Reliability of the Prediction of the Location of the Culprit Lesion from the ECG in Totally Occluded Arteries in Case of Single Vessel Disease

WA Dijk[1], AC Maan[2], NHJJ van der Putten[3], ET van der Velde[2], CA Swenne[2], R Hoekema[4], WRM Dassen[5], JP Busman[1]

[1]University Medical Center Groningen, Groningen, The Netherlands
[2]Leiden University Medical Center , Leiden, The Netherlands
[3]Erasmus Medical Center, Rotterdam, The Netherlands
[4]University Medical Center St Radboud, Nijmegen, The Netherlands
[5]Maastricht University Medical Center, Maastricht, The Netherlands

Abstract

This paper deals with the reliability of algorithms predicting the location of the culprit lesion in a totally occluded coronary artery from a 12 lead ECG recording. Four commercial ECG analysis programs and two specific algorithms were evaluated. Five hundred well documented cases were used for testing. Evaluation of the results reveals that all algorithms perform suboptimal.

1. Introduction

Invasive treatment through Percutaneous Coronary Intervention (PCI) of patients experiencing symptoms of acute myocardial ischemia has become widely accepted. In case of ST-elevated infarction (STEMI), minimising the time delay between onset of the symptoms and the first balloon inflation of the culprit lesion is of utmost importance for the patient's outcome. The electrocardiogram (ECG) recorded by the alarmed general practitioner or ambulance nurse is considered the single most important test for diagnosing myocardial infarction. Reflecting the electrical activity of the heart, the ECG is but an indirect indicator of the presence of a complete arterial occlusion. The consensus reached by the American Heart Association about nomenclature and location of the 17 myocardial segments assigns an area of the myocardium to specific coronary artery territories [1]. Also the coronary artery anatomy is described in 16 segments by the American Heart Association [2]. In this study we investigated the reliability of the prediction of the location of the culprit lesion from the ECG by commercially available ECG analysis programs handling the indirect approach and 2 recently proposed algorithms pinpointing directly to the occluded segment.

2. Methods

In the Netherlands the departments of Cardiology of the 8 University Medical Centers cooperate in the Interuniversity Cardiology Institute in the Netherlands (ICIN). In these centers 4 different commercially available ECG analysis programs are utilized (Table 1).

Table 1. Commercially available ECG analysis programs

Company	**ECG system**
Dräger	Megacare
General Electric	Muse
Mortara	Escribe
Philips	Tracemaster

The participating centers contributed to a database containing 508 well documented PCI procedures concerning patients suffering from a single vessel disease with Thrombolysis In Myocardial Infarction (TIMI) flow grade equal 0 and a digitally available standard ECG recording within a timeframe of maximal 2 hours previous to the first balloon inflation. In Table 2 the overall distribution of occluded segments is displayed. The right coronary artery (RCA, segment 1,2,3,4,16) was involved in 41% of the cases, the left descending artery (LAD, segments 6/10) in 42% and the circumflex artery (LCX, segments 11/15) in 17%. This distribution agrees well with other publications.

The diagnoses generated by the ECG analysis programs are grouped according to the affected artery in Table 3. The relation between the diagnosed injured area of the myocardium and the vessel concerned is defined by the above mentioned consensus by the American Heart Association. The left main stem has been discarded for the obvious reason that the chance that a patient with TIMI flow grade 0 reaches the hospital in time is negligible.

Table 2. Distribution of occluded segments.

Segment	#
1.Proximal RCA	74
2.Mid RCA	87
3.Distal RCA	39
4.Right posterior descending artery	9
5.Left main stem	0
6.Proximal LAD artery	112
7.Mid-LAD artery	86
8.Distal LAD artery	6
9.First diagonal branch	8
10.Second diagonal branch	1
11.Proximal LCX	33
12.Obtuse marginal branch	19
13.Mid-LCX	28
14.Ramus posterolateralis from LCX	4
15.Ramus postero decendens from LCX	0
16.Ramus posterolateral from RCA	1

Three specific algorithms identifying the culprit artery and the location of the occlusion were published by Fiol et. al. [3] and Tierala et. al. [4]. The latter paper deals only with the prediction of the RCA and LCX as culprit artery. For the identification of the LAD (algorithm 1) we used the results of the Fiol algorithm which states that, essentially, any ST elevation in the precordial leads that exceeds ST elevation in the inferior leads is decisive for the LAD as the culprit artery.

