Evaluation of Accuracy and Reliability of Electrocardiographs Interpreted By Emergency Medicine Assistants

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ABSTRACT

The purpose of this study is to evaluate accuracy and reliability of the electrocardiographs interpreted by the Emergency Medicine assistants and to determine compatibility between the interpretations of the electrocardiographs read by the emergency medicine assistants and cardiologist.

This study was performed in the prospective and sectional manner on 252 patients who applied to Uludag University Health Application and Research Center Emergency Department between 12.06.2008 and 12.07.2008 and whose triage categories were 1 and 2. The ECGs were evaluated by the Emergency Medicine assistants and cardiologist independently of each other. The interpretations made by the cardiologist accepted as the gold standard.

252 patients were included in the study. 60% of them was male (n= 152) and 39.7% of them was female (n= 100), and the mean age was found as 59.4 (± 13.6). 23% (n=58) of 73 ECGs interpreted by the cardiologist was seen that they normally interpreted by the Emergency Medicine assistants. 179 electrocardiograms evaluated by the cardiologist were determined that they contained the pathologies as the major for 39, as the potential clinical importance for 78 and as the minor for 62. 187 electrocardiograms evaluated by the Emergency Medicine assistants were determined that they contained the pathologies as the major for 25, as the potential clinical importance for 89 and as the minor for 73.

In our study, we detected that there was significantly compatibility between the interpretation skills of electrocardiograms for the cardiologist and Emergency Medicine assistants. We also distinguished that there were important deficiencies. The electrocardiogram interpretation skills can be further improved by the trainings that will be given bedside.

Key Words: Electrocardiogram, emergency medicine assistant, emergency department

Introduction

The heart diseases take place on the top within the diseases causing death at most around the world. Approximately eight million persons apply to the Emergency Departments with the chest pain every year (1). It was detected that heart disease prevalence was 6.7% throughout Turkey, coronary heart disease was 3.8% and hypertensive heart disease was 2.2% in the adults (2). Approximately 15% of the patients applied to the Emergency Department (ED) with the chest pain received the acute myocardial infarction (AMI) diagnosis and one-third of them progressed fatal (3).

The electrocardiogram (ECG) used in the diagnosis of cardiac diseases is the primary among the non-invasive, quick, reliable, easy and repeatable examinations. It has critical importance in the diagnosis of acute coronary events. The ECG interpretation is an ordinary skill for the emergency physicians in a timely and correct interpretation of the high-risk ECGs in many cardiac, metabolic, electrolyte and toxicological cases especially for those threatening the life. While the emergency physician training is seen to improve the ECG interpretation, it is seen that there are still faulty interpretations of the ECGs for the physicians working in the Emergency Departments at different levels in the diagnosis of the pathologies coming to existence and threatening the life (1). It was detected in the researches performed in the USA that 28-50% of the patients applied to the Emergency Departments with the chest pain complaint were not sufficiently examined and 2-5% of them were discharged from the hospital by misdiagnosing the AMI case (4). The initial ECG is diagnostic for the acute myocardial damage or ischemia in approximately 40-65% of the patients with AMI (5). The patients having an acute coronary syndrome (ACS) suspicious and patients having an ST-segment elevation myocardial infarction

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(STEMI) can be treated by an immediate acute percutaneous coronary intervention with a quick evaluation without occurring a severe damage in the heart muscle. The ECG interpretation made by the Emergency physician is extremely important for the patients in determining the diagnosis and treatments and discharging them from the hospital (6-7).

The Emergency physician is the person firstly evaluating the patients coming to the Emergency Department with the chest pain, firstly organizing the treatments and requesting the cardiology consultation for the patients or discharging them. Our purpose in this study is to determine the interpretation accuracy and reliability of the ECGs taken for the patients applied to Uludag University Health Application and Research Center (UU-HARC) Emergency Department by the Emergency Medicine assistants (EMA) and to evaluate the compatibility with the interpretation of cardiologist and also determine the deficiencies and provide to eliminate them.

