# Effect of Age and Gender on Diagnostic Accuracy of ECG Diagnosis of Acute Myocardial Infarction

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## Abstract

*Recently published ACC/ESC criteria for acute MI were not age and gender dependent. The aim of this study was to modify the criteria by incorporating age and gender based limits of ST amplitude, together with other ST-T measures, and to assess the effect on sensitivity etc.*

*A database of 789 ECGs from patients presenting with acute chest pain was used to develop criteria along with 1498 ECGs from normal individuals whose ECGs were used to control specificity. A third database of 1220 ECGs was also available as a test set.*

*The sensitivity of the new criteria increased from 41.5% to 46.8% while specificity improved from 96% to 98.5%. Similar improvements were seen for males and females. With respect to age, specificity improved in all deciles. Sensitivity decreased slightly in the middle deciles but improved dramatically for the remainder.*

*Age and gender based criteria markedly improved sensitivity and specificity of ECG criteria for acute MI.*

## 1. Introduction

One of the earliest classical signs of acute myocardial infarction is ST elevation on an electrocardiogram (ECG). Sometimes this can be extremely marked so that the diagnosis of an acute ischaemic change is straightforward. At other times, any increase in the ST segment amplitude is less marked, making the electrocardiographic diagnosis of ST elevation difficult in the event that the morphology of the ST-T waves is still relatively normal. It may well be that the clinical picture is more clear cut but nevertheless there is a requirement to provide diagnostic criteria for ECG analysis by computer which tries to optimise the reporting of abnormal ST elevation while maintaining a high specificity.

With this in mind, it was felt appropriate to develop diagnostic criteria which are both age and gender dependent as it is well known that ST amplitudes for example are one component of ECG waveforms which are clearly related to such constitutional variables [1].

On the other hand, the American College of Cardiology jointly with the European Society of Cardiology (ACC/ESC) introduced new criteria for acute myocardial infarction [2]. Basically these criteria provided a single threshold (STj > 0.2 mV) for abnormal ST elevation in V1-V3 and another single threshold (STj > 0.1mV) for the remaining nine leads. It was felt that it would be important to adjust the criteria to make them age and gender dependent and thereafter to assess the effect on a test population.

## 2. Methods

ECGs were available from 1498 apparently healthy adults aged from 18-78 years. Full details of this population are available in a separate publication [3]. These ECGs were used to develop age and gender related upper limits of normal ST amplitude based on measurements at the J point, i.e. the end of the QRS complex. This population was also used in the estimation of normal limits of other measurements such as ST/T and indeed $S/ST$ ratios. All measurements were obtained using the Glasgow program [4].

A database of 789 ECGs recorded from patients presenting with acute chest pain to the Accident and Emergency Department in Glasgow Royal Infirmary was also available for the development of diagnostic criteria. All patients were classified into one of three categories namely acute myocardial infarction, stable or unstable angina and finally non-cardiac chest pain. Details of this group are also available elsewhere [5].

Separately, a third database of 1220 ECGs recorded from patients presenting with acute chest pain to an American hospital was also available as a test set. These patients had a classification of acute myocardial infarction or not.

He modified ACC/ESC criteria were incorporated into the Glasgow program [4], which was then used to analyse the test set. The original ACC/ESC criteria were also assessed by a routine specially written for this purpose.

## 3.     Results

A typical equation for the upper limit of normal in males, in this case in Lead I, is as follows:

Upper Limit of Normal STj (I) = (-0.667 Age + 93.3) μV where age is in years.

It was found that the upper limit of normal ST amplitude in females, while completely different from that in males, was not age dependent. Some further details on upper limits of normal are available elsewhere [1].

There were 754 males aged from 31 to 95 years in the test set together with 466 females aged from 19 to 106 years.   Of these, 248 (20.3%) had an acute myocardial infarction.   75 were female and 173 were male.  Table 1 shows in more detail the distribution by age in decades of those with and without myocardial infarction.    Table 2 shows the distribution by gender.    It can be seen that there is a predominance of acute myocardial infarction in males while the percentage of infarcts by decade is approximately constant at 20% from age 40 onwards. The maximum number of infarcts in this data set was in the decade of 70 to 79 years of age.

