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Adequacy of Electrocardiogram Reading and Interpretation among Emergency Medicine Residents

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ABSTRACT

Background: *The basic skill of being able to read ECGs at a high level of proficiency and accuracy is one of the objectives of the Saudi Arabian Emergency Medicine Residency Training Program (SAEMRTP). Our objective in this study is to assess the ECG reading knowledge and skill proficiency of the residents enrolled in the SAEMRTP in the three major regions of the Kingdom of Saudi Arabia for a variety of clinically important, and in some cases, fatal diagnoses.*

Methods: *This is a prospective cross sectional observational study of Emergency Medicine residents enrolled in the SAEMRTP, with a questionnaire based assessment of the participating subject demographics, and their interpretation of ten 12-lead ECG tracings. The ECGs were selected from a well-known published book reference made for emergency physicians. All ECGs were representatives of deadly conditions that the residents are being taught about, and/or have seen in the clinical setting during their training. The residents were required to indicate the abnormalities in the traces, and their differential diagnosis, under timed conditions. All data was then collected, processed and analyzed to assess proportions, frequencies, and reading skill competency identified from a score of 2 for each ECG (2= correct, 1= partially correct, 0=incorrect). The reference for the findings was the ECG book. Statistical significance was ascertained by use of the Mann-Whitney U test for ordinal data and the Chi-squared test for nominal data.*

Results: *Over the three regions, 132 residents were included in this study. We found that the average overall ECGs read correctly were 16.14% [95% CI 22.71- 9.56%]. There was an observed trend of improving reading competency between the junior residents 10.89% [95% CI 17.72-4.05%] and the senior residents 23.96% [95% CI 29.25-18.67%] p-value < 0.0001. The Competency score mean ranged from: 18.18% for WPW syndrome, to 0.76% for Suspected Digoxin Toxicity.*

Conclusion: *Despite improvement in the interpretation competency with clinical experience, the overall performance of the residents remains alarmingly low. The proficiency of ECG reading skills fall well below the observed international levels of other international programs. Further research into methods for improving the resident proficiency at ECG reading, should be to done in order to improve the current standards.*

INTRODUCTION

In the rapidly developing world of medicine, the presence and acceptance of the emergency medicine physician (EMP) has been well established. Society, and the medical professional world, now look upon this specialized healthcare provider to deliver top quality healthcare to all those who present to the emergency department (ED) in extremis. Accordingly, EMPs are being thought of as being "The Expert" that deals with all things acute.

The skill of reading and interpreting electrocardiograms (ECGs) is an old one that was introduced by Einthoven in 1902. Today, and more than 100 years later, it is amazing that we are still discovering new patterns and criteria to diagnose cardiovascular disease. Use of the modern 12 lead ECG in the ED has served as a standard criterion in the noninvasive diagnosis of many cardiovascular diseases[1,2]. Its cheap cost, uncomplicated application, and applicability at the bedside has made it an invaluable tool for the modern EMP. While previous research has shown that inaccurate ECG interpretation has led to inappropriate clinical decision making, some of which was harmful, and in some cases even fatal, to patients in acute conditions[3,4], ECG training has since become an essential part of graduate medical education.

Starting from the notion that "the eye does not see, what the

brain does not know", both the American Boards of Internal Medicine and Emergency Medicine have added a requirement of ECG training for all house staff [5,6]. Despite this requirement, testing for ECG competency occurs currently in only 21% of all American programs, with only 12% of programs requiring the graduating resident to demonstrate their competency in ECG reading [6].

In Saudi Arabia, the Emergency Medicine Residency Training Program (EMRTP) is only 12 years old. Since its foundations and acceptance by the Saudi Commission for Health Specialties. The EMRTP has undergone a great many changes over the last five years. In 2014 a new curriculum book was produced outlining the different aspects of the specialty that the graduating resident needed to master [7]. In severe locations in this document, being proficient at ECG reading was mentioned, however to this date, no official testing of the ECG competency of the program graduate is being done.

In 2002, the American College of Physicians (ACP), presented recommendations for the training and competency of physicians at reading, assessing and, interpreting ECGs [8]. However, attaining competency varied widely from being able to read an estimated 100 – 800 ECGs.

To this end, we have conducted this study to look at the adequacy of ECG reading and diagnostic competency among the residents currently enrolled in the Saudi Board EMRTP. Our aim was to assess the ECG reading and diagnostic competency of residents in different program years (PGY) of the EMRTP to a variety of abnormal conditions.

METHODS

Study Design

This is a prospective cross sectional questionnaire based study of Emergency Medicine Residents currently enrolled in the Saudi Board Emergency Medicine Training Program (EMRTP).

