Comparison between Man and Machine in the Case of Acute Coronary Syndrome and Acute Myocardial Infarction Detection in a Chest Pain Cohort in the Emergency Department

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Abstract

Acute myocardial infarction is a major cause of death and disability. Its rapid and reliable diagnosis is a major clinical need. The electrocardiogram and the measurement of myocardial enzymes are among others two important diagnostic methodologies to decide further management of chest pain patient after their presentation at the emergency department each having its strengths and drawbacks (e.g. detection accuracy versus time needed until possible decision). We wanted to know if it is with today's current technology possible to replace the human decision blinded to clinical information after the patient's initial presentation at the emergency department by an automatic diagnosis only based on one single electrocardiogram. We compared both decision results against an independent reference based on all clinically acquired parameters including a patient follow-up.

1. Introduction

When a patient shows up at the emergency department (ED) with chest pain symptoms, one possible diagnosis is acute coronary syndrome (ACS). If the patient's diagnosis is an acute myocardial infarction (AMI), further treatment should be fast in order to safe as much viable myocardial muscle mass preventing additional disabilities. This is known as the "time is muscle" paradigm. The diagnosis is today based on myocardial enzymes being the most accurate decision markers unfortunately taking time until their blood concentration matches current guidelines [1]. Therefore, the patient's corresponding treatment may be delayed as today's patient arrived earlier at the emergency department due to better general people's knowledge about ACS/AMI and the improved current (para-)medical possibilities.

One way of improvement would be to find faster (i.e. more sensitive) cardiac enzymes [2]. Other way would be an accurate automatic detection based on the electrocardiogram which instantaneously shows corresponding electrical signs of AMI in contrast to myocardial enzymes which first have to diffuse in the patient's blood. The device decision is independent of the day, the ECG acquisition time and many other influencing parameters. We therefore raise the question if (i.e. hypothesize that) today's technology is able to replace the human decision at the ED both being blind to any clinically information acquired after the patient's primary presence at the ED.

2. Materials and methods

2.1. Population study

We included patients presenting symptoms of chest pain and angina that where suggestive of an ACS at the ED of the university hospital of Basel, Switzerland and in whom the onset of the peak of symptoms had occurred within 12 hours before presentation. All patients had to agree participating to the ongoing prospective study called APACE. We included 799 patients, where the first 400 patients were selected for the training set of the automatic detection algorithm.

All relevant patient data
Anamnesis performed at emergency department
Pain description such as location, amplitude, peak etc.
Diagnostic measurements at ED such as blood pressure, cardiopulmonary examination etc.
Cardiac proteins @ 1,2,3 and 6h
10s resting and exercise ECG including morphological description and measurement parameters
Findings of coronary angiography and possible interventions
Description of performed bypass surgery
Follow-up including death, AMI, PCI, PTA
GS / Reference defined by two independent cardiologists

Table 1. Clinical measurement parameters/subtypes.

2.2. Clinical assessment and reference

All patients underwent an initial clinical assessment that included a clinical history taking, a physical examination, 12-lead ECG, continuous ECG monitoring, pulse oximetry, standard blood measurements, and chest radiography. Cardiac troponin I or T, CK-MB, and myoglobin were measured at the presentation and 6 to 9 hours after presentation of as long as clinically needed (Tab. 1).

To determine the final diagnosis (reference, "gold standard") for each patient, two independent cardiologists reviewed all available medical records including a 60 day follow-up period. The references were defined as AMI, unstable angina pectoris, cardiac (non-coronary), cardiac (unkown) and non-cardiac as described in more detail in [2].

2.3. Comparison between man and machine

The 10 second, resting electrocardiogram (ECG) taken at the ED was acquired using an AT-110 (SCHILLER AG, Switzerland). Standard 12-lead recording was performed with a signal resolution of 5μV/bit and a sampling rate of 500Hz. The analysed diagnostic signal bandwidth was at least 0.05Hz up to 150Hz according to current device standards.

The recordings separated in a training (first 400 ECGs) and a test set (second 399 ECGs) were analysed by three different algorithms. The first algorithm reflects the current ACC/ESC guidelines for detection of AMI [3]. The second was improved using the training set including additional adding features such as limitation of ST/T ratio, restrictions on R and/or S-range, ST-depression and single-lead criteria [4]. The third algorithm was designed in order to match man's detection performance by adjusting the detection threshold (i.e. moving the receiver operator curve point along the detection line). The algorithm had knowledge of age, sex, height, weight, blood pressure whenever the data was plug into the device and the 12 leads of the 10 second ECG as described above. In contract, the deciding cardiologist had all primary clinical information available at time the ECG was performed at the ED including the resting ECG, but was blind to all further acquired data such as later arriving results of cardiac enzymes.