Table 1.     Distribution of MI in the test set by age, grouped into decades (decade 75 is the age group from 70 to 79, for example).   The percentages are by row so that, for example, people in their 50's were distributed 76.6% non-AMI and 23.4% AMI.

| Age (Decade) | No AMI(%) | AMI (%) | N |
|---|---|---|---|
| 15 | 100.000 | 0.000 | 1 |
| 25 | 100.000 | 0.000 | 7 |
| 35 | 91.892 | 8.108 | 37 |
| 45 | 78.632 | 21.368 | 117 |
| 55 | 76.571 | 23.429 | 175 |
| 65 | 79.125 | 20.875 | 297 |
| 75 | 81.694 | 18.306 | 366 |
| 85 | 77.083 | 22.917 | 192 |
| 95 | 77.778 | 22.222 | 27 |
| 105 | 100.000 | 0.000 | 1 |
| Total | 79.672 | 20.328 | |
| N | 972 | 248 | 1220 |

In general, the sensitivity of the new criteria increased to 46.8% compared to 41.5% using the old criteria. Similarly, specificity improved from 96% to 98.5%. Corresponding figures for males were 40.5% to 45.7% for sensitivity and 96.4% to 98.8% for specificity (Table 3). For females the data showed an improvement in sensitivity from 44% to 49.3% and in specificity from 95.4% to 98%. (Table 3).

Table 2.   Distribution of MI in the test set by gender.

| Sex | No AMI (%) | AMI (%) | Total (%) | N |
|---|---|---|---|---|
| Female | 40.226 | 30.242 | 38.197 | 466 |
| Male | 59.774 | 69.758 | 61.803 | 754 |
| N | 972 | 248 | | 1220 |

With respect to age, specificity improved in all deciles from 30 upwards, there being no MIs below this age range.   On the other hand, sensitivity decreased slightly in the 40 to 49 and 50 to 59 age ranges but improved dramatically in the other bands.  (Table 4).

Table 3.  Distribution of results by gender

| | Sensitivity % | | Specificity % | |
|---|---|---|---|---|
| | Glasgow | ACC/ESC | Glasgow | ACC/ESC |
| Males | 45.7 | 40.5 | 98.8 | 96.4 |
| Females | 49.3 | 44.0 | 98.0 | 95.4 |
| Total | 46.8 | 41.5 | 98.5 | 96.0 |

Table 4.   The sensitivity and specificity of the new (Glasgow) criteria compared to the ACC/ESC criteria with respect to deciles of age.

| | Sensitivity % | | Specificity % | |
|---|---|---|---|---|
| Decade | Glasgow | ACC/ESC | Glasgow | ACC/ESC |
| 10-19 | | | 100 | 100 |
| 20-29 | | | 100 | 100 |
| 30-39 | 100.0 | 97.1 | 100 | 33.3 |
| 40-49 | 40.0 | 48.0 | 98.9 | 94.6 |
| 50-59 | 39.0 | 48.8 | 99.3 | 96.2 |
| 60-69 | 58 | 45.1 | 97.4 | 99.4 |
| 70-79 | 49.3 | 37.3 | 98.0 | 94.6 |
| 80-89 | 38.6 | 36.3 | 99.3 | 97.3 |
| 90-99 | 33.3 | 16.7 | 100.0 | 90.5 |
| 100 + | | | 100 | 100 |