Materials and Methods

The research was started in the Department of UU-HARC Emergency Medicine and Department of Cardiology after obtaining the faculty clinic and laboratory researches ethical committee department approval. The study was performed between 12.06.2008 and 12.07.2008. The ECGs taken by the nurses for the patients who applied to the Emergency Department and whose triage category was l and ll were firstly interpreted by the EMA completed their third year and marked in the data collection form. The same ECGs were brought to the cardiologist and interpreted and recorded. This process was routinely made every weekday during the study and the EMA's ECG interpretations and cardiologist's interpretations were compared. The interpretations were made by depending on the ECG evaluation steps accepted by the American Heart Association (AHA) and American College of Emergency Physicians (ACEP) societies and shown in the reference and education manual. The ECGs were divided as the normal and pathologic ECG as a result of the evaluations. The normal ECG was described as an ECG in the normal sinus rhythm without pathologic changes. The pathologic ECG was previously described and included in one of three abnormal ECG categories. They contain the ECG abnormalities as the Category l not having the potential clinical importance (minor), as the Category ll having the potential clinical

importance and Category lll having the life-threatening clinical importance (major). The ECGs interpreted by the EMAs completed their three years were then interpreted again by a cardiology lecturer accepted as the gold standard to measure the accuracy and reliability of evaluations by depending on the blind and same category classifications. The Emergency Medicine assistants' ECG interpretations were compared with the cardiologist's interpretations. If the ECG findings interpreted by the EMA were exactly the same with the findings interpreted by the cardiologist, they were accepted as the compatible, and if they were interpreted differently, they were accepted as the incompatible. If the ECG interpretations accepted as the compatible contained any pathology, they were named as the compatible positive, and they did not contain, they were named as the compatible negative. The inconsistency was researched whether it was clinically significant in the second step of the analysis. The clinical significance is an ECG finding that will lead to any changes in the treatment intervention or type (in-patient or out-patient). The clinical significant and incompatible interpretations were divided into further subgroups as the major and minor false or negative and positive. Marking a not existing pathology by the EMAs even the cardiologist did not detect was named as the false positive, and not marking an existing pathology by the EMAs even the cardiologist detected was named as the false negative.

The Emergency Medicine assistants completed their third years were included in the study, although the training period is five years. The patients aged 18 and older and applied to the Emergency Department with the arrhythmia or chest pain were included in the study.

Statistical Analysis: Descriptive statistics of the studied variables were presented as count and percent. Kappa coefficient was performed to determine the agreement between the evaluations of the cardiologist and the emergency medicine assistances for the considering parameters. Statistical significance level was considered as 5% and SPSS (ver: 20) statistical program was used for all statistical computations.

Results

252 patients who applied to the Emergency Department between 12.06.2008 and 12.07.2008 and whose ECGs were taken included in the study. 60.3% (n=152) of the patients included in

Table 1. Age groups and gender distribution of patients included in the study

Age groups	Sex				Total	
	Male		Female			
	n	%	n	%	n	%
18-29	5	1.9	5	1.9	10	3.9
30-39	8	3.1	6	2.3	14	5.6
40-49	28	11.1	6	2.3	34	13.5
50-59	37	14.6	25	9.9	62	24.6
60-69	38	15	26	10.3	64	25.4
70-79	29	11.5	20	7.9	49	19.4
80-89	6	2.3	12	4.7	18	7.14
90+	1	0.4	0	0	1	0.4
Total	152		100		252	

Table 2. Compliance of cardiologists and emergency medical assistants in recognizing major ECG pathologies

ECG pathologies	False negative		False positive		Compatible positive		Compatible Negative		Kappa value
	n	%	n	%	n	%	n	%	
ECG compatible with AMİ	14	5.55	1	0.39	22	8.73	215	85.31	0.720
3rd degree AV block	0	0.0	0	0.0	2	0.79	250	99.2	1.00
AV junction rhythm <50 beats/ min	1	0.39	0	0.0	0	0.0	251	99.6	*
Atrial fibrillation > 200 beats / min	1	0.39	0	0.0	1	0.39	250	99.2	0.665
PSVT (<200 beats / min)	0	0.0	1	0.39	2	0.79	249	98.8	0.798
Ventricular tachycardia	0	0.0	0	0.0	1	0.39	251	99.6	1.00

the study was male and 39.7% (n=100) of them was female, and age groups and gender distributions of the patients were shown in Table 1.

