Evaluation of Emergency Medicine Residents Competencies in Electrocardiogram Interpretation

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Abstract- An electrocardiogram (ECG) leads physicians to diagnose many potentially life-threatening cardiac, metabolic, electrolyte, and toxicological conditions. This study was designed to evaluate the competency of emergency medicine residents (EMRs) in comparison with cardiologists in the interpretation of ECG when an interpretation checklist is used. This clinical trial was done in the emergency wards of the first grand general hospital of Iran. Patients were categorized in three classes of disorder severity based on ECG abnormalities. The two stages of the study included the survey phase (Stage I), training phase and intervention phase (Stage II). Accuracy of ECG interpretation by EMRs and cardiologists was compared before and after using a Daily ECG Check List (DECKList). One hundred and fifty ECGs were evaluated in Stage I, before DECKList usage, and 150 ECGs were evaluated in stage II, after DECKList usage by EMRs. Mean age of participants was 60.13 years in Stage I and 61.66 years in Stage II. Stage I and II were similar to each other in terms of disorder severity (P=0.22). Mean the ECG interpretation score was significantly different between Stages I and II (P<0.001). Concordance of ECG diagnosis between EMRs and cardiologists was significantly different in Stages I and II (P<0.01). In first-year EMRs, ECG diagnosis scores in stages I and II were not changed significantly. However, ECG interpretation scores increased significantly in first-year EMRs (P=0.04). In second-year EMRs, both ECG interpretation and ECG diagnosis scores improved significantly (P<0.05 and P<0.01, respectively). In third year EMRs, ECG interpretation was not improved but ECG diagnosis based on two methods improved significantly (P<0.05). The significant increase in accuracy of ECG interpretation and final diagnosis can be attributed to the utilization of a checklist by EMRs especially in the first year and second residents.

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Keywords: Electrocardiogram; Emergency medicine; Emergency ward; Interpretation checklist

Introduction

Electrocardiograms (ECG) are a common order in emergency conditions. In emergency departments (ED), initial ECG interpretations are performed by non-cardiologists. Decisions about patient care are made based on these interpretations. In 1991, Zappa *et al*., reported 13% error in ECG interpretation by emergency medicine residents (EMRs) (1). Moreover, in 1992, Schaffer *et al*., compared ECG interpretation between EMRs and cardiologists of a paramedic emergency center in which the agreement in ECG interpretation between EMRs and cardiologists was 96% (2). Todd *et al*., in 1996, investigated the effects of ECG interpretation education packages by cardiologist on ED practice. Todd *et al*., classified ECGs by severity to three classes: Class 1, normal or minor abnormalities only; Class 2, abnormalities with

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potential to alter case management; and Class 3, potentially life-threatening abnormalities (3). A thousand ECGs were interpreted by emergency medicine specialists and cardiologists in whom error in interpretation was found in 190 cases. These patients were then analyzed by a special group of cardiologists. In 72 cases, the diagnosis of emergency medicine specialists was confirmed and in the remaining 118 cases, 72 patients were admitted and 46 patients were discharged. Eight out of these 46 patients were categorized in Class 1 while none of the remaining 36 patients was classified in Class 3. This was one of the most important studies in this field. In another study in which the ST segment elevation has been studied, a high percentage of ECGs (94.9%) were accurately interpreted by emergency medicine professionals (4).

In 2002, Trzeciak *et al*., compared ECG interpretation accuracy and correct management of internal and emergency medicine residents, the results of which revealed similar interpretation and subsequent decision-making in these two groups (5).

In 2004, Pines *et al*., analyzed the results of teaching modalities for ECG interpretation in emergency medicine residency programs. Ninety-nine percent of program directors had planned training programs while 98% had special courses such as conferences and used the ECGs of admitted patients for their training programs (6). Wathen *et al*., examined the accuracy of ECG interpretation in pediatric emergencies. They studied 1653 ECGs of 1501 patients aged from 2 days to 21 years during 3.5 years. The major complaint to perform EGC was chest pain (21%). ECGs were categorized into four classes.

