roundness of the R loop
P107	Mean Rexc	Mean of the variable “eccentricity”, which describes the roundness of the R loop
P108	SD Rexc	Standard deviation for all measured heart beats of the variable “eccentricity”, which describes the roundness of the R loop. If the R-loop is a perfect circle, P108 equals 0.
P109	Median Texc	Median of of the variable “eccentricity”, which describes the roundness of the T loop
P110	Mean Texc	Mean of the variable “eccentricity”, which describes the roundness of the T loop
P111	SD Texc	Standard deviation for all measured heart beats of the variable “eccentricity”, which describes the roundness of the T loop. If the T-loop is a perfect circle, P111 equals 0.
P168	Median tR+ [b]	Median of the duration of the R loop before the R maximum
P169	Median tR- [b]	Median of the duration of the R loop after the R maximum
P170	Median Tst	Median duration of the ST segment
P171	Median tT+	Median of the duration of the T loop before the T maximum
P172	Median tT-	Median of the duration of the T loop after the T maximum
P220	Median alfaRIni	Median angle alfa of the vector pointing from the first point of the R-loop to the point 10 ms after the beginning of ventricular depolarization
P221	Median betaRIni	Median angle beta of the vector pointing from the first point of the R-loop to the point 10 ms after the beginning of ventricular depolarization
P224	Median alfaTIni	Median angle alfa of the vector pointing from the first point of the R-loop to the point 10 ms after the beginning of ventricular repolarization, i. e. the initial orientation of the T-loop
P225	Median betaTIni	Median angle beta of the vector pointing from the first point of the R-loop to the point 10 ms after the beginning of ventricular repolarization, i. e. the initial orientation of the T-loop

[a] Units of measurement: mV/ms.
[b] Units of measurement: ms.

Table 3. Comparisons of Different Parameters Between the Ischemic and Nonischemic Cardiomyopathies Groups [a]

Parameter	Nonischemic Cardiomyopathy	Ischemic Cardiomyopathy	P Value
P9	42.32 ± 30.69	35.96 ± 23.27	0.504
P12	91.69 ± 105.08	110.98 ± 65.93	0.525
P19	8.00 ± 12.70	11.06 ± 7.93	0.404
P20	7.10 ± 9.40	8.65 ± 5.46	0.560
P46	-6.71 ± 37.86	-10.36 ± 55.36	0.830
P47	-6.71 ± 37.73	-10.49 ± 55.45	0.824
P48	1.62 ± 0.98	1.98 ± 2.24	0.567
P49	-10.08 ± 9.95	-9.57 ± 14.27	0.906
P50	-10.27 ± 9.82	-9.63 ± 14.26	0.885
P51	1.05 ± 0.65	1.02 ± 0.69	0.887
p64	96.04 ± 108.71	63.58 ± 122.84	0.432
p65	100.10 ± 107.98	65.42 ± 122.13	0.399
p66	8.12 ± 12.64	10.12 ± 14.04	0.673
P67	1.73 ± 13.67	8.14 ± 18.73	0.279
P68	2.53 ± 13.99	8.53 ± 18.00	0.301
P69	2.91 ± 2.53	4.52 ± 5.59	0.311
P70	101.17 ± 116.00	74.09 ± 139.02	0.553
P71	126.07 ± 91.62	128.03 ± 88.17	0.951
P72	5.94 ± 7.52	7.60 ± 9.23	0.580
P85	4.47 ± 6.47	4.38 ± 2.10	0.956
P86	4.46 ± 6.38	4.28 ± 1.97	0.910
P87	0.39 ± 1.02	0.33 ± 0.36	0.820
P106	0.41 ± 0.15	0.48 ± 0.26	0.384
P107	0.42 ± 0.16	0.48 ± 0.26	0.429
P108	0.04 ± 0.03	0.02 ± 0.02	0.095
P109	0.50 ± 0.21	0.45 ± 0.25	0.526
P110	0.55 ± 0.25	0.51 ± 0.26	0.661
P111	0.08 ± 0.08	0.07 ± 0.06	0.738
P168	64.53 ± 18.28	52.00 ± 19.91	0.071
P169	73.93 ± 14.10	68.89 ± 18.14	0.387
P170	26.33 ± 68.15	13.72 ± 46.08	0.532
P171	146.13 ± 37.46	168.28 ± 46.50	0.148
P172	136.13 ± 42.99	144.89 ± 44.98	0.574
P220	68.86 ± 74.22	48.85 ± 79.83	0.465
P221	-7.97 ± 11.40	-10.05 ± 14.66	0.657
P224	132.97 ± 89.08	109.95 ± 78.57	0.436
P225	8.12 ± 8.07	5.90 ± 11.59	0.536

