Combining Sgarbossa and Selvester ECG Criteria to Improve STEMI Detection in the Presence of LBBB

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Abstract

ECG detection of ST-segment Elevation Myocardial Infarction (STEMI) in the presence of left bundle-branch block (LBBB) has long been a challenge. The purpose of this study was to add Selvester criteria (the 10% rule) to Sgarbossa criteria for further improved detection of STEMI in LBBB and report the combined performance.

Source data of the study group (143 with acute MI and 239 controls) comes from multiple sources. Elements of the Sgarbossa criteria and Selvester criteria (ST elevation ≥ *10% of* |S|-|R| plus STEMI limits) were tested separately and in combination with the Sgarbossa discordant ST elevation replaced by the 10% rule.

The combined Sgarbossa and Selvester criteria improved the sensitivity to 39%, specificity to 89%, positive likelihood ratio to 3.6 and the negative likelihood ratio to 0.68 compared with 30% sensitivity, 88% specificity, 2.5 positive likelihood ratio and 0.80 negative likelihood ratio with Sgarbossa criteria alone.

1. Introduction

Misinterpretation of admission electrocardiograms (ECG) in the emergency department for patients with suspected acute coronary syndrome (ACS) can lead to delays in treatment [1] or unnecessary coronary catheterization lab activation [2,3]. Left bundle branch block (LBBB) is a major ECG confounder for ST-Elevation Myocardial Infarction (STEMI) diagnosis using ECG. It has potential to cause both types of ECG interpretation errors, false positive driving false positive STEMI diagnosis leading to unnecessary catheterization lab activation or false negative STEMI diagnosis which causes delay in patient intervention. Diagnosing STEMI in the presence of LBBB has been a major challenge to cardiologists and emergency physicians, especially when no serial ECG is available.

Sgarbossa et al. introduced ECG criteria for detecting STEMI in the presence of LBBB [4]. The criteria have been thoroughly studied with conflicting results. The criteria are based on concordant ST-segment elevation, discordant ST elevation and anterior ST depression in leads V1-V3, with points assigned for each criterion. The total score with varied cut points determines STEMI diagnosis [4]. In several studies, the discordant ST elevation criterion has been shown to be less useful than the other two criteria to maintain a high specificity [5-7]. A score of three or greater generated from the Sgarbossa criteria has been commonly used by researchers. Interestingly, this selection effectively eliminates the discordant ST elevation criterion. Most complaints were associated with the low sensitivity of the Sgarbossa criteria.

In the present study, our aim was to improve the sensitivity by adjusting the ECG criteria, and to investigate the utility of a newer ECG criterion for detecting STEMI in LBBB, the Selvester 10% rule [8]. This rule requires ST elevation to be greater than the STEMI threshold plus 10% of |R – S| amplitude. The STEMI threshold for leads V2 and V3 is 200µV and 100µV for all other leads [9].

2. Methods

2.1. Study population

Source data of the study group (143 with acute MI and 239 controls) comes from multiple sources. One source was computer algorithm selected LBBBs (n=209) from patients with suspected ACS. Positive cases had a discharge diagnosis of acute MI (n=100) and the controls had no evidence of acute MI after rule-out (n=109). The second set included acute MI (n=43) and control (n=70) cases with selection criteria similar to the first set from the same hospital emergency department over a different time period. Additional controls were added from the CSE diagnostic set (n=12) and a community based population (n=48) [10,11]. The acute MI cases had to meet STEMI criteria which meant ST-segment elevation of 100µV in 2 or more contiguous leads [9]. Application of the STEMI criteria resulted in exclusion of 29 cases leaving a total test set of 353 cases.

2.2. ECG criteria

The Sgarbossa ECG criteria for detecting STEMI in the presence of LBBB is a scoring system developed from a subset of patients in the GUSTO trial [4]. Figure 1 shows the three ECG criteria which are: (a) concordant ST-segment elevation of 100µV or more (5 points); (b) discordant ST elevation of 500µV or more (2 points) and (c) ST depression of 100µV in leads V1, V2 or V3 (3 points). The three criteria carry a different weight, i.e. assigned points, based on their contribution in Sgarbossa's logistic regression STEMI classifier.

The details of the Selvester 10% rule are shown in Fig. 2. The ST-segment threshold is the sum of the fixed STEMI threshold and a component relative to the R and S-wave amplitudes.

