Effectiveness of Electrocardiogram Interpretation Programs in the Ambulance Setting

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Abstract

This study assessed the effectiveness of automated ECG reporting in patients with acute chest pain of suspected cardiac origin being transported to hospital by ambulance in one region of Denmark.

Prehospital 12 lead ECGs were transmitted to the attending cardiologist. If a diagnosis of ST Elevation Myocardial Infarction (STEMI) were made, the patient was taken to an interventional centre. 200 randomly selected ECGs collected by the University of Copenhagen, were made available for a pilot study.

The ECG report from the LIFEPAK 12 and by the Glasgow program was compared with the hospital discharge diagnosis. The sensitivity and specificity for a report of STEMI was 73% and 93% for the LP12 and 78% and 94% for Glasgow. Corresponding data for the attending cardiologist was 81% and 92%. There was no significant difference in sensitivity or specificity between the cardiologist's decision and the automated report.

1. Introduction

The use of prehospital ECGs by emergency services to expedite triage for patients with suspected acute coronary syndrome has been recommended by the American Heart Association[1]. The benefits of skilled use of these ECGs have been shown in studies in the US and in Europe, [1][2]. While it is generally acknowledged that a rapid diagnosis of ST elevation myocardial infarction (STEMI) will reduce the time to treatment of the patient, the accuracy of the computer algorithm interpretation of STEMI in the prehospital setting has not been so widely reported. Youngquist et al [3]compared the number of false positive activations between emergency department and out-of-hospital (OOH) activation of the catheterization team, and recommended that larger studies should be carried out to confirm their findings that the number of false positives was higher with the OOH automated interpretation than with the interpretation by the physician in the emergency department.

A study was carried out in Copenhagen, Denmark which examined the effect on the time to primary percutaneous coronary intervention (PCI) of direct referral of patients based on the prehospital transmission of their ECG to an attending cardiologist [4]. Patients with acute chest pain who were transported by ambulance to one of several hospitals in the region of Zealand between October 2003 and October 2005 were included in that study. The University of Copenhagen collected the data for patients who had a prehospital ECG recorded in the ambulance and transmitted digitally to the attending cardiologist's mobile telephone. The ECG tracing, automated diagnosis, patient data and triage decision were stored electronically.

The acquisition of data continued and the managers of the study kindly agreed to allow data for 1000 patients (collected from January 1st 2007 to March 1st 2008) to be made available for analysis. The hospital discharge diagnoses were available for each patient.

The purpose of this study is to evaluate the accuracy of the automated diagnosis of the ECG acquired in an ambulance using a LIFEPAK 12 (Physio-Control) defibrillator/monitor with respect to reporting acute myocardial infarction and comparing it against the accuracy of the interpretation given by the University of Glasgow ECG analysis program (Uni-G) [5].

A secondary aim of the study is to assess the validity of the cardiologist's decision of whether to send patients to an invasive centre or to a local hospital without facilities for primary PCI.

2. Methods

The data collected in Copenhagen included the prehospital 12 lead ECGs. If a diagnosis of acute myocardial infarction was confirmed, the patient was taken directly to an interventional centre; otherwise the patient was taken to a local hospital. The time and triage decision made were recorded. Three databases held related information. One database held the demographic details for all 1000 patients as well as the discharge diagnoses. The second database held the data on the

subset of 425 patients who subsequently had an angiogram and the third database held data on the 332 patients who had PCI.

The University of Copenhagen used a random key method to split the data set into two parts: a preliminary set of 200 patients and a test set of the remaining 800 patients. The purpose of the pilot study was to establish procedures to be used in collaborative studies with the University of Glasgow. The outcome of the analysis of this set is given here. It was noted that one patient had been entered in the study on 2 different occasions and another patient on 3 different occasions as they had been transported by the emergency services with suspected acute coronary syndrome each time. Each admission was treated as a separate case.

25 ECGs from the pilot study were excluded from the analysis, due, for example, to a missing discharge diagnosis or the presence of an implanted cardiac pacemaker. The set therefore consisted of 175 ECGs (111 male, 64 female, age 64.6±13.7 years).

14 patients had ECGs where the diagnoses had to be re-examined to determine if the patient was indeed given a discharge diagnosis of STEMI. For example, there were cases where there was a discrepancy between the discharge diagnosis recorded in the demographic database and the findings as recorded in the angiogram and PCI databases. One patient had a discharge diagnosis of NSTEMI but was reported in the PCI database as having had a STEMI. To guard against simple transcription errors, these cases were reviewed by experts in Glasgow and Copenhagen and agreement was reached.

The LIFEPAK 12 uses the 12SL version 14 ECG algorithm (GE, formerly Marquette)[6]. A statement "ACUTE MI SUSPECTED" is output when an injury pattern has been identified. The criteria for an injury include testing for ST elevation, ST:T ratio and reciprocal changes. Basically the thresholds used for determining ST elevation are 0.1mV in I, II, III, aVR aVL, aVF, V5, V6, and 0.2mV in V1, V2, V3, V4.