When the ECGs evaluated by the cardiologist were examined, the ECGs taken were detected that 28.9% (n=73) of them was completely normal and 71.1% (n=179) of them was pathologic. The same 252 ECGs evaluated by the EMA were detected that 25.8% (n=65) of them was completely normal and 74.2% (n=187) of them was pathologic. While 73 ECGs interpreted by the cardiologist was normal since the cardiologist was accepted as the gold standard, 58 of them was accepted by the EMA as the normal and 79.5% of both interpretations were seen to be compatible. The remaining 15 ECGs were interpreted as the pathologic (incompatible). 179 ECGs evaluated by the cardiologist as the pathologic detected that they contained the ECG changes as the major in 39 of them, as the potential clinical importance in 78 and as the minor in 62 of them. When the interpretations 187 ECGs were evaluated by the

EMA as the pathologic examined that they contained the ECG changes as the major in 25 cases, as the potential clinical importance in 89 cases and as the minor in 73 cases. When the ECGs for which the major changes were determined were examined, it was seen that the cardiologist marked totally 44 major pathologic findings in 39 ECGs and EMA marked totally 30 major pathologic findings in 25 ECGs (Table2).

While 126 pathologic findings were determined from Category ll in the ECGs of 78 cases containing the pathologic findings found by the cardiologist as the potential clinical importance, 111 pathologic findings were determined in the ECGs of 89 cases evaluated by the EMA. While the cardiologist interpretation was exactly the same for 83 of them (compatible positive 65.9%), the remaining was detected that 43 of them not determined by the EMA was evaluated as the false negative and 28 of them not determined by the cardiologist was evaluated as the false positive. The compatibility in determining the ECG pathologies found by the cardiologist and EMA as

Table 3. Compliance of cardiologists and emergency medicine assistants in recognizing potential clinical significance of ECG pathologies

ECG pathologies	False Negative		False positive		Compatible positive		Compatible Negative		Kappa value
	n	%	n	%	n	%	n	%	
Full RBBB	4	1.58	0	0.0	1	0.39	248	98.41	0.194
Full LBBB	3	1.19	0	0.0	6	2.38	243	96.42	0.184
ST-T changes showing ischemia	17	6.74	15	5.95	36	14.28	184	73.01	0.623
Left ventricular hypertrophy	7	2.77	5	1.98	3	1.19	237	94.04	0.309
Digital effect	3	1.19	0	0.0	2	0.79	247	98.01	0.566
Pace rhythm	0	0.0	1	0.39	4	1.58	247	98.01	0.746
Atrial Fibrillation	6	2.38	3	1.19	30	11.9	213	84.52	0.856
AV junction escape	1	1.19	0	0.0	0	0.0	251	99.6	*
Atrial flatter	2	0.79	4	1.58	1	1.19	245	97.22	0.239

Table 4. Compliance of cardiologists and emergency medical assistants in identifying minor ECG pathologies

ECG pathologies	False negative		False positive		Compatible positive		Compatible Negative		Kappa value
	n	%	n	%	n	%	n	%	
Sinus tachycardia	3	1.19	2	0.79	44	17.46	203	80.55	0.881
Sinus bradycardia	0	0.0	2	0.79	11	4.36	239	94.84	0.913
1st degree AV block	2	0.79	4	1.58	3	1.19	243	96.42	0.319
Incomplete left bundle branch block	4	1.58	5	1.98	1	0.39	242	96.03	0.359
Incomplete right bundle branch block	5	1.98	15	5.95	8	3.17	224	88.88	0.359
Low voltage in precordial leads	0	0.0	6	2.38	4	1.58	242	96.03	0.522
Low voltage in precordial leads	3	1.19	9	3.57	4	1.58	236	93.65	0.356
ECG changes compatible with the old MI	7	2.77	15	5.95	16	6.34	214	84.92	0.516
Right or left atrial anomaly	3	1.19	6	2.38	5	1.98	238	94.44	0.539
Early repolarization	4	1.58	4	1.58	1	0.39	243	96.42	0.184
Premature Ventricular Complex	6	2.38	3	1.19	17	6.74	226	89.68	0.771

the potential clinical importance was shown in Table 3.