The results revealed that 73% of pediatric emergency medicine specialists and cardiologists similarly interpreted the EGC with sensitivity and specificity of 75% and 98.50%, respectively. In that study, the majority of interpretation errors were observed in patients of class 0 and I (no abnormality and minimally abnormality respectively) (7). Although there are many studies reporting a wide range of concordances between the emergency physicians and cardiologists, there are few studies in the literature are comparing the emergency physicians' and cardiologists' decision making in presence of an ECG interpretation checklist.

In this study our specific objectives are to determine the competency of EMRs in ECG interpretation through the comparison of interpretation results with a cardiologist, and to establish whether the interpretation of the same ECG is changed when there is an interpretation checklist.

Materials and Methods

Study design

A clinical trial study was conducted in the emergency wards of Imam Khomeini complex hospitals, the first grand general hospital of Tehran University of Medical Sciences, Tehran, capital of Iran.

The local ethics review committee of Tehran University of Medical Sciences approved the study protocol.

Study setting and population

ECGs of all medical records of emergency wards were evaluated two times a day (12 MD and 12 MN) for one month in every phase of the study (First phase in July 2010 and second phase in March 2011). ECGs abnormalities were divided into three classes according to disorder severity (Table 1). ECGs which did not have any disorders were assigned to Class I, ECGs presenting a disorder which responded to therapeutic interventions were assigned to Class II, and ECGs presenting a life-threatening diagnosis were assigned to Class III (7).

Study protocol

This study was performed in two stages. Stage I included the survey phase, and Stage II consisted of the training phase and intervention phase.

Survey phase (Stage I)

In the first step, we sought out the EMRs who had ordered the ECGs. We then analyzed the patients' orders and Progress Note. ECGs in which the EMR who had ordered the ECG, had read it himself, were included for this study. If another EMR had read ECG, other than the EMR ordering the ECG, that ECG was excluded. From the 1500 selected cases, 150 cases were selected for each phase using cluster random sampling.

An internet-based survey instrument was created and named Daily ECG Check List (DECKList). Based on EMRs note, DECKLists were filled on the website by one of the authors in the survey phase. Chief complaints and diagnosis of diseases were obtained from patients' history, progress notes, and performed consultations. All selected ECGs were reviewed independently by a cardiologist. A DECKList was then completed by a cardiologist for every examined ECG. EMRs and cardiologist were blinded to the research project and each other's answers. In the designed website, there was the possibility of attaching data regarding cardiac scan and ECG description. Cardiologists were alerted of all new cases via email.

Training and intervention phase (Stage II)

Two, 4-hour training sessions were held in which DECKList usage was taught to EMRs. Moreover, DECKList was introduced as a new obligatory method of ECG interpretation in an emergency ward by the ED director. ECGs were studied and DECKLists filled out by EMRs in the emergency wards. Cardiologists then studied said ECGs and subsequently filled out DECKLists. EMR diagnosis and interpretation of ECGs were both marked in the provided checklists and the ECG uploaded in the website to be interpreted by a cardiologist.

DECKList performance by EMRs for every subject was controlled by emergency room' staff (6 persons), who take patient ECGs.

Table 1. Disorder severity classification criteria for ECG abnormalities

Class I	Class II	Class III
Sinus bradycardia/ tachycardia	Intraventricular conduction delay	Ventricular tachycardia
Ectopic atrial Rhythm		Chronic atrial tachycardia
Junctional rhythm		SVT/atrial tachycardia
Sinus arrhythmia		Atrial fibrillation
Wandering atrial pacemaker		Pacing with loss of capture
Left-sided axis deviation	Right-sided axis Deviation Northwest (superior) Axis	
Atrial enlargement	Right-sided ventricular Hypertrophy	
Consider LVH or RVH	Left-sided ventricular Hypertrophy Biventricular hypertrophy	
First-degree AVB Incomplete right BBB	Second-degree AVB Right or left BBB WPW Bifascicular/ trifascicular block	Complete AVB
Premature atrial Contractions	Frequent PVCs	
Nonspecific ST Changes	ST changes consistent with ischemia	ST changes c/w AMI
Low voltage	QTc prolongation Deep posterior loop/abnormal R-wave progression	

AMI = acute myocardial infarction; AVB = atrial ventricular block; PVC = premature ventricular contraction; BBB = bundle branch block; LVH = left ventricular hypertrophy; RVH = right ventricular hypertrophy; SVT = supraventricular hypertrophy; WPW = Wolff-Parkinson-White

