Evaluating Enhancing the Acute Myocardial Infarction Criteria in the Glasgow Electrocardiogram Analysis Program by Including ST Depression

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Abstract

The aims of this study were to investigate if the acute myocardial infarction (MI) criteria in the University of Glasgow ECG analysis program (Uni-G) could be enhanced by including new lead pairings and to explore alternative criteria based on STEMI equivalence.

912 12-lead ECGs were recorded in ambulances on patients with a suspected acute coronary syndrome. The ACC/ESC and the Uni-G criteria were modified to include pairings {III,-aVL}, {-III,aVL}, and {-V2,-V3}.

Using the hospital discharge diagnosis as the gold standard, the modified criteria were evaluated. Significant changes in sensitivity (SE) and specificity (SP) were evident using the modified ACC/ESC criteria: SE from 72.1% to 75.4% (p=0.002); SP from 88.1% to 86.6% (p=0.004). The current Uni-G criteria gave better results than the modified ACC/ESC criteria (SE 77.6% and SP 93.9%.). All attempts at extending the Uni-G criteria resulted in a decrease in SP.

1. Introduction

The accurate diagnosis of ST elevation myocardial infarction (STEMI) is of critical importance when determining the treatment of patients presenting with suspected acute coronary syndrome (ACS) [1]. The criteria for STEMI as defined by the American College of Cardiology (ACC) and the European Society of Cardiology (ESC) et al use ST elevation in two contiguous leads from the standard 12-lead electrocardiogram (ECG) [2,3]. There has been concern that the sensitivity of the ACC/ESC criteria is low. Various efforts have been made to enhance the criteria and, indeed, in the University of Glasgow ECG analysis program (Uni-G) [4], extending the ACC/ESC criteria by incorporating age and sex dependent criteria has resulted in improved performance [5].

A criticism of the 12-lead ECG is that it does not give enough information on some areas of the heart – in particular of the postero-lateral wall. Additional lead placements have been investigated [6]. Other investigators have looked at the possibility of using the basic 9 standard electrode positions to produce a 24-lead ECG [7,8], which, in addition to the standard 12 leads, includes a further 12 leads obtained by inverting the standard 12 leads. Modified ACC/ESC criteria using new lead pairings have been tested on small populations and it has been found that the sensitivity of the STEMI diagnosis improved [9, 10]. In particular, Wang et al [10] found that, by adding 3 new pairings of contiguous leads, the sensitivity improved without loss of specificity on a population of 116 patients. The authors of these two studies recommended that the extended criteria should be tested on larger populations of patients with suspected ACS.

The main aim of the present study was to evaluate the effect of extending the ACC/ESC criteria to include the new lead pairings (aVL,-III; -aVL,III and -V2,-V3) on a data set of 912 pre-hospital ECGs. The second aim was to evaluate extending the age and sex dependent STEMI criteria used in the Uni-G program in the same way. The third aim was to explore alternative potential enhancements to the Uni-G program criteria based on using ST depression, i.e. using STEMI equivalence.

2. Methods

912 prehospital ECGs recorded in ambulances were obtained from patients with suspected ACS in Zealand, Denmark. The method of collection of data and the use of the discharge diagnosis as the gold-standard for the presence of STEMI have previously been described [11]. 406 ECGs were randomly allocated to a training set and 506 to a test set. The purpose of these sets was to allow development of new enhancements to the STEMI criteria using the training set and objective evaluation using the test set. The training set consisted of 274 males and 132 females, mean age 65.4±13.2 years. The test set consisted of 327 males and 179 females, mean age 65.4±14.4 years.

The training set was run using both the ACC/ESC criteria and the Uni-G program criteria. Sensitivity (SE) and specificity (SP) values were obtained. The ACC/ESC criteria were interpreted as ST ≥ a threshold in any two contiguous leads in the limb leads aVL, I, -aVR, II, aVF, III or in chest leads V1 to V6. The ACC/ESC criteria

from 2000 [2] and 2007 [3] were both evaluated. The former uses a threshold of 0.2mV in leads V1, V2, V3 and 0.1mV in all other leads. The latter uses a threshold of 0.2mV in men and 0.15mV in women in leads V2 and V3 and 0.1mV in all other leads. The Uni-G program uses continuous equations to set the upper limits of normal ST amplitudes depending on age and gender [4]. There are therefore two different equations for each lead.

All sets of criteria were modified to include checking for ST elevation greater than or equal to 0.1mV in extra paired leads {III,-aVL}, {-III,aVL} and {-V2,-V3}, with corresponding horizontal or up-sloping ST segment. ECGs that were diagnosed as Left Bundle Branch Block (LBBB) were not classified as STEMI equivalent. ECGs that satisfied the criteria in the pairs {III,-aVL} or {-V2,-V3} that were also diagnosed as Right Bundle Branch Block (RBBB) were not classified as STEMI equivalent.

The 406 ECGs were re-analysed using these modified criteria and the corresponding SEs and SPs noted. The effect of reducing the threshold for {-V2,-V3} to 0.05mV as in the guidelines for STEMI [2] was measured.