## 4.     Discussion and conclusions

The results demonstrate quite clearly that the use of age and gender based criteria can improve sensitivity and specificity of diagnosing myocardial infarction.   While
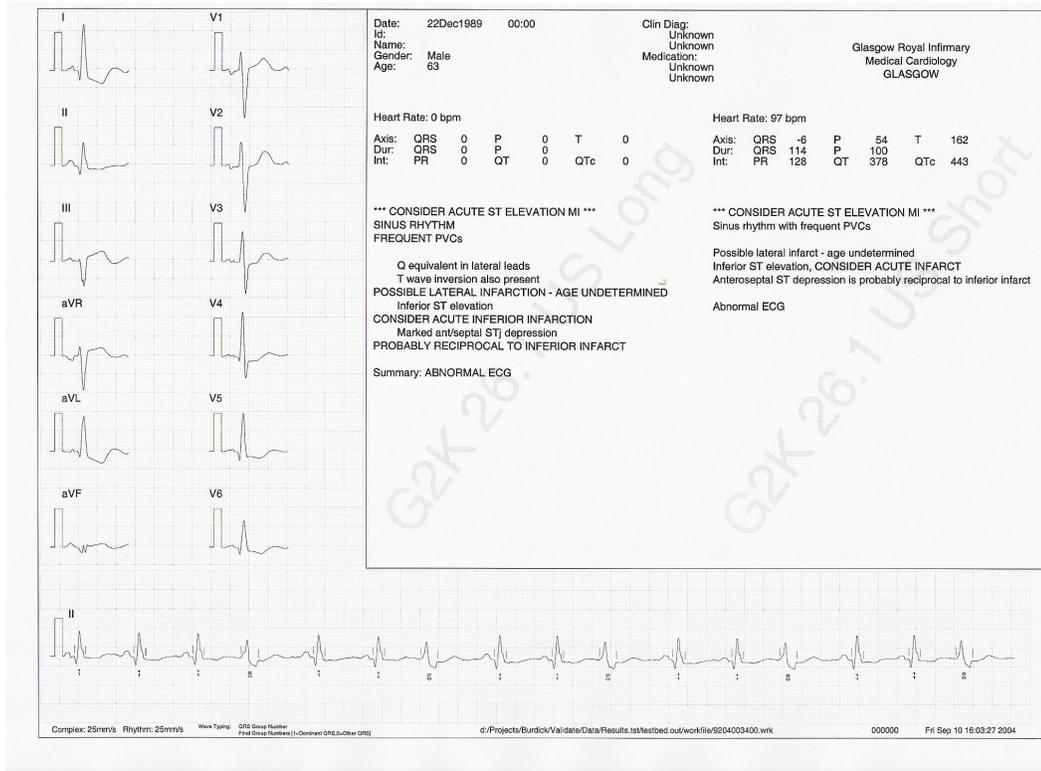
Figure 1. See text for further explanation.

Date: 22Dec1989 00:00
Id:
Name:
Gender: Male
Age: 63

Clin Diag:
Unknown
Unknown
Medication:
Unknown
Unknown

Glasgow Royal Infirmary
Medical Cardiology
GLASGOW

Heart Rate: 0 bpm

| Axis: | QRS | 0 | P | 0 | T | 0 |
|---|---|---|---|---|---|---|
| Dur: | QRS | 0 | P | 0 | | |
| Int: | PR | 0 | QT | 0 | QTc | 0 |

Heart Rate: 97 bpm

| Axis: | QRS | -6 | P | 54 | T | 162 |
|---|---|---|---|---|---|---|
| Dur: | QRS | 114 | P | 100 | | |
| Int: | PR | 128 | QT | 378 | QTc | 443 |

*** CONSIDER ACUTE ST ELEVATION MI ***
SINUS RHYTHM
FREQUENT PVCs

Q equivalent in lateral leads
T wave inversion also present
POSSIBLE LATERAL INFARCTION - AGE UNDETERMINED
Inferior ST elevation
CONSIDER ACUTE INFERIOR INFARCTION
Marked ant/septal STj depression
PROBABLY RECIPROCAL TO INFERIOR INFARCT

Summary: ABNORMAL ECG

*** CONSIDER ACUTE ST ELEVATION MI ***
Sinus rhythm with frequent PVCs

Possible lateral infarct - age undetermined
Inferior ST elevation, CONSIDER ACUTE INFARCT
Anteroseptal ST depression is probably reciprocal to inferior infarct

Abnormal ECG

Complex: 25mm/s  Rhythm: 25mm/s   Wave Typing:  QRS Group Number  Final Group Numbers [1=Dominant QRS,0=Other QRS]   d:/Projects/Burdick/Validate/Data/Results.tst/testbed.out/workfile/9204003400.wrk   000000   Fri Sep 10 16:03:27 2004



Figure 2. See text for further explanation.