Daily ECG check list (DECKList)

DECKList was designed based on the Novacode classification code for ECG abnormalities (8). The DECKList had two sections, ECG interpretation and ECG diagnosis. ECG interpretation section consisted of 12 items: 1) Rate, 2) Rhythm, 3) Axis, 4) P-wave characteristics and affected leads, 5) PR interval characterization, 6) Q wave affected leads, 7) QRS interval length and affected leads, 8) Undergoing ST changes (elevation or depression) and rate of ST changes, 9) ST changes affected leads, 10) T wave characteristics and affected leads, 11) QT interval characteristics, 12) U wave abnormality and affected leads.

ECG diagnosis section included types of arrhythmias, types of heart blocks, locations and types of acute coronary syndrome, ventricular hypertrophy and location, atrial enlargement and location, pacemaker evaluation in case of presence, other pathologic patterns such as, paroxysmal atrial contraction (PAC), pre exciting ventricular contraction (PVC), Wolff-

Parkinson-White pattern, pericarditis, digoxin toxicity, hyperkalemia, hypokalemia and hypothermia, and a section for a mandatory final diagnosis.

DECKList was regularized and standardized in 6 consequent sessions, by two cardiologists, one internist, and four emergency medicine specialists. All of the items on the DECKList had options for selecting, and just the last part had not any options (mandatory diagnosis).

Measurements

In the ECG interpretation section, one positive score was purposed for each correct choice of any 12 items and one negative score was purposed for each incorrect choice. In the case of no answer, no mark was given. Finally, a mark between -12 to +12 was dedicated as the ECG interpretation score. ECG interpretation scoring was done by one cardiologist.

ECG diagnosis was performed using two methods: Y/N method and a five-point Likert scale. There is a five-point Likert scale ranging from 1 (complete discordance) to 5 (complete concordance) for evaluating diagnosis agreement between EMRs and cardiologists (complete discordance (1), partial discordance (2), without any interpretation or unknown correlation (3), partial concordance (4), and complete concordance (5)). Two authors carried out ECG diagnosis evaluation and in case of trouble; one cardiologist reevaluated the agreement. At last, a scale between +1 to +5 was created. Likert 4 and 5 were considered to be a concordance. Finally, concordance or discordance was dedicated as Likert result of each ECG. In Y/N method, all parts of DECKList was investigated by one of the authors and final concordance rate between EMRs and cardiologist was denoted by Yes or No.

Data analysis

The Statistical Package of Social Science version 15.0 (SPSS, Chicago, Illinois, USA) was used for data analysis. Statistical significance was noted for P value of less than 0.05. *T-test* was used for comparison of age between two stages. Chi Square test was used for the gender difference, class difference and analysis of Y/N method results between two stages. For Likert scale results and ECG interpretation scores of two stages, Kruskal-Wallis test was used. Chi Square and Mann-Whitney u tests were used for analysis of results of Likert scale results and ECG interpretation scores among EMRs in different years of residency.

Results

During the study, 300 ECGs were analyzed – 150 ECGs were evaluated in stage I (from subjects whose ECGs were interpret before DECKList usage by EMRs) and 150 ones in stage II (from subjects whose ECGs were interpret after DECKList usage by EMRs). Mean age of participants was 60.13 years in stage I and 61.66 years in stage II with overall age range of 13 to 93 years. There is no significant age difference between the two stages (P=0.376). Overall 162 males (54%) and 138 females (46%) were included in the study; Ninety-three males (62%) and 57 females (38%) belonged to stage I, and 69 males (46%) and 81 females (54%) to stage II. There is no significant difference between genders in both two stages (P=0.12). Both stages were similar to each other based on disorder severity (Table 2).

Table 2. Disorder severity of ECG abnormalities in two stages of study

	Class I	Class II	Class III
Stage I	22.6%	46%	31.3%
Stage II	30.6%	38.6%	30.6%
***P*-Value**	P=0.226	P=0.226	P=0.226

*P<0.05 is significant

No significant difference was observed between stages I and II in the classes of ECG abnormalities severity (P=0.226).