Inclusion and Exclusion criteria

Subjects included in this study were residents, currently enrolled with active and valid status in the Saudi Board Emergency Training Program in the Kingdom of Saudi Arabia, regardless of healthcare sector sponsoring. Residents who have finished their training, dropped out, or passed their Saudi Emergency Boards were excluded from participation.

Hypothesis

It is our hypothesis, that residents in the Saudi Arabian EMRTP, will show a similar ECG reading competency as the international, and regional emergency medicine programs.

Study Protocol

The study was conducted in the three major regions of the Kingdom Saudi Arabia, mainly at three major sites:1- city of Jeddah, the seat of the western region part of the program. 2- city of Riyadh, the seat of the central region part of the program. 3- city of AlKhobar, the seat of the eastern region part of the program.

Residents enrolled in the EMRTP have a protected educational time every tuesday to attend academic lectures, simulation, reviews etc. As all residents who are not on leave, or on rotation outside the city, are under obligation to attend the academic activity, the study was conducted at the end of the activity during the third week in January 2016. Data was collected from all three cities simultaneously.

Participants were handed a stack of ten ECGs and asked to fill in a demographic questionnaire without prior knowledge of the study. Aims of the study were explained by the data collector at each site. Once the questionnaire had been completed, participants were instructed that for each ECG tracing provided, every resident was required to note any and all abnormalities seen on that ECG, and to provide a differential diagnosis in a *fill-in-the-blank* format. A one minute time limit was allowed for each tracing, after which the resident was supposed to turn to the next tracing. Data collection and time keeping was done and supervised by the data collector as well as the residency director in each region.

The ten ECG tracings included in the study were selected from the "ECG for the Emergency Medicine Physician" book by Amal Mattu and William Brady volumes 1 and 2 published in 2003 by BMJ books, and 2008 by Blackwell respectively. Both books are known to the residents of the EMRTP. ECGs in these reference books were originally collected from the teaching case files at the University of Maryland in Baltimore. Findings in each ECG was documented by the authors, who are well known and respected for their expertise in emergency medicine, and ECG education.

The participants were asked to note any and all abnormalities they can find, such that for example: T wave inversion in lead II (considered an abnormality), T wave inversion in lead III (considered an abnormality), tachycardia (considered an abnormality), irregular rhythm (considered an abnormality) etc. No clinical history was provided with any of the ECG tracings to avoid influencing the participant's interpretation of the ECG. As such, the participants were required to provide a differential diagnosis of each ECG tracing.

The ECG tracings were selected based on pathology that the emergency medicine residents have been taught about in their academic activity, and/or have seen in their clinical practice during their years of training in the ED. A time limit was imposed to simulate the usual time that an EMP looks at an ECG tracing during the shift and makes his/her clinical decision.

Scoring

The data provided by each participant was compared to

the findings and abnormalities mentioned in the reference book, from whence the ECG was taken. The participants were graded based on two items: the ability to note the abnormalities in the ECG tracing, and the inclusion of the book diagnosis within the differential diagnoses provided by the participant.

We have defined a successful reading as the ability of the participant to pick up more than 60% of all the abnormalities on the ECG noted by the book. A successful diagnosis was defined as the inclusion of the ECG diagnosis noted in the book as part of the participant differential diagnoses provided.

A score was given for each ECG based on whether or not a participant had a successful reading and/or a successful diagnosis for that tracing. A successful reading earns 1 point, and a successful diagnosis earns 1 point. Hence the maximum any one participant can get for any ECG tracing is 2 points out of 2. Should the subject get the successful reading and not the diagnosis or vice versa, they would receive 1 point out of 2. And should the subject have a failed reading (defined as NOT being able to note > 60% of the ECG abnormalities) and an incorrect diagnosis, or if no answer was provided, they would receive 0 points out of 2. The scoring was done by two blinded graders. As such, the maximum score for any participant in this study is a total of 20 points for all 10 ECGs.

Data Analysis

All collected data was entered into a Microsoft Access 2013 data base for cross referencing and analysis. Participants were divided by PGY and into junior and senior residents. Junior residents were those residents in PGY 1 and PGY 2, while senior residents were those residents in PGY 3 and PGY 4. Participants were also divided by regions into Western, Central and Eastern regions.

Microsoft Excel 2013 was then used in tandem to analyze proportions, frequencies, means and percentiles. Due to the non-normal distribution nature of the data statistical significance was defined as a p-value < 0.05 attained by the Mann-Whitney U test for ordinal data, and the Chi-squared test for categorical data.

