

# Automated Detection of the Culprit Artery from the ECG in Acute Myocardial Infarction

Elaine N Clark<sup>1</sup>, Yama Fakhri<sup>2</sup>, M Abdul Waduud<sup>1</sup>, Maria Sejersten<sup>3</sup>, Peter Clemmensen<sup>2</sup>, Peter W Macfarlane<sup>1</sup>

<sup>1</sup>University of Glasgow, Scotland

<sup>2</sup>Rigshospitalet, Copenhagen, Denmark

<sup>3</sup>Roskilde Hospital, Roskilde, Denmark

## Abstract

*The aim of this study was to develop, implement and evaluate criteria for automated detection of the culprit artery in patients with an acute myocardial infarction.*

*ECG and PCI data was retrospectively gathered in Zealand, Denmark, from patients who had presented with symptoms suggesting an acute coronary syndrome, had a prehospital ECG recorded, had PCI on the same day as the ECG recording, and were subsequently identified as having single vessel disease.*

*307 patients were selected (218 male, 89 female, mean age  $61.8 \pm 12.3$  years) as a training set. ECG criteria were designed to locate the culprit artery based on the location of ST deviation. The training set was used to optimise the criteria which were then incorporated into the Glasgow ECG analysis program. The ECGs were analysed using the enhanced software and the suspected culprit artery for each ECG was identified.*

*The sensitivity and specificity of identifying each type of occlusion was calculated, using the location determined from the coronary angiogram as the gold standard. The SE and SP for a report of LAD was 69% and 94%, for RCA was 64% and 94% and for LCX was 57% and 96%. In conclusion the detection of the culprit artery from an ECG can be automated with an acceptable degree of accuracy.*

## 1. Introduction

The AHA/ACC guidelines recommend that, for patients with acute myocardial infarction (MI), the likely culprit artery should be stated as part of the automated interpretation of an ECG [1]. A report of acute ST elevation MI (STEMI) on an ECG is used by many emergency services as the determining factor in sending a patient for percutaneous coronary intervention (PCI). The pre-hospital ECG can provide additional information

relating to the likely site of occlusion that may be useful for the receiving clinicians [2].

There have been several algorithms proposed in the last few years for determining the culprit artery as left anterior descending artery (LAD), right coronary artery (RCA) or left circumflex artery (LCx) [3,4]. In a previous study carried out by the authors [5], different automated algorithms for determining the culprit artery were assessed on ECGs recorded in an emergency setting. Using these algorithms, there was an acceptable degree of sensitivity and specificity for identifying the culprit artery as LAD or RCA, but less satisfactory results for identifying LCx. A recurring feature in these studies was the low number of confirmed LCx occlusions available for analysis. In addition, it has been observed that many LCx occlusions are not reflected in ST changes in the 12-lead ECG [6].

The aim of the present study was, to gather a dataset with sufficient numbers in each category of LAD, RCA and LCx occlusions and develop ECG criteria for automated detection of the culprit artery in the presence of an ECG diagnosis of STEMI and to implement and evaluate the new algorithm.

## 2. Method

Patients in the Zealand region of Denmark presenting between 2003 and 2012 with symptoms suggesting an acute coronary syndrome were eligible for inclusion in this study if an ECG were recorded in an ambulance at the time of symptoms and PCI was performed on the same day. Only patients with single vessel disease were included. The ECGs were transmitted to an on-call cardiologist at Rigshospitalet, Copenhagen University Hospital, Denmark. The entries in the PCI database were examined for duplicate patient identifiers, and for the extent of the main occlusion. Cases were excluded if there were missing data or if the culprit artery were marked as a vein graft or if the occlusion were less than 75%. If there were more than one ECG downloaded from the

ambulance, the latest recording was used. The gold standard for the location of the culprit artery was determined based on the description of the PCI-procedure as entered in the angiogram database by the PCI operator.

The location of the culprit artery was categorised under four main headings: LAD, RCA, LCx and other. Eligible ECGs in each of these main categories were identified. There were 757 ECGs eligible for inclusion. Of these, 107 had previously been used in the study for comparison of algorithms [5]. These cases were used as training examples. A further 200 of the eligible ECGs were selected to enhance the data set for the study. To maintain the ratios for the locations of the culprit artery, cases were selected at random from each of the four groups.