Mean ECG interpretation score was 1.52 in stage I and 9.72 in stage II. Mean ECG interpretation score was significantly different between stage I and stage II (P=0.001).

Concordance of EMRs with cardiologist in ECG diagnosis, according to Y/N method, was 43.3% in stage I and improved in stage II, to 76.2% (P=0.01).

Concordance of EMRs with cardiologist in ECG diagnosis, according to Likert scale, was 63.3% in stage I and improved in stage II, to 85.3 % (P=0.04).

ECG interpretation scores of several years (different years of residency) of EMRs were significantly different in the first stage (P=0.04).In the stage I where no checklist was used, no significant differences was detected between the EMRs of first, second, and third-year residents in ECG diagnosis, according to Y/N method (P=0.777). Furthermore, according to Likert scale, no significant difference was seen between the EMRs of first, second, and third year (P=0.926).

We compared the EMRs in the first, second, and third years in stage II. The results of ECG diagnosis and ECG interpretation scores showed p values of 0.160 and 0.747, respectively.

In the stage II (with DECKList), the ECG interpretation scores of EMRs, improved from 64.1% in the first years to 96.2% in the second years, which was significantly different between residents of different years (P=0.01). Accordingly, Likert scale showed a significant difference between the EMRs of different years in ECG diagnosis (P=0.001), while no significant difference was observed in the ECG diagnosis based on Y/N method (P=0.097). These results suggest the probable effect of using checklists and education in enhancement of EMRs´ knowledge.

Between the stage I and II, in first-year EMRs, ECG diagnosis score based on Y/ N method and Likert scale was not changed significantly (respectively P=0.253 and P=0.18). However, ECG interpretation score was increased significantly in first-year EMRs (P=0.04). In the second year EMRs, both ECG interpretation and ECG diagnosis scores improved significantly (respectively $P<0.05$ and $P<0.01$). In third-year EMRs, ECG interpretation score was not improved but ECG diagnosis based on two methods has improved significantly ($P<0.05$ and $P<0.05$).

In stage II, ECG interpretation score of EMRs in several years of residency, did not have significant difference (P=0.097), but ECG diagnosis score based on Y/N method, was 64.1% in first year ones, 96.2% in second year and 98.6% in third year EMRs and significant difference was achieved among EMRs (P=0.01). Furthermore, based on a five-point Likert scale, a significant difference was shown among EMRs (P=0.001).

Discussion

The American College of Cardiology and the American Heart Association (ACC/AHA) have suggested the use of three criteria to establish physician competency to interpret ECGs (9). However, these three criteria did not have enough efficacy in the ED to make about 100% competency in emergency room and the ability to interpret ECGs correctly at the bedside, is more important for the competent emergency physician than the ability to read ECGs in isolation long after important patient care decisions have been made (10).

Despite the increased demand of high-tech equipment in healthcare education, there are a number of areas where these educational approaches need to be enhanced. There is currently a wide range of teaching techniques that can be used to train healthcare professionals in the use of 12-lead ECG monitoring equipment and ECG interpretation such as lectures, videos, hospital education beside patients, simulated patient and computerized ECG interpretation.

There are several studies in the literature comparing the assessment of ECGs between different disciplines, and some of them have assessed the accuracy of the ECG interpretations between the emergency physician and a cardiologist. In these studies total discordance rates range from 22% to 58% and ‘‘clinically significant’’ discordance rates are from 8% to 19%. In only a few cases the cardiologists’ interpretation altered patient care (3, 11-13), but new education tools for improve ECG interpretation is needed (14) to improve EMRs’ ECG interpretation into zero discordance. In one of these studies, 8.3% of 400 ECGs had ‘‘undetected potentially significant or critical ECG abnormalities’’; however, in only 2 cases (0.5%) the misinterpretation had adversely affected patient care (12). In another study, on 716 ECGs where 143 were abnormal, discordance rate between the emergency physician and the cardiologist was 58%. Seventeen percent of these were clinically significant, and in only 2 cases (0.03%) would patient care have been altered (11).

Several methods were analyzed but further studies are needed to clarify the optimal training method to build effective ECG interpretation skills (15), to make a correct diagnosis and therefore, improve emergency care of patients with cardiovascular diseases (CVD).

