A Novel Electrocardiographic Display

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Abstract

A new type of electrocardiograph, which analyses the frequency content of the T wave of the ECG in particular, has been introduced. At the time of the study, a limited number of measures of the energy of the various frequencies was available for study and these were grouped into left and right ventricular measures for early and late repolarisation.

A study of 75 apparently healthy individuals and 75 randomly selected patients was undertaken.
Results showed that the indices of repolarisation were clearly sex dependent, though not age dependent, which was a reflection of the predominance of young individuals in the healthy group.
The maximum T wave amplitude from any lead correlated highly with T wave energy.

Approximate normal ranges of repolarisation measures were also developed. It was also found that a few patients with a normal ECG had an abnormally low energy pattern based on the output from the new device.

1. Introduction

Electrocardiography is a frequently used investigation in medical practice. The reasons for this are that electrocardiography is a non-invasive, easy to perform, inexpensive investigation and the result, an electrocardiogram (ECG), can provide unique information. An ECG conventionally displays 12 waveforms (leads) derived from the electrical activity of the heart. This involves using 10 electrodes on the surface of the body, which record the electrical activity from the cardiac muscle cells (cardiomyocytes) [1].

An ECG displays the overall electrical activation of the heart and can detect various cardiac pathologies [1]. However, it has its limitations, with some pathological processes producing no ECG changes. Therefore, this is one of the limitations of the conventional ECG as a 'normal' conventional 12 lead ECG recording does not guarantee that the heart is healthy.

There has been increasing interest in analysing ECG signals in a different way. One new approach is to study the frequency content of the ECG. An ECG signal contains components of differing frequencies. For example, the T wave contains low frequency components less than 10 cycles per second. A new type of display has recently been developed by HeartSciences and is incorporated in their electrocardiograph known as the MyoVista. This machine uses advanced mathematical techniques to determine the frequencies within the QRS and T waves and the energy of each frequency [2], which can be thought of as similar to assessing the loudness of a sound at a particular frequency. The strength of each frequency at any instant in the cardiac cycle is then displayed using colour techniques [2] which can be seen in Fig 1.

At the time of this study, the MyoVista had, as its only output from the frequency analysis, summary measures of the energy of the T wave. These repolarisation indices were termed Ventricular Indices Early Measure (VIEM), Ventricular Indices Late Measure (VILM) and Ventricular Indices Average Measure (VIAM). For each measure, there is a value for the Right Ventricle (RV) and Left Ventricle (LV). The average measures are the sum of the early and late measures divided by heart rate, for the RV and LV. All indices are said to be adjusted in an undisclosed way according to age and gender [2]. The machine also generates and displays an overall MyoVista energy category (High, Moderate and Low) from the repolarisation indices and any abnormalities in the repolarisation period. In addition, the MyoVista outputs a report on the conventional 12 lead ECG based on the University of Glasgow ECG Analysis program, which uses software to provide measurements for certain parameters [3] some of which are output.

The aim of this project was to find the 'normal' range of the ventricular repolarisation indices in a healthy adult population, and to see if there are any differences with respect to age or sex. In addition, hospital patients were studied to see if it is possible to have an abnormal MyoVista ECG but a normal 12 lead ECG.

 ISSN: 2325-887X DOI: 10.22489/CinC.2018.067

Figure 1: MyoVista Display, (from HeartSciences 2018). The hsECG machine displaying the conventional ECG tracing and the MyoVista energy waveform on the left. On the right of the display is the MyoVista Energy Category (top), MyoVista Ventricular Indices (middle) and University of Glasgow Analysis Report (bottom).

1.1. Methods

1.2 ECG Recording

Ethical approval was obtained from the Medical, Veterinary and Life Sciences College Ethics Committee for the use of the ECG machine in healthy adult volunteers. For this part of the study, an Information Sheet and Consent form were generated. Healthy adult volunteers were recruited via word of mouth, by posters located in Glasgow Royal Infirmary (GRI) and the University Wolfson Medical School Building (WMSB) and through an email to medical students.

Volunteers read an information sheet, were given the opportunity to ask questions, and could then agree to take part in the study with written consent. To be eligible for the study, participants needed to be apparently healthy adults. The main exclusion criterion was any condition which could affect the cardiovascular system e.g. hypertension or cardiac valvular abnormalities.

The West of Scotland NHS Research Ethics Service Office approved the use of the MyoVista machine to facilitate its evaluation in patients who required an ECG to be recorded as part of their usual clinical care. Therefore, patients in the cardiac wards of Glasgow Royal Infirmary (GRI) were recruited to take part in the study. In addition, patients attending a cardiology clinic were also invited to take part in the study. The patients were informed about the study, in particular why the new machine was being used and invited to take part. Verbal consent was gained.