Each automated report from the LIFEPAK 12 was examined for the presence of an acute MI statement which was considered equivalent to STEMI. This was then compared against the discharge diagnosis for each ECG.

The raw data for the ECGs was extracted by Physio-Control from their ECG management system and sent to Glasgow. The ECGs were re-analyzed using the Uni-G which uses age and sex based criteria for STEMI [5]. The presence or absence of STEMI as reported by this program was also compared against the discharge diagnosis for the same set of ECGs.

The sensitivity and specificity of the occurrence of acute myocardial infarction in the automated ECG output were calculated for both analysis programs. The sensitivities and specificities were compared using a non-parametric test option. McNemar's test was run to compare the results, using a binomial distribution due to the small number of cases. The statistical package used was SPSS (version 15; SPSS Inc, Chicago, Illinois). The level of significance was set at $p < 0.05$.

The cardiologist's decision of where the patient should be sent (i.e. to an invasive centre or local hospital) was compared with the discharge diagnosis. It was also compared with the automated computer output for both the LIFEPAK 12 and the Glasgow program. In cases where the triage decision did not match the discharge diagnosis of STEMI, the data was examined to see if the patient was subsequently transferred from a local hospital to an interventional centre.

3. Results

The output from the LIFEPAK 12 program and the Uni-G program were compared with the discharge diagnosis (Table 1).

Table 1. Cross tabulation results for the preliminary set showing discharge diagnosis and results from LIFEPAK 12 and Uni-G programs.

Discharge diagnosis			LIFEPAK 12		Total
			Not STEMI	STEMI	
Not STEMI	Uni-G	Not STEMI	97	4	101
		STEMI	3	4	7
	Total		100	8	108
STEMI	Uni-G	Not STEMI	13	2	15
		STEMI	5	47	52
	Total		18	49	67

From table 1, the LIFEPAK 12 program has a sensitivity of 73% and specificity of 93% and Uni-G has a sensitivity of 78% and specificity of 94%. McNemar's test was applied. The differences in sensitivity and specificity for the preliminary set were insignificant ($p=0.453$ and $p=1.000$ respectively).

When analyzing the validity of the triage decision, it was found that of the 175 patients in the pilot study, 63 were sent directly to an invasive centre by the attending cardiologist. 54 of these cases (86%) were discharged with a diagnosis of STEMI. A representation of the admission route followed by the 175 patients is shown in the following figure.

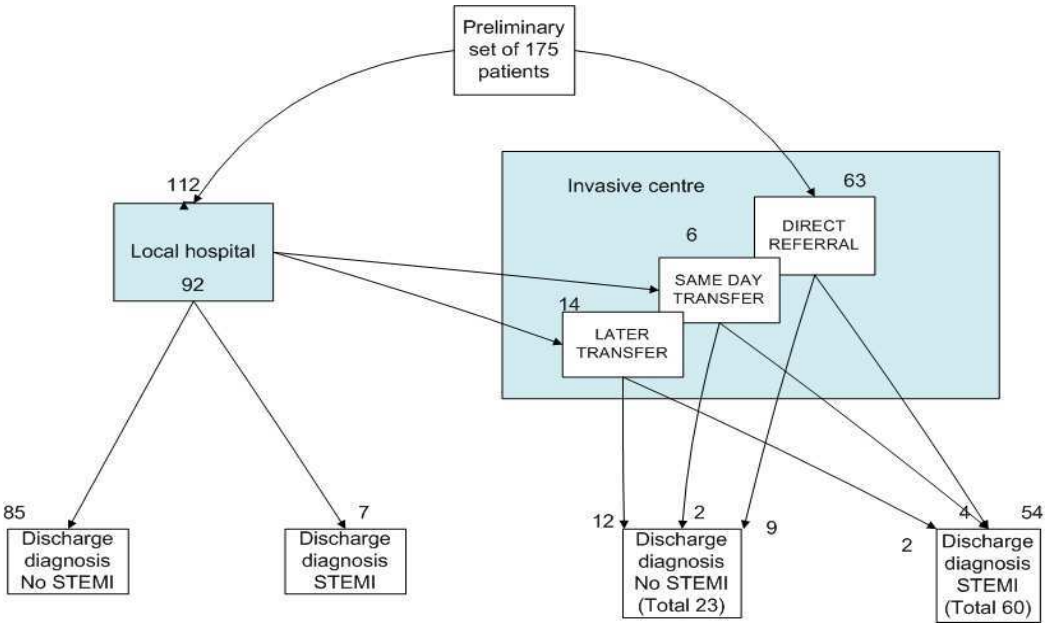

Figure 1. Admission route of patients following triage and showing final discharge diagnosis.