Our study was done in an educational hospital, which contains all medical specialties (internal medicine, infectious disease, general surgery, vascular surgery, obstetrics and gynecology, oncology, orthopedics, neurosurgery and pediatrics). Our center has a helicopter pad, and nearly 400 patients are transferred here by air transportation annually. We have 12 emergency medicine specialists and 2-3 consisting of EMRs in each shift. EMRs are taught in three stages from the first year to third year. Five thousand patients are referred to emergency wards of our hospital each year with almost half being hospitalized in emergency wards. Diagnosis of CVD and management of them in the first step was done by EMRs, in our hospital such as other centers (emergency medicine-based EDs). Different educational approaches were reviewed for improving EMR diagnosis and interpretation skills. DECKList increases the rate of ECG diagnosis in senior EMRs especially and ECG interpretation score was higher in senior EMRs also. Maybe it means high level of knowledge in seniors can present in more right diagnosis by a DECKList in medical records. On the other hand, DECKList showed less improvement in interpretation and diagnosis in junior’s residents. This observation exhibits a low level of medical knowledge, not the accuracy of medical knowledge on ECG interpretation and diagnosis.

Of all the 300 ECGs, we observed 59% of concordance in diagnosis while 41% of cases showed no agreement in diagnosis. However, in a study conducted in 1991, Zappa *et al*. reported 13% discordance between the reports of assistants in emergency medicine unit and cardiologists (1). In another study conducted in 1992, the rate of agreement between ECG interpretation by a cardiologist and a specialist of emergency medicine was reported to be 96% (2).

The agreement rate between the specialist and cardiologist was estimated to be 94/9% in a study conducted by Braddy *et al*. in 2001 (4).

In another study conducted in 2005 in the pediatric ED, the correlation between the specialists of pediatric emergency medicine and cardiologists was reported to be 73% (7).

Interestingly, the error rate in our study is very different from those studies conducted by EMRs. Of course, this difference needs more contemplation. The causes of this conflict could include better training of residents in other centers and requirement of accurate and complete information registration. In the next step, the effect of DECKList in the concordance of the EKG diagnosis should be considered. So that, in stage II in which ECG diagnosis was recorded according to a specified framework, the concordance rate rose to 76.2%.

Such a comparison and scoring has not been performed in previous studies. Another criterion was also used for detection of the match, the accuracy of which was much higher than the agreement. The reason is that little differences in diagnosis of ECG were reported as non-compliance, but as we divided the diagnosis into 5 groups, the error rate decreased.

Using this criterion (Likert scale), the compliance was estimated to be 63.3% (Likert 4 and 5 were considered as agreement). Hence, by applying these three criterions, the accuracy of EMRs in ECG interpretation was evaluated.

In Stage II, the efficacy of DECKList in ECG interpretation score was different in different years of residency, and a greater increase in ECG interpretation score was seen in senior residents. This was especially observed in their ECG diagnosis.

The significant increase in accuracy of ECG interpretation can be attributed to the provision of a DECKList. On the other hand, as the first and second sampling interval was 6 months, it is possible that the training process during this period, their own experiences or lack of similarities between the EMRs of first and second stages has an important impact on the results. Thus, these confounding factors must be considered as well as.

Considering the above data; it can be concluded that lack of checklist can even eliminate the effect of training and knowledge of assistants in the correct diagnosis of ECG. In this way, no significant difference can be observed between the assistant in different years of assistance.

However, in the second stage with the presence of a checklist, a significant difference was observed between the EMRs of different years. The agreement rate was 64.1% in first-year assistants while it was 96.2% in second years (P<0.001).

Similarly; according to Likert a significant difference (P<0.001) was reported between the different years of EMRs while no significant differences was reported according to the accuracy rate (P=0.097). These results suggest the effect of educating the EMRs and DECKList in ECG interpretation.

Discuss shortcomings and biases related to study design and execution. Highlight areas where future investigations and/or different methods of analysis might prove fruitful.

Therefore, it is important to evaluate the accuracy of ECG interpretations of emergency medicine residents.

We conclude that the DECKList in ECG interpretation can reduce junior's errors more than seniors of EMRs.

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