The amplitude at the J point for each of the standard 12 leads, as measured by the program, was output to a spreadsheet. Visual inspection of these amplitudes was used to identify ECGs that displayed STEMI equivalence, and to develop new criteria.

Different criteria for marked ST depression were evaluated on the training set. If the criteria were met and there was no relevant conduction defect, then one of two statements was output, e.g. "Marked anteroseptal ST depression, CONSIDER ACUTE INFARCT" or "Marked anteroseptal ST depression accompanies the infarct". The latter statement was printed if an acute ST elevation infarct was detected in another wall. The set of criteria that gave the best results against the final diagnosis was selected and then evaluated on the test set.

Finally, the SEs and SPs with and without the new pairings for ACC/ESC criteria and the Uni-G program were obtained for the complete set of 912 ECGs.

The SE and SP values were compared using McNemar's test. The statistical package used was SPSS (version 15; SPSS Inc, Chicago, Illinois). The level of significance was set at $p < 0.05$.

3. Results

For the training set, adding the new pairings to the 2000 ACC/ESC criteria resulted in a significant change of SE from 66.4% to 70.6% (p=0.031) and an insignificant change in SP from 89% to 87% (p=0.063). The SEs and SPs for each of the additional pairings and for the combination of the 3 new pairings are given in Table 1.

Table 1. SEs and SPs for new pairings based on the training set.

	ACC /ESC	With -V2 -V3	With -III aVL	With III -aVL	With 3 new pairings
SE(%)	66.4	67.8	67.8	69.2	70.6
SP(%)	89	88.5	89	87.5	87

Modifying the threshold for -V2 and -V3 to be 0.05mV improved SE to 73.4%, but SP decreased to 85.9%.

Adding the new pairings to the 2007 ACC/ESC criteria resulted in an insignificant change of SE from 69.2% to 72.7% (p=0.063) and SP from 85.6% to 83.7% (p=0.063). It was decided to use the 2000 criteria for the rest of the analysis as the specificity was higher than for the 2007 criteria and as these criteria were used by Martin et al [9].

The criteria in the Uni-G program already included the pairing {III, -aVL}. The criteria were extended for the other 2 new pairings. The results for the training set were not statistically significant. SE changed from 74.8% to 75.5%, and SP changed from 93.9% to 93.5%.

For the complete dataset, adding the new pairings to the ACC/ESC criteria gave statistically significant changes. There was an increase in SE and decrease in SP (Table 2).

Table 2. SEs and SPs for ACC/ESC 2000 criteria plus new pairings for the complete set of 912 cases.

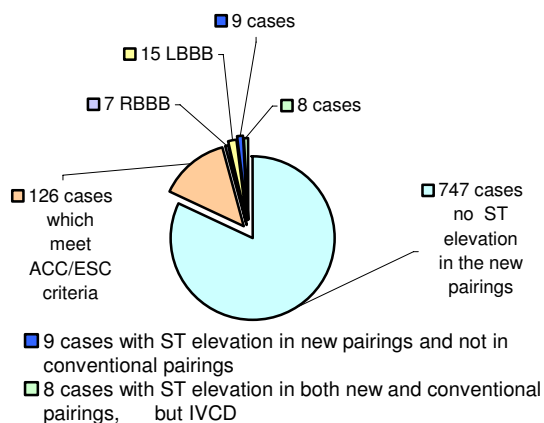|	ACC/ESC	ACC/ESC with new pairings	P value
SE(%)	72.1	75.4	0.002
SP(%)	88.1	86.6	0.004

Adding the two pairings {-III, aVL} and {-V2, -V3} to the criteria in the Uni-G program did not result in significant results (Table 3).

Table 3. SEs and SPs for Uni-G program plus new pairings for the complete set of 912 cases.

	Uni-G	Uni-G with new pairings	P value
SE(%)	77.6	78.3	0.5
SP(%)	93.9	93.2	0.125

Out of the 912 cases in the data set, there were only 17 which met the STEMI equivalence criteria in the new pairings but which did not meet the ACC/ESC ST elevation criteria and which were not diagnosed as LBBB or RBBB (Figure 1). 8 of these 17 had ST elevation levels reaching the ACC/ESC limits but also exhibited an intraventricular conduction defect. So only 9/912 cases met the STEMI equivalence criteria and did not meet ACC/ESC ST elevation criteria.

Figure 1. Representation of proportions of cases with ST elevation in the new pairings.

■ 9 cases with ST elevation in new pairings and not in conventional pairings
■ 8 cases with ST elevation in both new and conventional pairings, but IVCD

Different criteria for marked anteroseptal, inferior and lateral ST depression were evaluated on the training set. The presence of a "Marked ST depression, CONSIDER ACUTE INFARCT" statement was used to indicate STEMI equivalence MI. The best result obtained was 3 more true positive results. SE increased from 74.8% to 76.9% (p=0.25) with no change to SP (93.9%). However, evaluating the criteria for the test set gave one more false positive result. So for the test set, SE was unchanged (80.1%) and SP decreased from 93.2% to 92.9% (p=0.25).