Criteria for automatic location of the culprit artery were developed. Previously published algorithms for identifying the culprit artery were considered. A pre-requisite for invoking the use of the criteria was set as the presence of a STEMI and identification of the site of the STEMI e.g. inferior, anteroseptal etc., as determined by the current version of the Glasgow 12-lead resting ECG analysis program [7]. The STEMI criteria were based on the definitions by the American College of Cardiology and the European Society of Cardiology [8] with enhancements to use age and gender dependent criteria. The performance of these criteria have previously been reported [9,10]. The site of infarction has been used as an indicator of the culprit artery for many years [11] and was used as the primary factor in this algorithm. Criteria were added based on observations from the authors' review of ECGs outside this training set where the culprit artery was known. In addition, ST elevation levels in V6 with or without ST depression in aVL were used in criteria for predicting LCx as the culprit artery. A flowchart showing the logic is given in Figure 1.

Following re-analysis of all the cases using the new automated detection in the Glasgow program, the resulting predicted culprit artery was compared with the gold standard and sensitivities (SE), specificities (SP), accuracy (defined as the ratio of the sum of true positive and true negative results to the total number in the data set) and positive predictive values (PPV) were obtained using Microsoft Excel.

### 3. Results

There were 218 males (mean age was  $60.4 \pm 11.9$  years) and 89 females (mean age was  $65.4 \pm 12.6$  years) in the data set. The number of cases in each of the occlusion categories is shown in Figure 2.

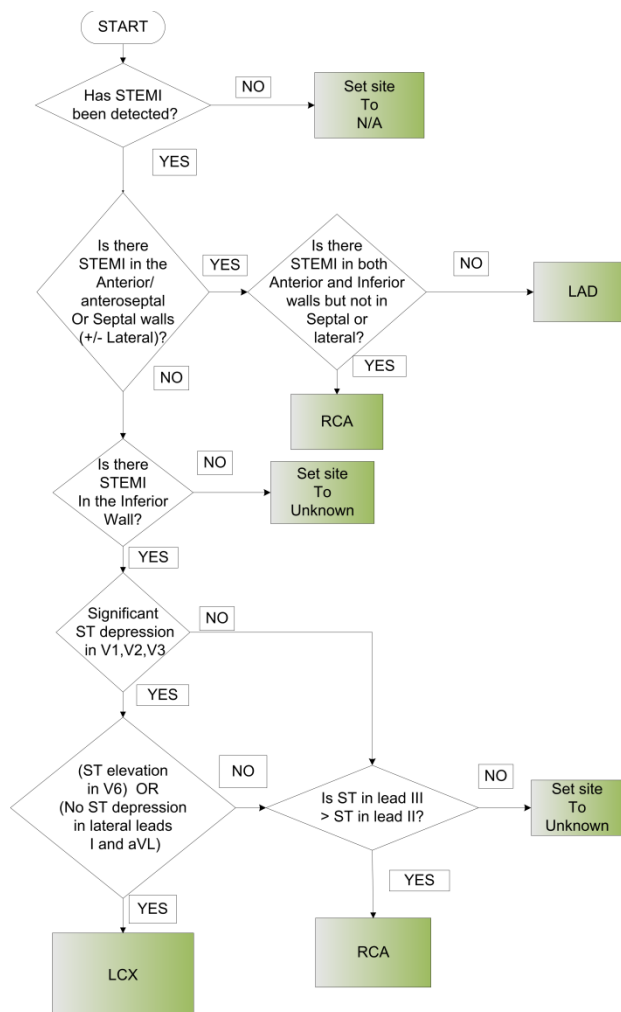


Figure 1. Flow chart for determining the culprit artery.

#### Distribution of locations of culprit artery

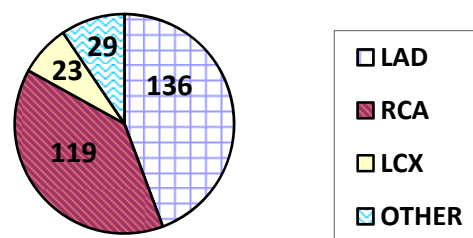


Figure 2. Distribution of locations of the culprit artery in the data set (n=307).

The SE and SP for the data set are given in table 1.

Table 1. Indices for reports of locations of culprit artery for the data set (n=307).

	SE	SP	Accuracy	PPV
LAD	69%	94%	83%	90%
RCA	64%	94%	82%	87%
LCX	57%	96%	93%	54%

STEMI was reported by the program in 75% (231/307) of cases in the data set. Repeating the calculation of sensitivities and specificities only for those that are reported as STEMI, resulted in increased SE and accuracy and decreased SP (Table 2).