Ethics

This study protocol and proposal has been review and approved by the internal review board of the King Abdullah International Medical Research Center at the King AbdulAziz Medical City of the Ministry of the National Guard Health Affairs – Jeddah – Saudi Arabia. The Study protocol was passed and approved with protocol number RJ16/007/J on 13/1/2016.

RESULTS

Data for this study was collected at the three sites of Jeddah, Riyadh, and AlKhobar simultaneously. A total of 132 residents were surveyed, out of 187 registered residents. The missing residents were designated as follows: 5 were on sick leave, 12 were on annual leave and the rest were on rotation outside the three main study sites, and were logistically difficult to get a hold of.Below table 1 shows the demographics of the participants enrolled in the study by sex, year and region.

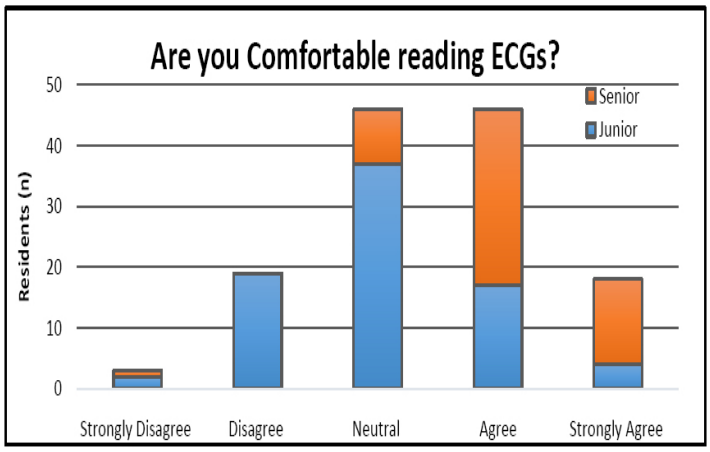
Table 1. Demographics of study population (n=132)

Sex	
Male	**85 (64.4%)**
Female	**47 (35.6%)**
Program year	
PGY 1	**47 (35.6%)**
PGY 2	**32 (24.2%)**
PGY 3	**26 (19.7%)**
PGY 4	**27 (20.5%)**
Region	
Western	**21 (15.9%)**
Central	**85 (64.4%)**
Eastern	**26 (19.7%)**

The participants were asked to indicate their level of confidence and comfort on a scale from 1 to 5 at reading ECGs. Where 5 is being strongly confident and comfortable at ECG reading and interpretation, and 1 is being completely uncomfortable andnot confidant. The mean (SD) for each year was: PGY1 = 2.77/5 (0.87), PGY2 = 3.41/5 (0.76), PGY3= 3.81/5 (0.57), and PGY4 = 4.26/5 (0.90). With increasing years in the program the residents claimed better comfort and confidence in their ECG reading ability as shown by graph 1.

We sought to determine whether there was any correlation between the ECG competency reading scores and the self-rated proficiency of the program residents across the program years, the correlation coefficient r ranged from 0.0157 to 0.271 showing a slight positive correlation but all p values were > 0.05, indicating a non-significant association.

The ECG interpretation scores for each ECG tracing is shown in table 2. The scoring for the ECG competency was done based on the participant's ability to pick out the abnormalities in the ECG tracing, and then form a differential diagnosis. The participant was then given a Correct answer (score of 2) for getting a successful reading and the diagnosis of the ECG correct. A Partially Correct answer (score of 1) was given if the participant had either a successful reading with an incorrect diagnosis, or a failed reading with a correct diagnosis (i.e. one or the other, but not both). An Incorrect answer (score of 0) was given if the participant had a failed reading, and the diagnosis was incorrect, or if no answer was given. As such each participant will have a score out of 20 for all ECGs in the study, this is what we have referred to as "the competency score".