We performed one tail statistical significances test of the detection performance of man and machine based on the clinical reference of ACS and AMI using a significance level of α=0.05. The null hypothesis was defined as no significant difference between man and machine ($\theta = \theta_0$), the alternative hypothesises were defined as either man was better than machine ($\theta < \theta_0$) or machine was better than man ($\theta > \theta_0$).

3. Results

Out of 799 patients, 29 presented left bundle branch block, 53 right bundle branch block and 15 had a pacemaker, which were excluded from the statistics. 266 patients had an acute coronary syndrome (141 part of the training set) thereof 129 patients were diagnosed with an AMI, Fig. 1, (70 part of the training set). Thereof 32 had an ST-elevation myocardial infarction (25 part of the training set).

In the case of AMI as gold standard, we found an optimal detection level of ST-segment elevation of 100μV with an age dependency for precordial leads (Tab.1). The sensitivity was 13% ($p<0.001$, $\theta<\theta 0$), the specificity 98% ($p<0.001$, $\theta>\theta 0$) in the training set, and 5% ($p<0.001$, $\theta<\theta 0$) and 99% ($p<0.001$, $\theta>\theta_0$) in the test set using the ACC/ESC guidelines and a significance level of a=0.01.

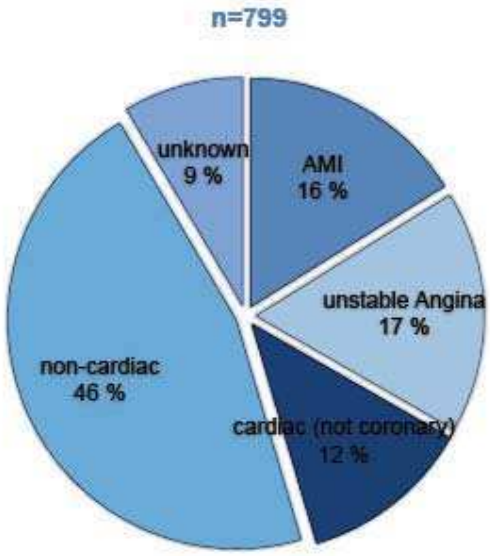

Figure 1. The distribution of patients' reference diagnosis (n=799).

By lowering this threshold and adding features such as limitation of ST/T ratio, restrictions on R and/or S-range, ST-depression and single-lead criteria, the sensitivity can be improved while keeping a high level of specificity. In this case, the designed algorithm has a detection performance of 34% ($p<0.001$, $\theta < \theta_0$) and 99% ($p<0.001$, $\theta > \theta_0$) in the training set and 7% ($p<0.001$, $\theta < \theta_0$) and 99% ($p<0.001$, $\theta > \theta_0$) in the test set.

Matching the algorithm's detection ability to man's by lowering the specificity in order to gain in sensitivity, the sensitivity improved to 64% (n.s.) with 84% specificity (n.s.) in the training set resp. to 39% (n.s.) with 82% specificity (n.s) in the test set. In the case of ACS detection, the values were 41% ($p=0.002$, $\theta < \theta_0$) resp. 88% (n.s.) for the training set and 32% ($p=0.007$, $q<q0$)

resp. 85% (n.s.) in the test set using the ACC/ESC guidelines. The algorithm's detection performance had a sensitivity of 48% (n.s.) and a specificity of 88% (n.s.) in the training set, and 34% (n.s.) and 85% (n.s.) in the test set.

	1-Specificity "False Alarm"	Sensitivity "Hit"	Discriminability $d = (\mu 2-\mu 1)/\sigma$
10μV	61.2%	77.1%	0.46
20μV	40.9%	65.7%	0.63
30μV	28.8%	55.7%	0.70
40μV	18.2%	48.6%	0.87
50μV	10.9%	45.7%	1.12
60μV	8.5%	42.9%	1.19
70μV	6.1%	38.6%	1.26
80μV	3.9%	35.7%	1.39
90μV	1.5%	34.3%	1.77
100μV	1.2%	34.3%	1.85
110μV	0.9%	27.1%	1.75
120μV	1.2%	22.9%	1.51
130μV	0.9%	17.1%	1.41
140μV	0.9%	15.7%	1.35
150μV	0.9%	12.9%	1.23

Table 2 Discriminability (ROC) of different ST-elevation thresholds

4. Conclusions

By using automatic detection of AMI, the algorithm can be designed to match man or to be more specific. In the latter case, the machine's detection performance has a statistically significant lower sensitivity but a statistically significant higher specificity compared to man. The same is true for the ACC/ESC guideline's performance with a lower sensitivity compared to the algorithm.

When the algorithm's performance is adapted to man's lower specificity, we did not find a statistically significant difference between the detection performance of man and machine.

We had to accept the hypothesis of similar detection performance of man and machine in the case of ACS detection, too. Applying the ACC/ESC guidelines, we found a statistically significant lower sensitivity compared to man's performance.

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