The ST-T changes showing the ischemia in 53 were detected by the cardiologist. While 36 of the ST-T changes interpreted by the EMA were exactly the same with the cardiologist's interpretation (compatible positive 67.9%), the remaining was detected that 17 of them not determined by the EMA was evaluated as the potential false negative and 15 of them not determined by the cardiologist was evaluated as the potential false positive. While 6 cases interpreted by the EMA as the potential left bundle block were exactly the same with the cardiologist's interpretation (compatible positive 66.6%), 3 cases that could not be determined by the EMAs were evaluated as the potential false negative. While 156 pathologic findings were determined from Category I in the ECGs of 62

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cases containing the minor pathologic findings found by the cardiologist, 185 pathologic findings were determined from Category I in the ECGs of 73 cases containing the minor pathologic finding found by the EMA. While 117 of these pathologic findings were exactly the same with the cardiologist's interpretation (compatible positive 75%), the remaining was detected that 39 of them not determined by the EMA was evaluated as the false negative and 68 of them determined by the EMA was evaluated as the false positive. The correlation between the compatibility in determining the minor ECG pathologies of the cardiologist and EMA was shown in Table 4.

Discussion

When the studies researching the ECG interpreting compatibility between the cardiology and emergency physicians in the literature are examined, we see that there are different results at the significant level between two physician groups. W.K.Wu et al (8) detected in their studies that the ECG interpretation skills of emergency physician and cardiologist were compatible as 76% and evaluation of the risk factors was compatible as 85%. Hazell W (9) detected the accuracy rate of the senior assistants' ECG interpretation skills as 67.5% in his study. They also detected the accuracy rates in the rhythms of VTs and VFs threatening the life as 43.8% and 70.8% low, as the typical STE AMI and as 100% correct in the right bundle block, respectively. Ho et al (10) detected in their studies that 13 (5.5%) of 236 cases having the AMI findings were misinterpreted by the emergency department physicians. It was frequently stated in the same study that the small ST segment changes and bundle blocks could not be determined by the Emergency Department physicians. Lee et al (11) revealed that even the ECG findings of 21 (4.7%) of 445 AMI cases being a candidate to the thrombolytic treatment shoed the AMI, it could not be determined by the Emergency Department physicians. In our study, it was seen that 22 (61.1%) of 36 cases determined by the cardiologist to have compatible findings with the MI was interpreted by the EMA as the compatible and 14 of them was differently interpreted. When this difference was examined it was determined that 5 cases interpreted by the cardiologist as the subacute MI were described by the EMA as the chronic MI and 3 cases evaluated by the cardiologist as the AMI were interpreted by the EMA as the myocardial ischemia. It was

understood that 5 of 6 cases interpreted by the cardiologist as the AMI was accepted by the EMA as the normal and one case could not be determined due to the atrial flatter rhythm. Thus, 9 (25%) patients diagnosed by the cardiologist as the AMI were skipped by the EMA. This is a very important deficiency. When it was compared with the studies in the literature, while the studies performed in the same period were at 5-6% level, obtaining it as 25% in our study revealed that we had a very important deficiency.

However, the success rate is seen to be higher in the studies performed recently. This proves that the Emergency Department physicians develop themselves in time. The success rates of the studies performed increase between the assistants according to senior assistants.

Hoyle et al (12) detected in their prospective double-blind sectional studies that the general accuracy rates in evaluating the ECG interpretation skills between four-year and two-year assistants receiving the emergency medicine training were 67.5% for the senior assistants and 49.6% for two-year assistants and the rates intended to the specific diagnoses were 100% and 85% for the AMI and 43.8% and 37.8% for the atrioventricular complete block and ventricular tachycardia, respectively. The most frequent false diagnosis was supraventricular tachycardia (SVT). Boulouffe et al (13) detected the rates of correct reading the ECG between the medical students, assistant physician and experienced emergency physician in their studies as 59%, 69%, and 77%, respectively. Eken et al (14) compared the ECG interpretations of the cardiologist and emergency physicians in their studies. While the emergency physicians detected 131 patients as class 1 for 31 (23.7%), as class 2 for 66 (50.4%) and as class 3 for 25 (19.1%); the cardiologists evaluated them as class 1 for 32 (24.4%), as class 2 for 60 (45.8%) and as class 3 for 28 (21.4%). The consistency between the emergency physicians and cardiologist in interpreting the ECG was 94.6% for the class 1 patients (kappa = ¼ 0.85), 78.6% for the class 2 patients (kappa = ¼ 0.57) and 79.3% for the class 3 patients kappa = 0.36). While the consistency was 90.8% (kappa = 0.30) for the likelihood classification between two groups to predict the pain as angina or non-cardiac, it was 95.6% (kappa = 0.26) for the classification as the ACS or stable angina and 86.3% (kappa = 0.61) for the low likelihood or medium-high likelihood as the patients.