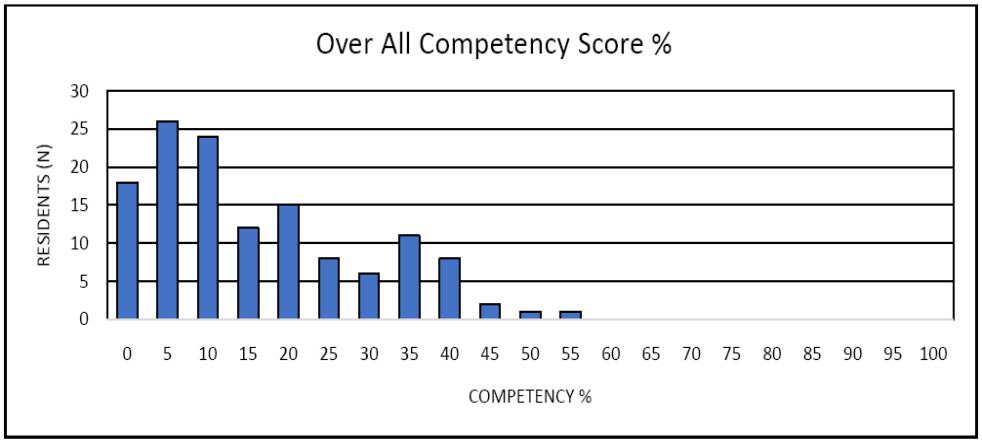


Graph 1.

The overall score competency for the residents was 16.14% [95% CI 22.71- 9.56%]. There was an observed trend of improving reading competency between the junior residents 10.89% [95% CI 17.72-4.05%] and the senior residents 23.96% [95% CI 29.25-18.67%] *p*-value < 0.0001. As it is apparent in table 2, the highest competency score given by all residents was that of WPW syndrome (18.18%). The lowest competency score was that of Digoxin toxicity, Hypertrophic cardiomyopathy, and surprisingly hyperkalemia (0.0%). The most common abnormality noted by residents was that of the biphasic T wave of the Wellens sign (41.67%), unfortunately most of those participants did not know what the abnormality meant as only 1.5% included Wellens syndrome in their differential diagnosis. Over all, the competency scores are below the 60% mark as is evident in graph 2.

Table 2. ECG Interpretation Competency Scores

No.	Diagnosis	Correct		Partially Correct		Incorrect	
		n	%	n	%	n	%
1	Intracranial Hemorrhage	1	0.76	19	14.39	112	84.85
2	Brugada Syndrome	16	12.12	14	10.61	102	77.27
3	LMCA Occlusion	1	0.76	38	28.79	93	70.45
4	Prolonged QT Interval	2	1.52	45	34.09	85	64.39
5	Hyperkalemia	0	0.00	51	38.64	81	61.36
6	WPW Syndrome	24	18.18	45	34.09	63	47.73
7	Pulmonary Embolism (S1Q3T3)	10	7.58	21	15.91	101	76.52
8	Hypertrophic Cardiomyopathy	0	0.00	25	18.94	107	81.06
9	Wellens Syndrome	2	1.52	55	41.67	75	56.82
10	Regularized AF (Digoxin Toxicity)	0	0.00	1	0.76	131	99.24



Graph 2.

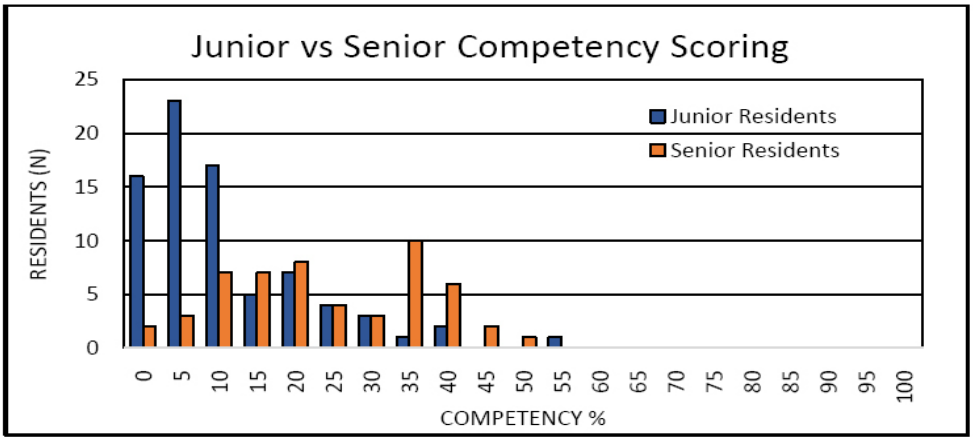
With regards to the regions that the participants subscribe to, table 3 give the details and percentiles for the competency scores observed across the program years.

In each region there seems to be a PGY that seems to stand out. In the Eastern region the PGY1s did somewhat better than the other two regions, while PGY2s the Western and Central region performance were the best. The Central region's PGY3s outdid their counter parts in the other regions, and the PGY4s in the Western and Eastern regions showed the best performance of the entire cohort. All results and differences observed were found to be of statistical significance and unlikely to be due to chance.