Date: 22Dec1989 00:00
Id:
Name:
Gender: Male
Age: 48

Clin Diag:
Unknown
Unknown
Medication:
Unknown
Unknown

Glasgow Royal Infirmary
Medical Cardiology
GLASGOW

Heart Rate: 0 bpm

| Axis: | QRS | 0 | P | 0 | T | 0 |
|---|---|---|---|---|---|---|
| Dur: | QRS | 0 | P | 0 | | |
| Int: | PR | 0 | QT | 0 | QTc | 0 |

Heart Rate: 65 bpm

| Axis: | QRS | 12 | P | 30 | T | 47 |
|---|---|---|---|---|---|---|
| Dur: | QRS | 88 | P | 110 | | |
| Int: | PR | 130 | QT | 428 | QTc | 437 |

SINUS RHYTHM

WITHIN NORMAL LIMITS

Summary: NORMAL ECG

Sinus rhythm

Normal ECG

Complex: 25mm/s  Rhythm: 25mm/s   Wave Typing:  QRS Group Number  Final Group Numbers [1=Dominant QRS,0=Other QRS]   d:/Projects/Burdick/Validate/Data/Results.tst/testbed.out/workfile/9003005400.wrk   000000   Fri Sep 10 16:03:21 2004

the absolute increase in each was modest, the relative increase in some cases was substantial e.g. a 13%increase in absolute terms in sensitivity in the 60 to 70 age group actually represents a 29% relative increase in sensitivity.

In the youngest decade with the presence of a myocardial infarction, i.e. age 30-39, the sensitivity of the Glasgow Program was 100% compared to 33% using the ACC/ESC criteria. The absolute numbers of myocardial infarction were exceptionally small in this decile, there being only three cases.

Although the sensitivity was slightly less for the revised criteria in the age range 40 to 60 compared to the ACC/ESC criteria, the specificity was considerably higher at approximately 99% compared to an average of a little over 95% for the unmodified criteria. This is hugely important in terms of correct administration of thrombolytic therapy.

Figure 1 provides an example where the revised criteria result in a diagnosis of acute ST elevation myocardial infarction but the original ACC/ESC criteria do not. This is due to the fact that ST elevation does not exceed 0.1 mV in two contiguous inferior leads. Figure 1 also illustrates two types of diagnostic statement produced by the Glasgow Program in this research format output. The left hand column provides reasons together with diagnostic statements and is suited to the family practitioner environment. The right hand column with the short form version of the statements is more suited for hospital use.

Figure 2 provides an illustration where the ACC/ESC criteria are falsely positive. This follows from ST elevation exceeding the appropriate thresholds in V3 and V4. The ST-T morphology is certainly not suggestive of an acute myocardial infarction and the Glasgow Program does not report abnormal ST elevation on the basis of the new criteria.

It was also reassuring to find that the gender dependent criteria performed better in both males and females compared to the original ACC/ESC criteria. It would have been disappointing if the results had been otherwise given the significant alterations made to the original criteria.

There is no doubt that the simplicity of the ACC/ESC criteria have much to commend them particularly for visual application. However, there is a fundamental flaw in applying the same criteria to V1 as for V2 and V3. For visual interpretation in any revision of the ACC/ESC criteria, at least V1 should be given the same threshold of 0.1 mV as for V4-V6 and the limb leads.

On the other hand, for computer application, there is no reason why the more complex age and gender based criteria incorporating additional measures compared to the single ST amplitudes used by the ACC/ESC criteria should not be utilised.

It is therefore relevant to conclude by indicating that the new criteria have been incorporated into the latest version of the Glasgow Program for automated ECG interpretation.

## References

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