Graphic Visualization of ECG Estimated Myocardial Infarct Size Using the Standardized Seventeen Segment Bull's Eye Plot

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Abstract

The b*ull's* eye plot has been successfully introduced in multiple cardiac imaging diagnostic modalities and standardized by AHA in recent years. The ECG estimated myocardial infarct (MI) size is a quantitative measure of the size of the infarct region in left ventricular myocardium and is a proven tool to assist cardiologists in clinical decision making. MI size has been presented as a percentage of the left ventricle (LV) mass based on Selvester ECG scoring system. The scoring system has 50 ECG criteria with corresponding points. The reported MI size is not associated with a specific location in LV. This study applied the Selve*ster scoring system and bull's* eye plot to create a quantitative MI size presentation with visual location in the LV. The automated Selvester scoring algorithm was validated using a database of 688 ECGs with and without MI. The automated ECG-MI size was tested against two cardiologist*s'* manual scores resulting in 94% correlation.

1. Introduction

Bull's eye plot is commonly used cardiac imaging to provide exact MI location and relative MI size in the left ventricle. AHA/ACC/HRS committees on the standardization of the electrocardiogram have recently recommend calculation and reporting of ECG estimated MI size based on the Selvester scoring system [1]. Graphical presentation of MI size is not possible on traditional 2-dimensional ECG plot. For people who are not familiar with ECG reading, visualization of the MI location from ECG is not obvious. The bull's eye plot makes the 3 dimensional visualization of ECG estimated MI size possible. The aim of this study was to introduce a graphics display of ECG-MI size in a bull's eye plot as a bridge to connect ECG with imaging modalities. This study also reports our experience in the implementation and validation of the ECG estimated MI size.

2. Bull's eye plot in seventeen segments

The bull's eye plot has been commonly used in cardiac imaging, such as echocardiography, cardiac CT, SPECT, cardiac magnetic resonance and coronary angiography. The number of segments varied from 9 for early clinical application to 144 for research. AHA has standardized the bull's eye plot and recommended 17 particular segments for assessment of the myocardium and the left ventricular cavity [2]. Vertically, the left ventricle is equally divided into three circular basal (1, 2, 3, 4, 5, 6), mid-cavity (7, 8, 9, 10, 11, 12) and apical (12, 14, 15, 16) regions plus the apical cap (17) corresponding to short axis views. Horizontally, the basal and mid-cavity circular regions are equally divided into 6 segments corresponding to long axis views in the anterior (1, 7), anteroseptal (2, 8), inferoseptal (3, 9), inferior (4, 10), inferolateral (5, 11) and anterolateral (6, 12) segments. The mid-cavity circular regions are divided into 4 segments by anterior (13), septal (14), inferior (15) and lateral (16) directions. The plot, seen in Fig. 1, provides location and relative size of a myocardial infarct in the left ventricle when used in cardiac imaging.

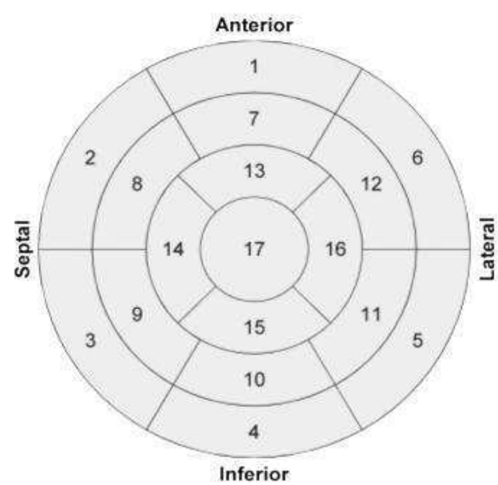

Figure 1. Bull's eye plot of left ventricle in 17 segments as if looking down the LV long axis from apex to base.

3. ECG-estimated MI size

Dr. Selvester's ECG-estimated MI size scoring system has been thoroughly studied by numerous research groups. The scoring system has 50 ECG criteria, where each criterion is associated with points that contribute to MI size. Each criterion is also associated with a specific location in the left ventricle. The Selvester score has been automated and validated against manual reading by Pope and later by Horáček [3,4]. Previously, the Selvester score has been validated against many different references including autopsy, ventriculogram, and most recently, MRI [5-7] .

The ECG database for this study was the Dalhousie body surface mapping (BSM) superset which has been described previously [4]. The study population consisted of 377 subjects with clinically established MI and 328 controls with no evidence of infarct for a total of 705 subjects. The patient selection for the test set started with 705 subjects. After excluding ECGs with LBBB or very small R-waves (R amp. < 20μV), the test set included a total of 670 ECGs.