ECGs were recorded for over 20 seconds. After the recording, the repolarization data from the MyoVista was transferred to a spreadsheet. From the machine, the following information was obtained: the six repolarisation indices, MyoVista energy category, University of Glasgow analysis summary (Normal, Borderline or Abnormal) and the largest T wave amplitude. The T wave amplitudes were reported by the University of Glasgow program and the maximum absolute value was also noted. Patient information (sex, age, height and weight) was also added to the spreadsheet.

1.3. Statistical Analysis

For data analysis, volunteer and patient data was recorded in Excel spreadsheets, and then imported into SPSS and Minitab in order to analyse the data.

Firstly, the mean and standard deviation of the six repolarisation indices for groups of male and female volunteers was calculated. To compare the means of the sexes, Student's T-test was used as the data was normally distributed, with equal variances not assumed, as not all of the indices had equal variance between the samples.

To calculate an approximate normal range for males and females, the mean ± two standard deviations was used. To test the correlation between ventricular repolarisation indices and age, and then between ventricular repolarisation indices and maximum T wave amplitude, Spearman's correlation was calculated.

2. Results

2.1. Volunteers

75 ECGs from healthy adult volunteers (34 males aged 31.8±16.7 years, 41 females aged 27.6±12.5 years) were recorded. One male was excluded due to exclusion criteria being met.

2.2. Sex

There were significant differences found when comparing the means of each of the ventricular repolarisation indices in male and female volunteers. Repolarisation indices were higher in males than in females (Table 1). In the early measure of ventricular repolarisation, the mean difference was 42.81 and 39.75 for the right and left ventricles respectively. The mean difference for the late measure was 40.42 and 37.53 for the right and left ventricles respectively. For the average measures of repolarisation, there was a significant mean difference of 1.71 and 1.53 for the right and left ventricles respectively. All of the mean differences were highly significant, each with $p < 0.001$.

	Female			
	Mean	SD	Reference Range	
			Lower	Upper
VIEM (RV)	97.74	23.51	50.72	144.76
VIEM (LV)	90.16	34.56	21.03	159.29
VILM (RV)	92.97	21.84	49.29	136.65
VILM (LV)	85.86	32.12	21.23	150.48
VIAM (RV)	2.71	0.82	1.07	4.35
VIAM (LV)	2.57	1.19	0.19	4.95
	Male			
	Mean	SD	Reference Range	
			Lower	Upper
VIEM (RV)	140.6	40.26	60.03	221.08
VIEM (LV)	130.0	40.71	48.49	211.32
VILM (RV)	133.4	38.12	57.16	209.63
VILM (LV)	123.4	37.91	47.56	199.20
VIAM (RV)	4.42	1.45	1.51	7.32
VIAM (LV)	4.10	1.58	0.94	7.26

Table 1: Mean (Standard Deviation) of MyoVista Ventricular Repolarisation Indices and Reference Ranges for females and males.

2.3. Age

Spearman's correlation indicated that there was no significant correlation between age and any of the ventricular repolarisation indices in this study, for male or female volunteers.

2.4. Maximum T Wave Amplitude

Comparison of the ventricular repolarisation indices against the maximum T wave amplitude showed that there were positive correlations. The Spearman's correlation between maximum T wave amplitude and each of the repolarisation indices ranged from 0.490 to 0.622 (VIEM (RV): 0.621, VIEM (LV): 0.502, VILM (RV): 0.609, VILM (LV): 0.490, VIAM (RV): 0.622, VIAM (LV):0.502). All of these correlations were highly significant ($p < 0.001$) as seen in Figure 2.

2.5. Energy Categories

No relationship was found between ventricular repolarisation indices and energy category for males and females. There was no obvious cut off value for the repolarisation indices for each overall energy category.

2.6. Reference Ranges

The reference ranges for the six repolarisation indices, for healthy adults, were also calculated for males and females, as shown in Table 1. There is some overlap in the reference ranges between males and females.

2.7. Patients

75 ECGs from patients in GRI (56 males aged 59.8±16.8 years, 19 females aged 69.6±16.6 years) were recorded. Four ECGs from patients (2 males and 2 females) with implanted cardiac pacemakers were excluded.

There were a few patients whose repolarisation indices were outside of the reference ranges generated from the healthy volunteers for each index. There were some patients below the reference range, which would be expected. However, interestingly, there was also a number of patients whose indices were above the reference range.