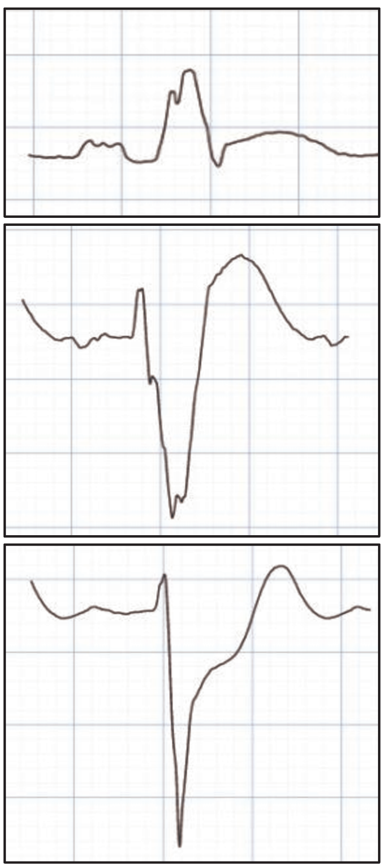

Figure 1. Example QRS-T complexes to illustrate the three Sgarbossa criteria for detection of STEMI in the presence of LBBB. The top panel shows concordant ST-segment elevation greater than 100µV. The middle panel shows discordant ST elevation greater than 500 µV and the bottom panel shows ST depression deeper than 100µV in lead V2.

2.3. Test Method

ECGs were processed retrospectively using the Philips DXL algorithm to select LBBB cases and measure ST level at the J point. Elements of the Sgarbossa criteria (discordant ST elevation of 500µV, concordant ST elevation of 100µV, ST depression in V1-V3) and Selvester criteria (ST elevation ≥ 10% of |S| - |R| plus STEMI limits) were tested separately and in combination. Four algorithms for detection of STEMI in the presence of LBBB were tested, first the Sgarbossa score with a threshold of 2, second the Sgarbossa score with a threshold of 3, third the Sgarbossa criteria with the Sgarbossa discordant ST elevation replaced by the Selvester ST elevation 10% rule and finally, the combination again except that the Selvester 10% rule discordant ST elevation had to be positive for two or more leads rather than a single lead. ECG criteria and algorithm performance were evaluated for sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, also determining their 95% confidence intervals. Diagnostic odds ratio was used as a method to evaluate relative performance of each algorithm by a single number.

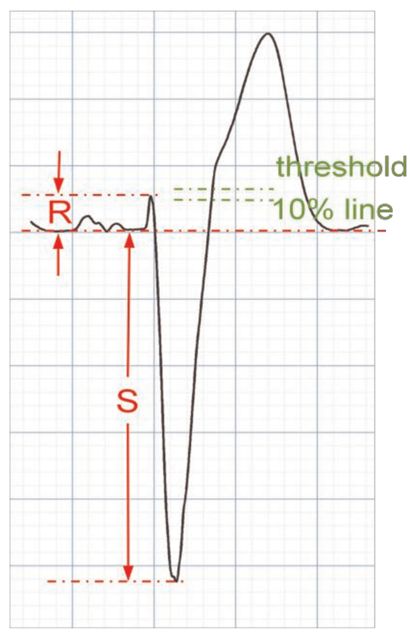

Figure 2. Illustration of the Selvester 10% rule for discordant ST-segment elevation on a single QRS-T complex. The threshold is 100µV + 10% of (|S| - |R|) which in this case equals 100µV + 10% (2600µV – 250µV) = 335 µV.

3. Results

Performance of the individual ECG criteria used in the Sgarbossa score and combined algorithms are given in Table 1. Concordant ST elevation and anterior ST depression (leads V1-V3) both showed high specificity but low sensitivity. The Selvester 10% rule had a higher sensitivity, while maintaining the same 90% specificity as the Sgarbossa discordant ST elevation.

Table 1. Performance of individual ECG criterion for detection of STEMI in LBBB in terms of sensitivity (%), specificity (%), positive likelihood ratio (LR+), negative likelihood ratio (LR-) and diagnostic odds ratio (OR).

ECG criterion	Sens (%)	Spec (%)	LR+	LR-	OR
Discordant STelev. Number leads ≥ 1	22	90	2.3	0.87	2.6
Discordant STelev. Number leads ≥ 2	13	95	2.8	0.91	3.1
Concordant STelev. Number leads ≥ 1	8.7	99	10.4	0.92	11
Anterior STdepr.	5.2	98	2.5	0.97	2.6
10% rule STelev. Number leads ≥ 1	39	90	3.7	0.68	5.5
10% rule STelev. Number leads ≥ 2	25	95	4.6	0.79	5.8

Since the usefulness of the discordant ST elevation criterion has been questioned due to its low specificity, a threshold of two or more leads was tested for discordant ST elevation of 500µV to increase the specificity of the ECG criterion. When the threshold was changed, the sensitivity dropped from 22 to 13% and the specificity increased from 90 to 95%. Similarly, the Selvester 10% rule showed an increase in specificity from 90 to 95% but the sensitivity remained much higher at 25%.