When the studies researching whether the inconsistencies were clinically significant were

examined, Westdorp et al (15) stated in a study they performed retrospectively that the ECG interpretation of 35% of 716 patients whose ECGs were evaluated was normal and 65% of them was pathologic. In this study, it was stated that the ECG interpretation of 59 of 143 cases discharged in the ECG evaluations made by the cardiologist was compatible with the Emergency Department physician's interpretation and they observed the interpretation inconsistency between two physicians in 83 cases. It was clinically significant for 25 of 83 patients for whom the inconsistency was seen in the ECG interpretations between the cardiologist and Emergency Department physician. While the total inconsistency rate was 58% for the patients discharged in the study, the clinical important inconsistency rate was detected as 17.5%. While there was a compatible ECG as the abnormal rhythm for 7 and as the ischemia or infarct for 15 of the cases having the clinical significant interpretation inconsistency, it was observed that 3 of them did not have a diagnosis. While the most frequent skipped arrhythmia was the AF in the study, the most frequent skipped ischemia or infarct was seen to be the ischemia belonging to the heart's front face. Accordingly, it was reported that the interpretation of the ECGs interpreted in the emergency department would be compatible if they were interpreted by the cardiologist as a result of the study. Bouida et al (16) detected the compatibility rate between the Emergency Department physicians and cardiologist as 76% in a similar study. Snoey et al (17) prospectively evaluated the ECG of the consecutive 300 cases in another study performed and they notified that they found pathologic 198 of 300 ECGs interpreted. 154 ECGs misinterpreted in the study were detected that 56 of them had the small importance in terms of the patient's diagnosis and treatment, 89 of them had the medium level importance and 9 of them had the potential clinical importance. Snoey et al notified in their studies that reevaluating the ECGs and making the ECG controls in the observation would be compatible for not affecting the patients' treatment upon detecting the ECG interpretation inconsistency between the cardiology and emergency department physician. In our study, when the clinic results of the cases interpreted differently were examined, it was seen that the cardiac ischemia was thought for all the cases and consultation was requested from the cardiology department. The question of how the ischemia was thought for the patients whom ECGs were interpreted as completely normal can come to mind here. However, it should not be forgotten that not only the ECG findings but also ischemic pain pattern and general clinic features of the patients are the conditions to be considered in the acute cardiac ischemia. The ECG findings were classified as class 1 for the normal or minor abnormalities, as class ll for the abnormalities that will change the approach to the patient and class lll for the life-threatening abnormalities in a study well-organized by Todd et al (18) and the compatibility was detected as 78%. The compatibility was detected in a study performed by Eken et al (14) as 94.6%, for the ST elevation, as 78.6% for the ischemic changes and as 79.3% for the dynamic ECG changes. Todd et al (18) also notified as a result of the study that reevaluating the ECG evaluations by the cardiologist again would be unnecessary since they were made by the emergency physician. Jayes et al (19) reported that the emergency physicians read 41% of the abnormal ST changes and 36% of the abnormal T waves as normal by mistake. Once again, Kuhn et al (20) determined in a similar study performed on 400 cases that the cardiology and emergency department physician made the same interpretation in 164 of 289 cases, there were inconsistencies containing the minor abnormalities having no clinical importance in terms of the patient seriousness in the interpretations of two physicians in 89 cases and there were differences containing the severe clinical importance in the ECG interpretations in 25 cases. The abnormality containing the differences having the severe clinical importance were determined by the Emergency Department physician in 7 of these cases and by the cardiologist in 18 of them, however, there were no changes in the treatment of these cases.

In our study, we detected that there was significantly compatibility between the cardiologist and EMAs in interpreting the ECGs taken in the emergency department. However, it was also seen that the inconsistencies determined did not affect the clinical course of the patients, because the cardiology consultation was requested for almost all of these patients. Especially, if there were more than one abnormality in the ECG, the EMAs were observed that they were in a tendency to plan the treatment by primarily and frequently evaluating the vital findings. The EMAs' interpreting deficiencies can result from giving importance only to the patients who are important and have vital findings since they have to make a quick decision. An EMA should have the skills to evaluate the ECG as much as a cardiologist makes.

Giving weight to the ECG interpretation in the training seminars made periodically for the EMAs, organizing the case presentations and testing their skills with the bedside ECG interpreting through the frequent quality evaluations are suggested.