The following figures 2 and 3 show ECGs with marked ST depression as well as ST elevation. In the tracing shown in figure 2, when using the new marked ST depression criteria, inferior ST depression is reported. ST elevation in leads –III and aVL is evident but the ST elevation in lead aVL was measured as 92 microvolts and so below the required threshold for the new pairings. In the tracing in figure 3, a STEMI was reported by the Uni-G program due to the ST elevation in leads I and aVL. The new ST depression criteria result in an additional report of marked ST depression in the anteroseptal leads.

Figure 2 This ECG was reported as septal infarct. There is

also marked inferior ST depression.. The patient was sent for primary percutaneous coronary intervention, and the discharge diagnosis was STEMI.
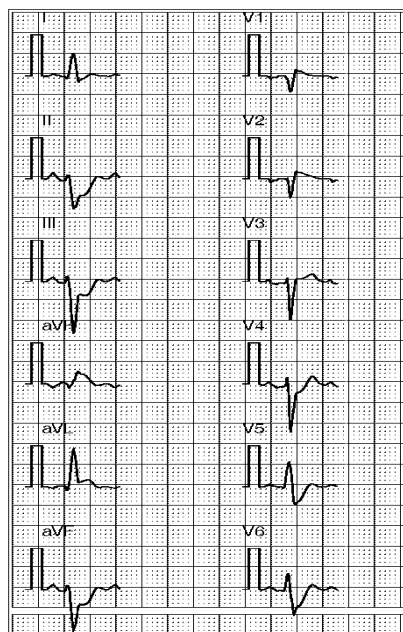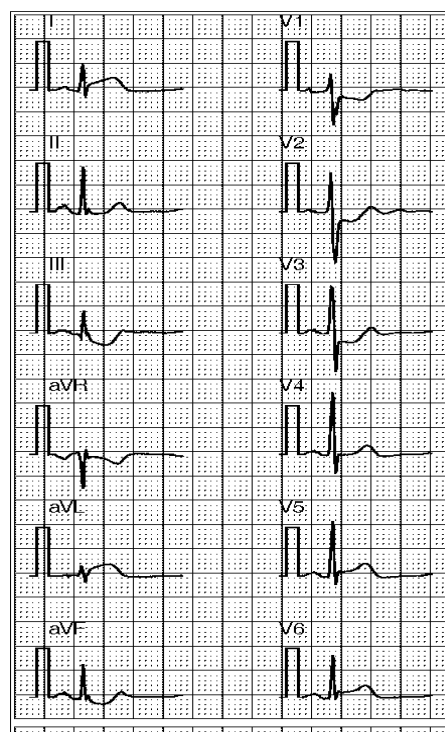

Figure 3. An example of ST depression in leads V1-V3 accompanying ST elevation in the lateral leads. The automated report was lateral infarct. The patient was admitted to a local hospital and later transferred for pPCI.

4. Discussion

In this study of 912 patients, the use of the new lead pairings gave a small but significant improvement in SE when using the ACC/ESC 2000 criteria along with a significant decrease in SP. We did not observe the same degree of improvement in detection of STEMI that had been found in previous studies when STEMI equivalence criteria had been used. This may be due to a number of factors, e.g. different populations, both in size and location, and different settings. One major difference between this study and that by Martin et al [9] is in the method used to determine if a STEMI had occurred. In our study, we used the discharge diagnosis as the gold standard. Martin et al used contrast enhanced MRI, and the presence of delayed hyperenhancement as evidence of infarction.

A factor to be considered when interpreting the results is that the physicians who were reading the ambulance ECGs were most likely using the 2000 guidelines for detection of a STEMI to determine which patients should be admitted for pPCI. They were not using STEMI equivalence in their criteria.

However, the main observation was that there was little evidence of ECGs with STEMI equivalence only. Less than 0.02% of ECGs met that criterion. The different findings may be due to the timing of the ECG, i.e. in our study the pre-hospital ECG was used and in the study by Martin et al [9] the admission ECG was used. Another possible explanation is that, in the latter study, there was a significantly longer delay from time of symptom onset until the initial ECG in the group showing STEMI equivalence than in the group with ST elevation. The time from symptom onset was not available in our study.

Reciprocal ST segment depression is said to be a highly sensitive indicator of acute MI [12] and it was considered worthwhile to modify the Uni-G program criteria for reporting ST depression both stand-alone and reciprocal to an acute infarct in another site to improve the quality of the reporting. This is in accordance with the possibility considered by Gettes of modifying algorithms and statements to recognize ECG changes related to transmural ischemia [13].

5. Conclusion

The current Uni-G program gave better results in this study than the expanded ACC/ESC criteria. All attempts at extending the Uni-G criteria resulted in a decrease in SP. It may not be possible to greatly improve the diagnosis of STEMI using the 12 lead ECG and hence it may be necessary to record additional leads to obtain a more comprehensive view.

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