Algorithm performance appears in Table 2. Sgarbossa score≥3 resulted in a low sensitivity (9.6%). By changing to a cut point of score≥2, the sensitivity increased to 29.6% but the specificity dropped from 97.9 to 88.2%. Combined algorithm A using the Selvester 10% rule in place of the Sgarbossa discordant ST elevation increased the sensitivity to 39.1% while also increasing the specificity slightly. The diagnostic odds ratio for the combined algorithm is better than the Sgarbossa algorithm using either threshold. If a higher specificity is desired, combined algorithm B uses concordant ST elevation in one or more leads, Selvester 10% discordant ST elevation in two or more leads or ST depression in any of V1, V2 or V3 resulting in a sensitivity of 26%, specificity of 94%, positive likelihood ratio of 4.1, negative likelihood ratio of 0.8 and a diagnostic odds ratio of 5.3. Both of the combined criteria A and B have a higher odds ratio than the Sgarbossa score at either threshold of 2 or 3.

Table 2. Comparison of Sgarbossa criteria and combined Sgarbossa and 10% rule by sensitivity, specificity, positive likelihood ratio, negative likelihood ratio and their 95% confidence intervals. [a]The difference in sensitivity between combined algorithm A and the Sgarbossa criteria (9.6%) is significantly higher by 95% confidence interval (2.5-17%). [bc]Selected differences in specificity are statistically significant.

Algorithm	Sens (%)	Spec (%)	LR+	LR-	OR
Sgarbossa score≥2	29.6[a] 22–39	88.2[b] 84–92	2.5 1.6-3.9	0.80 0.7-0.9	3.2
Sgarbossa score≥3	9.6 5–16	97.9[c] 95–99	4.6 1.6-13	0.92 0.9-1.0	4.9
Combined criteria A	39.1[a] 31–48	89.1 85–92	3.6 2.3-5.5	0.68 0.6-0.8	5.2
Combined criteria B	26.1 19-35	93.7[bc] 90-96	4.1 2.3-7.4	0.80 0.7-0.9	5.3

4. Discussion

A careful evaluation of the criteria reveals that the Selvester 10% rule and the combined 10% rule and Sgarbossa criteria differ only with respect to Sgarbossa anterior ST depression criterion. The 10% rule applies to both concordant and discordant ST elevation. The anterior ST depression criterion does not make an appreciable difference in the test results, but this is no surprise because only ECGs passing STEMI criteria were included in the test set. When the 29 cases excluded due to requiring two continuous leads of ST elevation were instead included in the test set, the anterior ST depression criterion did lead to a slight improvement in sensitivity from 33.3% to 35.4%. This supports our recommendation for retaining the anterior ST depression criterion in the algorithm even though it does not lead to an improvement in the test set as defined in the present study.

Exact definition of concordant and discordant with relation to the ST level and QRS polarity were not discussed in Sgarbossa's paper [4]. For most QRST complexes, concordant or discordant ST elevation is quite clear. On the other hand, there are cases with ST elevation and QRS complexes with nearly equal R and S-wave amplitudes. In those cases, concordance and discordance is ill-defined. We decided to define ST elevation as concordant when R-wave amplitude was at least twice the amplitude of the Q or S-wave. ST elevation was defined as discordant when the Q or S wave was at least twice the amplitude of the tallest R-wave. This strategy results in a trade off of higher specificity and lower sensitivity. With a loose definition of concordant and discordant ST elevation, R/S ratio greater than one (concordant) or less than one (discordant), the algorithm performance changed according to the results in Table 3. There was no change for the discordant ST elevation criterion. As expected, the sensitivity increased while the specificity decreased. Note that the odds ratio did not improve, meaning that the use of the loose definition of concordance and discordance does not result in an improved algorithm just a sensitivity/specificity trade-off and a very small increase in sensitivity at that.

Table 3. Performance of the concordant ST elevation ECG criterion for detection of STEMI in LBBB comparing a loose and tight definition for "concordant" and "discordant" ST deviation.

ECG criterion	Sens (%)	Spec (%)	LR+	LR-	OR
Concordant STelev.	9	99	10	0.92	11
Concordant STelev. Loose definition	11	98	4.5	0.91	4.9

The limitations of the present study are mainly due to the retrospective ECG collection. Subsets from different patient populations were combined to arrive at a larger test set size on the order of that in other studies [8]. Since the threshold values were not determined by this study, there was no need for separate test and training sets.

5. Conclusion

Several studies have come to the conclusion that the best threshold for the Sgarbossa score is greater than or equal to 3. The weakness of the Sgarbossa score is in the discordant ST elevation criterion with an absolute limit of ST elevation which results in more false positives. In our combined algorithm, the discordant ST elevation definition was modified so that the threshold is no longer a fixed limit of 500μV, but the regular STEMI thresholds plus 10% of |S|-|R|. With this change from an absolute threshold value to a relative threshold value, performance of the new algorithm improved sensitivity by 10% from 29 to 39% while maintaining the specificity. In fact, the odds ratios show that the new combined algorithm is an improvement over the Sgarbossa score with a threshold of 2 or 3.

If ECG criteria with higher specificity are desired, combined algorithm B with positive Selvester 10% rule discordant ST elevation in two or more leads compares favorably to the Sgarbossa score with a threshold of 3. The sensitivity is higher while maintaining equivalent specificity.

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