The ECGs from the participating centers were transformed into one intermediate format: 10 s of the 8 independent leads I, II, V1-V6 with a sample frequency of 500 Hz as comma separated ASCII values. These CSV ASCII files were converted to a Megacare-specific format (Siemens Data Format, .sdf) and imported into the Megacare database. For each ECG a new measurement matrix and the corresponding interpretation was generated based on the built-in GRI interpretation program by MacFarlane et. al. [5]. For each ECG the calculated ST-segment amplitude of each of the 12 leads was exported. These values were then used as input for the algorithms, programmed in the Matlab environment according to figures 1 and 2.

Since the description of the original algorithms did not explicitly define ST-elevation, we defined elevation as an amplitude > 200 µV in V1 and > 100 µV in all other leads, measured 60 ms after the J-point.

ST-depression was defined as < -100 µV in all leads. Isoelectricity was defined as absence of both elevation and depression.

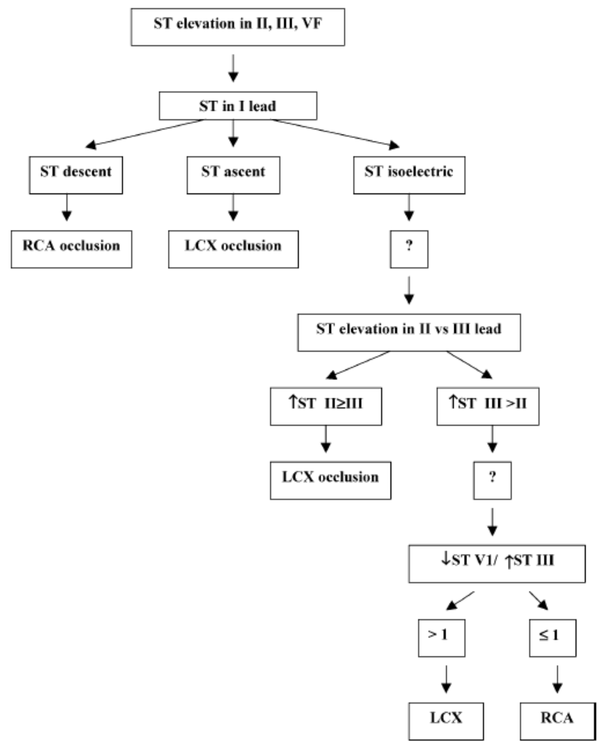

Figure 1. Algorithm 2 according to Fiol et. al. [3] to decide for RCA or LCX as culprit artery.

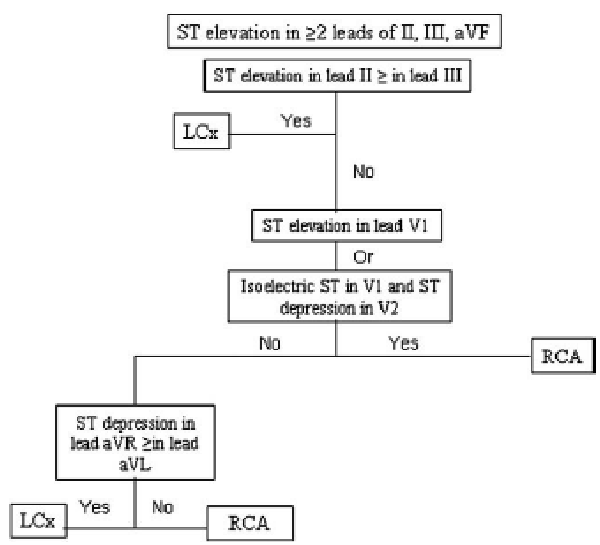

Figure 2. Algorithm 3 according to Tierala et. al. [3] to decide for RCA or LCX as culprit artery.