2.8. University of Glasgow Automated ECG Report

In addition, for patients and volunteers, the overall energy category was compared with the summary generated from the University of Glasgow Analysis Report, which can be seen in Table 2??. This showed that the majority of volunteers had a normal ECG with high energy level, whereas most patients had an abnormal ECG result with low overall energy category. However, it also showed that it is possible to have, on the one hand, a normal ECG interpretation with an abnormal energy level or, on the other hand, an abnormal ECG with a high overall energy level. For example, nine patients had a normal 12 lead ECG of whom one had an abnormal and eight a moderate overall MyoVista energy category.

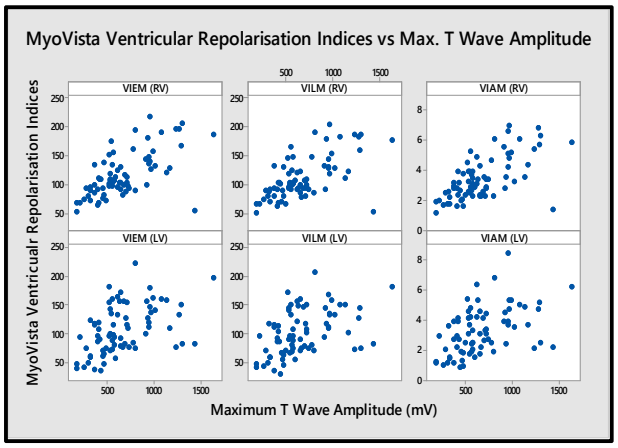

Figure 2: Scattergraph plotted to show Ventricular Repolarisation Indices against maximum T wave amplitude for volunteers. All graphs show that there is a positive correlation between the ventricular repolarisation indices and the maximum T wave amplitude.

3. Discussion

This project provided a unique opportunity to study the output of a new ECG machine, focusing primarily on the ventricular repolarisation indices it generates.

Male repolarisation indices were consistently higher than those of females. However, no adjustment was carried out for multiple testing, which would make the likelihood of false positive results more likely. However, p values were less than 0.001 across all indices indicating that it would be extremely unlikely that this was not a significant result. This is the first report of the MyoVista ventricular repolarisation indices being sex dependent.

The reference ranges in Table 1 are very wide because variation in each index was large. In addition, it is unlikely that a small sample size, of 41 females and 33 males, could create a useful reference range. The males had a higher variation of measurements within an index leading to larger reference ranges created in the male group. To calculate a reference range, the number of standard deviations around the mean was 2, rather than 1.96, because the standard deviation was not from the whole population, but was calculated from the sample.

No significant correlation between ventricular repolarisation indices and age was found. However, this could be a result of study design in terms of recruitment. The majority of the volunteers were students, resulting in most of the volunteers being aged between 20 and 25, which is a limitation of the study. Therefore, there was not a good spread of ages to facilitate meaningful tests.

There is a small trend with increasing values of repolarisation indices being associated with a higher overall energy category, although this is more apparent in the female volunteers compared to the males. However, interestingly there is no clear boundary within a repolarisation index for each energy category. This means that there are other factors influencing the energy category generated by the MyoVista algorithms.

Finally, a comparison of the University of Glasgow automated ECG interpretation summary with the MyoVista Energy Category exhibited a general trend that healthy people with a normal ECG had the high energy category, while patients with abnormal ECG results had the low energy category. However, there were some patients who had normal ECGs with low and moderate energy levels, suggesting that this machine is providing some extra information not found in the conventional ECG.

Patients in the cardiac ward were there for a multitude of reasons with many comorbidities and were not a defined group. Therefore, it is difficult to say to which section of a hospital population these results would apply. In addition, more male patients were recruited than female patients, mainly due to a higher proportion of male patients in the wards visited for study and to more females than males declining to participate in the study. Furthermore, although volunteers said they were healthy, that may not have been the case. However, this is a recognised hazard of recruiting apparently healthy volunteers for any study but it would not have been feasible to confirm that each volunteer was healthy in this short study.

There is huge scope for further studies involving this new machine. Indeed, once this small undergraduate study was completed, a larger study of 188 patients was published indicating that the MyoVista could be used to detect myocardial relaxation abnormalities [4].

3.1. Clinical Implications

This study on the MyoVista has revealed some previously unpublished, basic information about the measurements produced by this new ECG machine. The study has found that, in healthy adults, males have significantly higher repolarisation indices than females, but it did not find any difference in repolarisation indices with respect to age. This study has also shown that the new machine gives different information to that given by the conventional ECG in terms of its overall energy category. However, with further study, it will be interesting to see if this new ECG machine could take on the role of screening for heart disease in the future. Whether or not the results from the present study will have some influence on the diagnostic criteria used within the MyoVista in future remains to be seen.

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