[a] Values are Presented as Mean ± SD.

Figure 1. Cardiogoniometry Machine

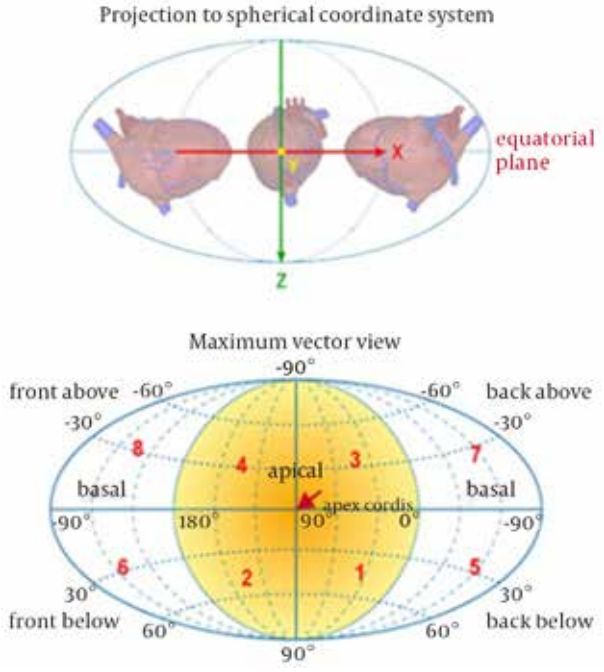

Figure 2. Cardiogoniometry System, Normal Graphs

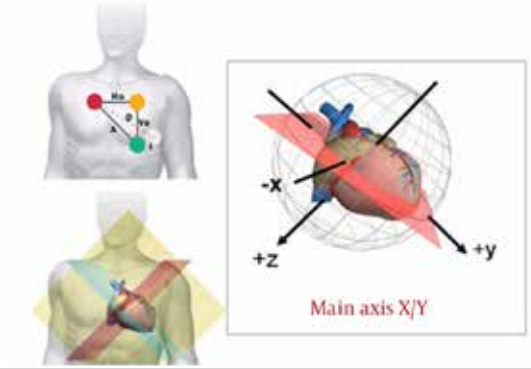

Figure 3. Cardiogoniometry Vectors

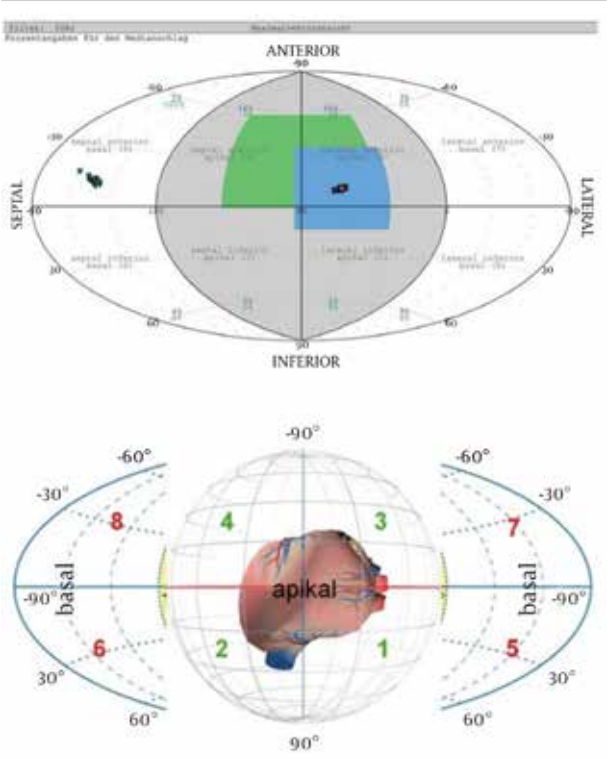

Figure 4. Cardiogoniometry Normal Spherical Graphs

5. Discussion

The present study recruited 33 patients and assigned 15 patients to the nonischemic cardiomyopathy group and 18 patients to the ischemic cardiomyopathy group. A comparison of the ischemic and nonischemic patients yielded no significant differences in any of the 40 CGM parameters between the two groups. However, CGM has been used before and shown acceptable sensitivity and specificity. In one study on the noninvasive detection and risk stratification of myocardial ischemia, the results showed that CGM was accurate in detecting ≥ 50% stenoses at rest (sensitivity 73% and specificity 84%, respectively) (7).

Birkemeyer et al. employing five different CGM parameter sets, evaluated 1027 patients undergoing CGM and coronary angiography and found that the sensitivity and specificity of CGM for detecting ischemia were 84% and 90%, respectively (8). Elsewhere, Tolg et al. investigated the effectiveness of CGM in discriminating patients with acute coronary syndromes without ST-segment elevation [NSTE-acute coronary syndrome (ACS)]. In that study, a total of 210 patients were analyzed (157 with NSTE-ACS and 53 controls) and compared to the ECG or the troponin test, CGM achieved a highly significantly better diagnostic accuracy (9). Additionally, Birkemeyer et al. compared the accuracy of CGM with cardio-MRI by unselectively recruiting 40 patients and performing CGM before cardio-MRI within the routine diagnostic pathway. The authors compared the CGM findings against pathological perfusion and/or the presence of late enhancement (20 patients in total) during cardio-MRI. CGM reached sensitivity of 70% and specificity of 95%, and there was a positive predictive value of 93% (10). Huebner et al. in a large study practiced a