Table 3. Diagnoses generated by ECG analysis programs versus segment coronary artery

Defined territories [1]	Myocardial area	RCA					LAD					LCX				
		1	**2**	**3**	**4**	**16**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
RCA region	Inferior (4,10,15)	31	42	13	6			4				19	4	21	2	
	Inferoseptal (3,9)	16	9	10		1							1	3		
LAD region	Anterior (1,7,13)	7	2	1			59	44		3	1		5	1		
	Anteroseptal (2,8,14,17)						13	16								
LCX region	Inferolateral (5,11)	1	3							1						
	Anterolateral (6,12,16)	14	21	8			35	22	4	4		8	5	2		
	No infarction diagnosis	5	10	7	3		5		2			6	4	1	2	

3. Results

In table 3 the results of the ECG analysis programs are displayed. The columns represent the artery segments and the rows the infarcted myocardial area. The rows are grouped according to the segments that are assigned to the 3 main vessels [1]. The bottom row of the table shows the number of diagnoses not containing any reference to an infarction. The anterolateral segments, denoted by the AHA committee as a LCX territory, does not show any preference to any coronary artery. The same observation can be made for the inferior region, where the contribution of occluded LCX segments even doubles that of its own "home" territory.

Table 4 shows the results of the algorithms by Fiol and Tierala. Columns 3, 4, 5 and 6 relate to the Fiol algorithm, columns 7, 8 and 9 relate to the Tierala algorithm (which did not include a specific LAD algorithm). Columns 6 and 9 display the number of segments that were not classified as infarction. Both algorithms lower the misclassifications of the LCX contribution in the inferior segments, but no improvement can be seen for the anterolateral region.

In table 5 the sensitivity and specificity of the algorithms are displayed. The described algorithms 1,2 and 3 perform slightly better than the average of the commercial products, except the sensitivity for the LCX.

Table 4. Results of algorithms 1, 2 and 3

	SEGMENT	RCA Alg 2	LAD Alg 1	LCX Alg 2	Und Alg 2	RCA Alg 3	LCX Alg 3	Und Alg 3
RCA region	**1**	51	10	1	12	50		14
	2	64	10	1	12	53	1	23
	3	27	1		11	25		13
	4	7			2	7		2
	16	1				1		
LAD region	**6**		98		14			14
	7		72	1	13			14
	8	1	4		1	1		1
	9		3		5			5
	10		1					
LCX region	**11**	7	9	4	13	7	2	15
	12	3	3	1	12	2	1	13
	13	9	7	4	8	9	3	9
	14	1	2		2	1		2
	15							
	Total	**171**	**220**	**12**	**105**	**156**	**7**	**125**

4. Discussion and conclusions

The data originates from patients with angiographically confirmed single totally occluded segments. Therefore the resulting diagnosis from the different algorithms can be analysed in a straightforward manner. It is remarkable that all algorithms generate a significant number of non infarction related diagnoses: 9, 20 and 24% respectively. In this study we used the commonly accepted definition of ST-elevation and ST-depression, resulting in a substantial number of non-classifiable cases for algorithms 1, 2 and 3. As the electrocardiogram is the single most important test for diagnosing acute myocardial infarction, this high percentage of false negatives hampers patient care significantly. Further investigations should take place to optimise the definition of ST-deviation.

According to expectation, the accuracy of diagnosing the LAD as culprit artery exceeded that of diagnosing the RCA and LCX as the artery with the culprit lesion.

Table 5. Sensitivity and specificity of the algorithms

Algorithm	Vessel	Sensitivity	Specificity
ECGsystem	RCA	60.9	81.8
ECGsystem	LAD	63.8	94.5
ECGsystem	LCX	17.8	73.3
2	RCA	71.4	93.0
1	LAD	83.6	85.8
2	LCX	10.6	82.7
3	RCA	64.8	93.3
3	LCX	7.1	79.4

The sensitivity and specificity of the algorithms (table 5) does not identify a superior algorithm. Due to the large percentage of non classification, the sensitivity and specificity of the algorithms is rather low, with a minimum for the LCX. The numbers indicate that, under the described conditions, substitution of the acute single vessel disease algorithms in the commercial systems by the specifically designed ones is not advisable.

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Address for correspondence

Arnold Dijk
Thoraxcenter
University Medical Center Groningen
Hanzeplein 1
9713 EZ Groningen
The Netherlands
W.A.Dijk@thorax.umcg.nl