Table 2. Indices for reports of locations of culprit artery for ECGs in the data set which were reported as STEMI (n=231).

	SE	SP	Accuracy	PPV
LAD	98%	93%	95%	90%
RCA	80%	91%	86%	87%
LCX	62%	95%	92%	54%

#### 4. Discussion

Improving ECG interpretative algorithms to accurately report the culprit artery in line with the AHA/ACC guidelines has been a challenge for developers. The main area of difficulty is distinguishing between RCA and LCx occlusions and increasing SE without detrimental effect on SP.

Posterior myocardial infarction could be reflected in ST elevation in the V7-V9 leads or in ST depression in leads V1-V3. Leads V7-V9 are not available in the standard 12-lead programs. Simulated V7-V9 data can be obtained by transforming standard lead data and the data from lead V6 is the main input [12]. A future enhancement may be to carry out the transformation and use the results from the simulated lead data. One of the aims in developing the algorithm was for simplicity of use. Ideally, the algorithm could also be used manually.

When the program correctly reports STEMI, the SE and SP for locating the culprit artery are high. Improving the accuracy of reporting STEMI is an on-going target. In

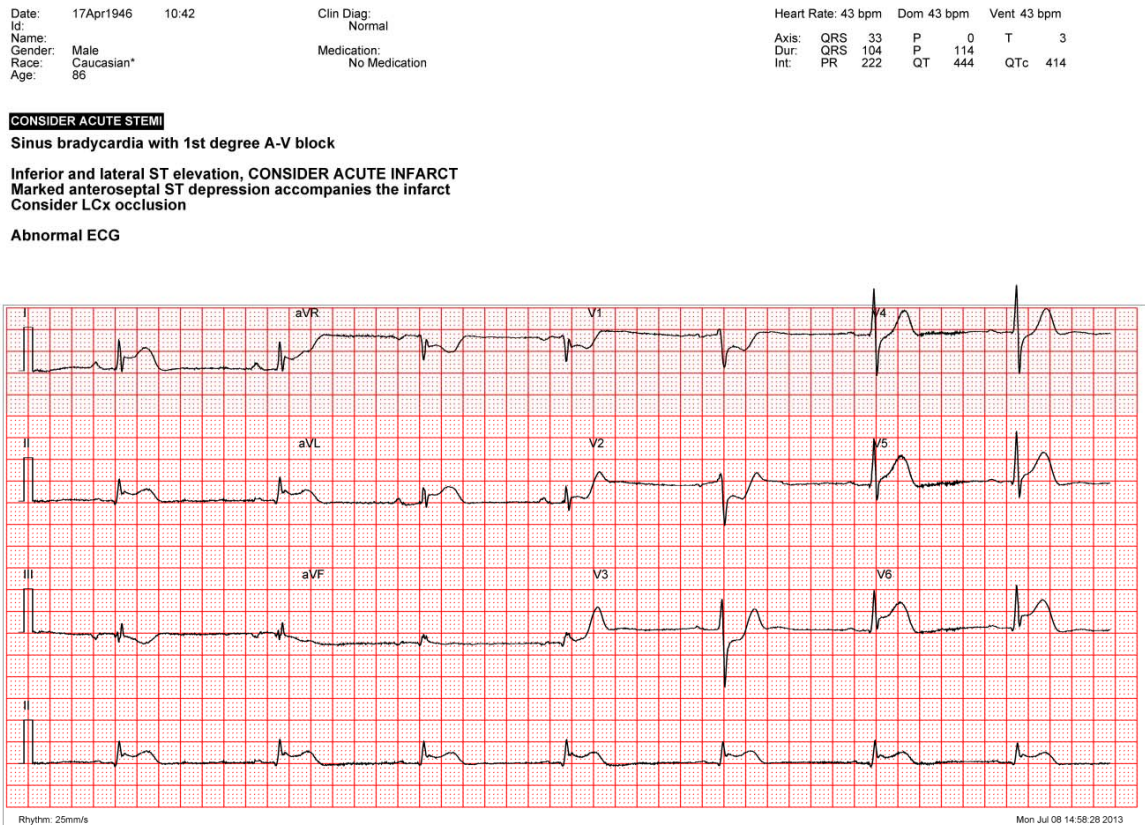


Figure 3. ECG from an 86 year old male patient with a STEMI. The PCI showed that the occlusion was indeed in the LCx.

particular, it was evident that if STEMI were reported, SE and SP for LAD were > 90%. There were only 2 false negative LAD reports. In both cases, a lateral infarction had been reported. The results for LCx were higher than previous studies but numbers were again small. An example of a true positive report of LCx as the culprit artery is shown in Figure 3. The criteria of inferior STEMI, ST depression in leads V1-V3 and ST elevation in V6 can be clearly seen.