Of the 112 sent to a local hospital, 99 (88%) did not have STEMI in their discharge diagnosis. Of the remaining 13 who were given a discharge diagnosis of STEMI, 4 were transferred to an invasive hospital the same day and 2 subsequently.

By using the triage decision as an indication of whether or not the cardiologist thought that the patient had a STEMI and analyzing this with respect to the discharge diagnosis, a sensitivity of 81% and a specificity of 92% were obtained for the cardiologist's decision. Comparing these sensitivity and specificity values against those of the automated reports from Uni-G program (78% and 94% respectively) showed no significant differences (P=0.754 for both comparisons using McNemar's Test). The Uni-G program had increased specificity due to giving 2 fewer false positive results than the cardiologists (7 against 9 out of 108) and similarly the cardiologists had higher sensitivity due to giving 2 fewer false negative results (13 against 15 out of 67).

4. Discussion and conclusions

Unlike the study on pre-hospital patients from a North American population [7], running the Uni-G program, which uses age and sex dependent criteria for diagnosing STEMI, did not result in any significant improvement in sensitivity with respect to the discharge diagnosis. However, the specificity (94%) was higher than that of both the LIFEPAK 12 (93%) and the cardiologists (92%). The positive predictive value was 88% compared to 84% for the LIFEPAK 12 and 86% for the cardiologists. This reflects a decrease in the number of false positive results. False positive and false negative rates have been recognised as an area of weakness of automated reporting [1]. Figure 2 shows an example of an ECG which the Uni-G program reported as a lateral STEMI, but the LIFEPAK 12 did not.

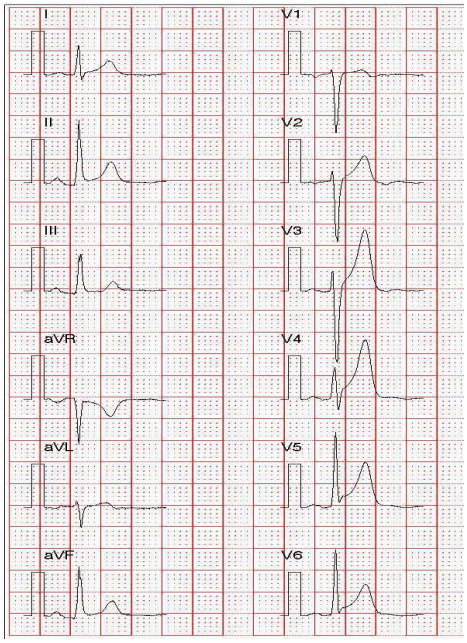

Figure 2. Example of ECG which the Uni-G program reported as STEMI but the LIFEPAK 12 reported as normal.

The patient was a 49 year old man. The attending cardiologist sent him to an invasive hospital. The time of first symptom was 08:00 and the time for the first balloon was 09:40. The procedure was considered a success.

The gold standard for this study was the discharge diagnosis. When monitoring the automated reports on ECGs, different studies use different methods of determining if a patient has a STEMI. Some studies use cardiologist interpretation while others use enzymes as a guide[7]. In this pilot study, enzyme results were readily available in only 23 cases.

With respect to the accuracy of the triage decision, there was a good agreement between the decision of where to send the patient and the final discharge diagnosis. This outcome was not due to the expertise of one particular cardiologist but rather to that of a number of attending physicians who were on call. However there was no significant difference in sensitivity or specificity between the cardiologist's decision and the automated report. On this evidence, there is no great advantage to using a cardiologist to over read the ECGs recorded in the ambulance. However, the sensitivity was higher for the cardiologist than for the programs, indicating that the cardiologist was more successful in diagnosing STEMI. It could be argued that if a cardiologist is not available then the automated report gives a reliable indication for triage. However, this result must be treated with caution as there were only 67 patients diagnosed with STEMI in the pilot study and further analysis needs to be undertaken using the full data set of 1000 ECGs.

Using ECGs to expedite triage was an effective strategy in this study when judged on the above percentages. The ratio of patients referred to an invasive centre who did not have a STEMI (1 in 7) could be an area to be improved. In these cases, the automated report was correct in 67% of the cases. However the programs were missing about 1 in 5 of cases which were finally confirmed as STEMI. Of course some of these cases may not have shown STEMI on the ambulance ECG. To look at this aspect, we compared the automated reports with the cardiologist's decision. Of the 63 patients referred to an invasive center, the LIFEPAK 12 had reported 49 (78%) of the ECGs as STEMI. The Uni-G program reported 51 (81%).

Further work needs to be done to see if the perceived improvement in specificity and positive predictive value of Uni-G program is evident in the full data set. Perhaps with proven improvements in the automated diagnosis of STEMI, the cardiologists may give more weight to the automated reports.

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