methodological approach to 658 patients (405 with coronary stenosis ≥ 50%) to prove that there is at least one CGM parameter that is significant and suitable for the detection of each individual CAD category. They reported that one significant parameter found to be electrophysiologically plausible can be allocated to one CAD category (11). Along similar lines, the same authors conducted another study focused on how a single CGM parameter, namely the spatial position of the T-loop, can differentiate healthy patients from those with CAD and reported that the sensitivity and specificity of this singular CGM parameter was 67% and 72%, respectively (12). In summary, what the previous experiences have indicated is that in comparison with the other noninvasive tests, CGM is more accurate and has more sensitivity in the detection of ischemic heart disease. For example in one study, CGM was 2.5 times more sensitive than the ECG and troponin test and could correctly differentiate between ischemic and nonischemic patients in 75% of the cases. Even in acute coronary syndrome patients, in whom both ECG and troponin testing finally remained negative, CGM still reached a two-third detection rate (13). In our study, in spite of the limitation of a small sample size, we showed that this method has no acceptable diagnostic ability to determine whether cardiac ischemic patterns are present in patients with underlying LBBB.

First and foremost among the limitations of our study is its relatively small sample size. Further investigations with larger sample volumes are recommended to validate the findings reported here. Also, additional studies will help to stratify each parameter according to the distribution of the affected myocardial areas. Finally, angiographic findings only have a modest correlation with the presence and extent of ischemia.

When LBBB is the underlying rhythm, CGM cannot differentiate between ischemic and nonischemic patients with good accuracy. Needless to say, large studies are needed to confirm our statement.

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