References

1. Nicholas D. Hartman, Natasha B. Wheaton, Kelly Williamson, Erin N. Quattromani, Jeremy B. Branzetti, and Amer Z. Aldeen. A novel tool for assessment of emergency medicine resident skill in determining diagnosis and management for emergent electrocardiograms: a multicenter study. The Journal of Emergency Medicine 2016; 51: 697-704.

2. Altan Onat, Günay Can. Prevalence of heart disease in our adults, new coronary events and prevalence of death from heart. TEKHARF 2017.

3. Tığlı D, Atilla R, Topaçoğlu H, Kaynak F. Door to reperfusion time in ST elevation myocardial infarction: four-year experience of an emergency department in Turkey. Türkiye Acil Tıp Dergisi 2006; 3: 122-131.

4. Green GB, Hill PM. Cardiovascular Disease: Approach to chest pain in: Tintinalli JE, Kelen GD, Stapczynski JS: Textbook of emergency medicine sixth ed 2004; 7: 333-343.

5. Eray A. Kalp Hastalıklarında Nükleer Tıp Yöntemleri. In: Cordan J, (eds) Kardiyoloji 2005; 3: 99-105.

6. William J. Brady, Amal Mattu, Robert E. O'Connor. Real-time cardiology overread of the electrocardiogram: where is the value added? American Journal of Emergency Medicine 2011; 29: 316-318.

7. Martin Stockburger, Birga Maier, Georg Fröhlich, Wolfgang Rutsch, Steffen Behrens, Ralph Schoeller, Heinz Theres, Stefan Poloczek, Gerd Plock, Helmut Schühlen. The Emergency Medical Care of Patients With Acute Myocardial Infarction. Deutsches Ärzteblatt International 2016; 113: 497-502.

8. W. Kelly Wu, Maame Yaa A.B. Yiadom, Sean P. Collins, Wesley H. Self, Ken Monahan. Documentation of HEART score discordance between emergency physician and cardiologist evaluations of ED patients with chest pain. American Journal of Emergency Medicine 2017; 35: 132-135.

9. Wayne Hazell. Level of practice for ECG interpretation skills should be 'expert. Emergency Medicine Australasia 2007; 19: 81-85.

10. Ho MT, Kudenchuk PJ, Eisenberg MS, Weaver WD, Martin JS, Litwin PE. Patient selection for thrombolytic therapy. Emergency physician versus electrocardiographer. J Am Coll Cardiol 1990; 15:192A

11. Lee TH, Weisberg MC, Brand DA, Rouan GW, Goldman L. Candidates for thrombolysis among emergency room patients with acute chest pain. Ann Intern med 1989; 60: 219-224.

12. Rachel J Hoyle, Katherine J Walker, Graeme Thomson and Michael Bailey. Accuracy of electrocardiogram interpretation improves with emergency medicine training. Emergency Medicine Australasia 2007; 19: 143-150.

13. Caroline Boulouffe, Bruno Doucet, Xavier Muschart, Bernard Charlin, Dominique Vanpee. Assessing clinical reasoning using a script concordance test with electrocardiogram in an emergency medicine clerkship rotation. Emerg Med J 2014; 31: 313-316.

14. Eken C, Goksu A, Eray O, Yalçınkaya S. The consistency of emergency physicians' and cardiologists' ECG interpretation and likelihood classificationof chest pain patients. Int J Clin Pract 2006; 60: 1194-1197.

15. Westdrop EJ, Gratton MC, Watson WA, ED interpretation of electrocardiograms. Ann Emerg Med 1992; 21: 541-544.

16. Bouida W, Dridi Z, Nouira S. Evaluation of electrocardiogram's interpretation in the ED. Tunis Med 2004; 82: 358-362.

17. Snoey ER, Housset B, Guyon P. Analysis of emergency department interpretation of electrocardiograms. J Accid Emerg Med 1994; 11: 149-153.

18. Todd KH, Hoffman JR, Morgan MT. Effect of cardiologist ECG review on emergency department practice. Ann Emerg Med 1996; 27: 16-21.

19. Jayes RL Jr, Larsen GC, Beshansky JR, D'Agostino RB, Sekler HP. Physician electrocardiogram reading in the emergency department accuracy and effect on triage decisions: findings from a multicenter study. J Gen Intern Med. 1992; 7: 387-392.

20. Khun M, Morgan MT, Hoffman JR. Quality assurance in the emergency department: evaluation of the ECG review process. Ann Emerg Med 1992; 21: 10-15.