## 5. Limitations

The ECGs were initially analysed in Denmark at the time of recording using a different resting ECG program (GE Marquette) [13]. The differences in reporting STEMI between the two programs have been analysed [10]. There was little difference in SE. The possibility of developing the criteria to be more precise in defining the site of occlusion e.g. proximal or distal has not yet been investigated.

## 6. Conclusions

In the presence of a STEMI, the culprit artery can be detected automatically by the use of a computer program and this method could be integrated into current ECG recording devices. The accuracy of the automated method for the detection of the culprit artery needs to be confirmed in a larger patient population

## References

- [1] Wagner GS, Macfarlane P, Wellens H et al. AHA/ACCF/HRS Recommendations for the Standardisation and Interpretation of the Electrocardiogram Part VI: Acute Ischemia/Infarction. *JACC* 2009;53: No. 11, 1003-11.
- [2] Birnbaum Y, Bayés de Luna A, Fiol M, Nikus K, Macfarlane P, Gorgels A, Sionis A, Cinca J, Barrabes JA, Pahlm O, Sclarovsky S, Wellens H, Gettes L. Common pitfalls in the interpretation of electrocardiograms from patients with acute coronary syndromes with narrow QRS: a consensus report. *J Electrocardiol* 2012;45(5):463-75.
- [3] Tierala I, Nikus KC, Sclarovsky S et al. Predicting the culprit artery in acute ST-elevation myocardial infarction and introducing a new algorithm to predict infarct-related artery in inferior ST-elevation myocardial infarction: correlation with coronary anatomy in the HAAMU trial. *J Electrocardiol* 2009;42: 120-127.
- [4] Fiol M, Cygankiewicz I, Carrillo A et al. Value of electrocardiographic algorithm based on “ups and downs” of ST in assessment of a culprit artery in evolving inferior wall acute myocardial infarction. *Am J Cardiol* 2004;94: 709-714.
- [5] Waduud MA, Clark EN, Payne A, Berry C, Sejersten M, Clemmensen P, Macfarlane PW. Location of the culprit artery in acute myocardial infarction using the ECG.

- Computing In Cardiology 2011;38:417–420.
- [6] Gettes LS. A sensitive issue. *J Electrocardiol*. 2007; 40:470-71.
  - [7] Macfarlane PW, Devine B, Clark E. The University of Glasgow (Uni-G) ECG analysis program *Computers in Cardiology* 2005;32:451-4.
  - [8] Thygesen K et al. Universal definition of myocardial infarction: ESC/ACCF/ AHA/WHF expert consensus document. *JACC* 2007;50: 2173–95.
  - [9] Macfarlane PW, Hampton D, Devine B, Clark E, Jayne CP. Evaluation of age and sex dependent criteria for ST elevated myocardial infarction. *Computers in Cardiology* 2007;34:293-296.
  - [10] Clark EN, Sejersten M, Clemmensen P, Macfarlane PW. Automated electrocardiogram interpretation programs versus cardiologists’ triage decision making based on teletransmitted data in patients with suspected acute coronary syndrome. *Am J Cardiol* 2010;106: 1696-1702.
  - [11] Birnbaum Y, Drew B. The electrocardiogram in ST elevation acute myocardial infarction: correlation with coronary anatomy and prognosis. *Postgrad Med J* 2003; 79(935): 490–504.
  - [12] Horáček BM, Warren JW, Wang JJ. On designing and testing transformations for derivation of standard 12-lead/18-lead electrocardiograms and vectorcardiograms from reduced sets of predictor leads. *J Electrocardiol* 2008;41(3):220-9.
  - [13] 12SL ECG Analysis Program Physician’s Guide. Milwaukee, WI: GE Marquette Medical Systems, 2000:7.14 –7.612.

Address for correspondence.

Elaine Clark  
 Electrocardiology Section, Level 1, QEB,  
 Institute of Cardiovascular and Medical Sciences  
 Royal Infirmary  
 Glasgow  
 G2 2ER  
 Elaine.clark@glasgow.ac.uk