This automated Selvester scoring system was implemented in the Philips DXL ECG analysis algorithm in two steps. First, all ECG measurements by lead were converted to global measurements as suggested by Dr. Horáček [4]. The second step was implementation of the 50 ECG criteria enumerated in the scoring summary sheet developed by Dr. Selvester and studied by Hindman [6,7]. The automated Selvester score was compared to scores manually coded by two cardiologists who are ECG experts with extensive knowledge of the Selvester scoring system. The scores coded by the cardiologists were based on a high resolution display of waveforms with a time scale of 100 mm/sec and an amplitude scaling of 40 mm/mV which is four times the standard 12-lead ECG scale. In addition, all leads were time aligned to facilitate the ability to determine global timing of the earliest onset and the latest offset of each QRS complex.

The manual and automated scores were compared and a 94% correlation was obtained with an adjustment of 2 ms to the computer interval measurements. The 95% confidence interval (CI) for the correlation coefficient was 93-95% as shown in Figure 2.

4. Visualization of ECG-estimated MI location and size

The ECG based estimation of MI size is useful for ECG experts. It may not be useful for people who are not ECG experts and have difficulty visualizing the location of MI in the left ventricle by looking at the 1-dimensional ECG waveform. Based on the bull's eye plot which is a tool familiar to cardiac imaging experts, we created an automated tool to visualize the ECG estimated MI location and size. This display may be better suited for clinicians more familiar with imaging modalities and less familiar with ECG [8].

ECG based MI location is an approximation. Dr. Selvester developed the scoring system based on the Ideker 12 segment left ventricular model [9]. The exact mapping between the 12 leads in ECG and the 17 segments in bull's eye plot may not be so critical. The main idea is the same in both segmentation methods. The left ventricle is segmented in 3 equal circular slices perpendicular to the LV long axis and either 4 or 6 slices parallel with the LV long axis. The main difference occurs in the areas of apical and basal locations of the left ventricle. With the bull's eye, the apex has 5 segments including the 17th segment for the apical cap. The apex has 4 segments in the Ideker segmentation. The basal and mid circular slides of the bulls eye have 6 segments in each circular slice while in the Ideker segmentation, each of the 3 circular slices has 4 vertical segments throughout the basal, mid and apical portions of the left ventricle. Selvester discussed the correspondence of the bull's eye 17 segments versus Ideker 12 segments. Dr. Selvester believes that the angular alignment is nearly matching between the two segmentation methods [10].

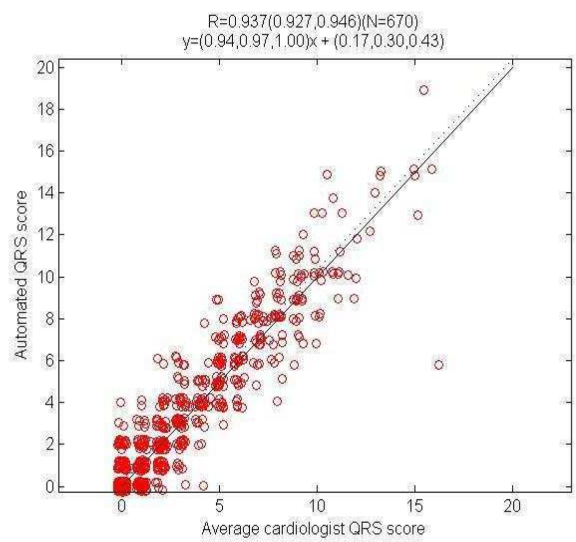

Figure 2. Scatter plot of automated scores (y-axis) versus the average of two cardiologist manual scores (x-axis).

In the bull's eye plot, each segment was colored. The intensity of the color was associated with its contribution to the total infarct size estimated by ECG. We found this approach to be intuitive. The colors indicate the size of the infarct in the location and the color variation helps to convey the fact that the location is an estimate with lower spatial resolution than more exact imaging methods. Figure 3 shows an example of the correspondence between ECG and the bulls eye.

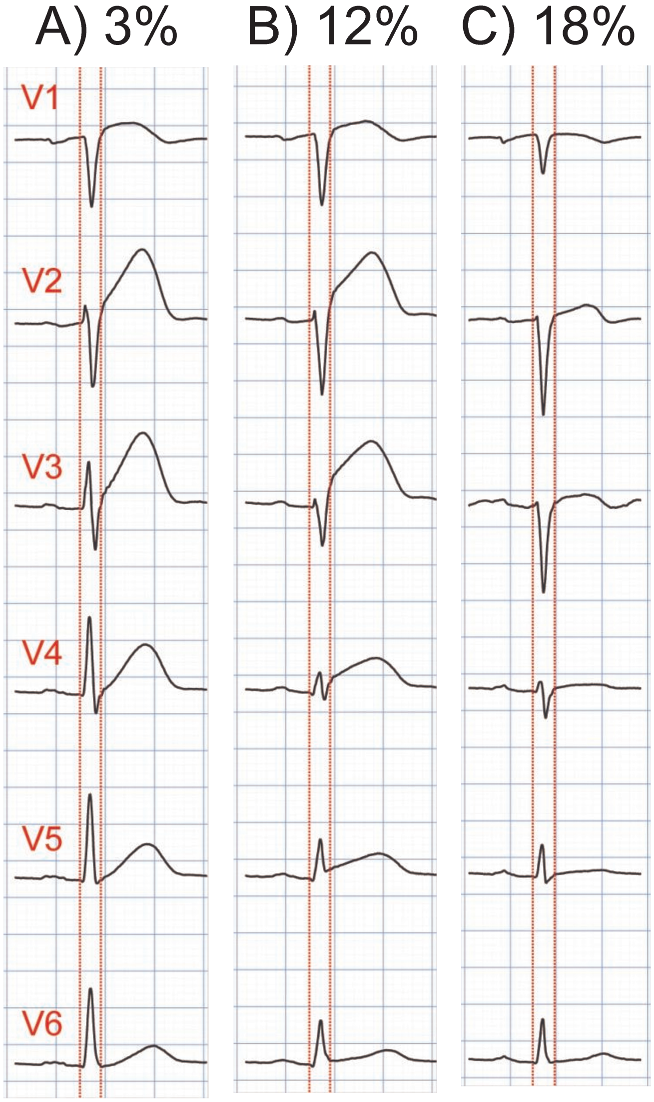

Figure 3. Precordial lead average beat from serially recorded ECG from a 66 year old male patient with evolving MI. The second ECG (panel B) was recorded 1 hour after the first ECG (panel A) and the third ECG (panel C) was recorded 3 hours after the second. An increased MI size can be seen from the loss of R-wave in the ECG precordial leads V2, V3 and V4. A mid-LAD stenosis was found during percutaneous coronary intervention between the second and third ECGs

5. Discussion

Selvester ECG-estimated MI size is a helpful clinical tool for patient risk stratification and patient management decision support. A large sized myocardial infarction is associated with poor patient outcomes in both short and long term follow up after acute MI [11]. The bull's eye plot display of ECG estimated MI size and location provides a helpful tool to non-ECG experts.

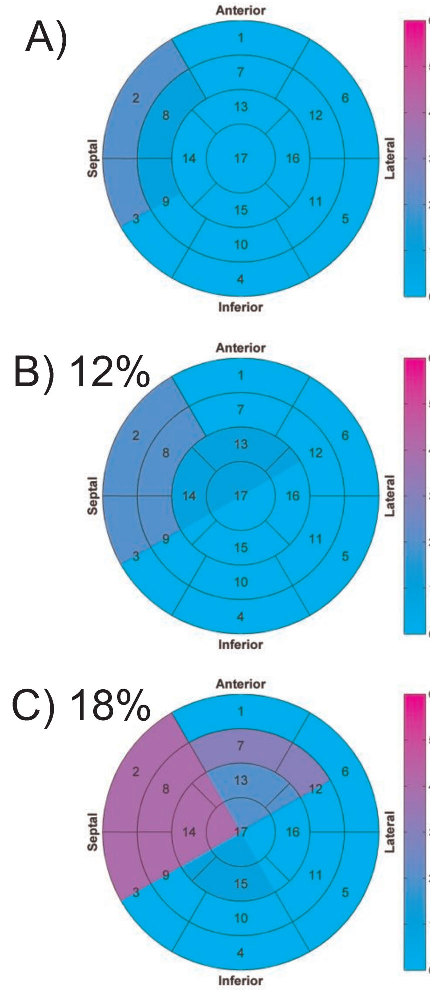

Figure 4. Seventeen segment bull's eye plots corresponding to the ECG in Fig 3. MI size by ECG increased in the anteroseptal region from 3 to 12 to 18% in panel s A, B and C.

The most difficult part in implementing an accurate Selvester scoring program is the qualification of small ECG waves. This is true for both manual scoring and automated scoring. We found the most common reason for differences between the automated algorithm and the manual score to be classification of low amplitude short duration Q and R-waves near the classification threshold values. Although the current technique allows measurement of 10 µV deflections, we also do not classify any deflection with amplitude < 20µV as a wave as suggested by Horáček [4]. Artifact may overwhelm a true physiological deflection of this size. Wagner observed significant differences in scores generated from

ECG waveforms printed in high resolution versus standard scaling [12]. The computer based algorithm measures ECG waveforms on an averaged beat to reduce the effect of artifact as much as possible on true physiologic deflections.

ECG experts transform information from one dimension to 3 dimensional space in their mind when they read ECGs. They may not need the bulls eye map for visual 3D orientation of all ECG leads. In addition, they may not like the bull's eye plot tool for MI location and size due to the fact that a two dimensional plot is used to represent the 3D content. When MI is located in the basal portion of the left ventricle for instance, the size on the bull's eye plot looks much bigger than it should in 3D. The opposite is true for MI located in the apical portion of the left ventricle, where the MI size looks much smaller than it should due to the 3D to 2D flattening of the bull's eye plot. The concentric circles of the bulls eye plot progressively shrink more than the left ventricle actually does progressing from base to apex.

6. Conclusion

Intuitive visualization of infarction size and location by Selvester score on a commonly used bull's eye plot might open up the use of ECG beyond ECG experts. These new users can feel confident in the result because the Selvester score has been validated and well studied by many authors [7].

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