Table 3. All ECG Competency Scores Based on Program Year

	PGY 1	PGY2	PGY3	PGY4	*p*-value
	Competency Score %	Competency Score %	Competency Score %	Competency Score %	
Western Region					
• Mean	5	18.33	12.5	28.75	
• Median	5	15	12.5	32.75	**0.00018**
• SD	5.590	19.66	10.61	13.15	
Central Region					
• Mean	6.97	19.06	20.5	3.63	
• Median	5	17.5	20	35	**< 0.00001**
• SD	7.39	13.19	11.57	14.25	
Eastern Region					
• Mean	9	12.5	10	27.14	
• Median	5	10	10	30	**0.00113**
• SD	10.83	4.86	4.08	6.99	
Over All					
• Mean	6.81	16.88	18.27	29.44	
• Median	5	12.5	15	35	**< 0.00001**
• SD	7.40	12.75	11.22	12.27	

Although the overall resident ECG reading competency was low, it was observed that the competency scoring of the senior residents was somewhat better than the junior residents. This is, of course, an expected trend to find as residents who have been in the EMRTP longer should be more experienced than those who have just joined. This difference is seen in the plot in graph 3.



Graph 3.

DISCUSSION

It is absolutely clear from the results of this study, that the ECG reading competency skills of the emergency medicine residents enrolled in the Saudi Arabian EMRTP is very low, and leave a lot to be desired. Previous research into this question has shown EMPs to have ECG reading discordance with cardiologist, taken to be the gold standard in these studies, from 22-58%, and "clinically significant" discordance from 8-19% [3,15,16]. While this was true of fully certified physicians, previous studies that looked at the resident's ability to read and interpret ECG, showed that the emergency medicine residents reading accuracy ranged from 36% - 80% [3,8,10]. Previously in the US family practice program, the resident competency scores reached 70% [17]. While scores of their counterparts in family practice in the UAE, for the same ECG tracing were only about 38% [11].

Having said that, in all fairness, we need to point out two items of information that may explain the large difference seen in the competency score results of this study and those of previous studies. The first item that was different in our study was the time limit that was imposed on each ECG. To our knowledge all previous ECG studies done looking at residents ECG reading ability did not employ a time limit. This was in part to simulate the clinical setting, as most physicians in the clinical shift do not look at an ECG for more than 1 minute, as well as this is what these residents will face during aCanadian Medical Evaluation Exam (CMEE), a US Medical License Exam (USMLE)or the Saudi Arabian Board of Emergency Medicine Exam (SABEM).

The second item is that the ECGs that were chosen in previous studies were more in line with what one might find in the ACLS. ECGs with diagnoses such as : Acute anterioseptal MI, Ventricular Tachycardia, Sinus bradycardia, first and third degree heart block, Atrial fibrillation, atrial flutter, and acute pericarditis. The only two ECG diagnoses we have presented to our subjects in this study that were included in previous studies were Hyperkalemia, and WPW syndrome. We have deliberately deviated from what was studied before, simply because we do not consider the identification of sinus bradycardia or atrial flutter for example by the emergency medical resident, a triumph, in any way shape or form. Instead we expect that the emergency resident in training to be able to identify more serious and subtle diagnoses just as easily.

Hence, to our knowledge this is the first ECG study that included intracranial hemorrhage, Brugada Syndrome, Wellens Syndrome, Pulmonary Embolism, Hypertrophic Cardiomyopathy, Prolonged QT, Left Main Coronary Artery Occlusion, and Digoxin Toxicity, as ECG diagnoses being tested. Should we have used the diagnoses previously used we suspect the results would have been better and more consistent with the international numbers observed previously.

Selection of the ECGs was done to include clinically significant diagnoses. All diagnoses have been taught in the academic activity of all residents, and the majority were seen in clinical practice by the residents at some point during their training. Proper interpretation of these ECGs in real life is important, and inaccurate reading can lead to inappropriate management that results in an increased morbidity and even mortality in some cases. |We have thus made our selection of ECGs from a well referenced book, and made our reference findings for each ECG, those that were listed in the book. We could have just as easily used two blinded cardiologists to read the ECGs and then looked at their agreement coefficient kappa. However this is just as reliable, and more appropriately so as residents are expected to learn what is in the reference books as their board exam questions use the book answers as the reference of a correct answer in the exam.

The definition of a successful reading was if the participant picked up 60% of the findings on the ECG. This percentage was chosen simply by consensus, as the passing mark on the end service exams, and the board exam is 60%. We have looked hard in the literature to find what constituted ECG competency, however we have found that there has never been an agreed upon definition of what was needed to attain ECG reading competency. Since this is integral to our question, the only avenue that remains is the comparison of the residents in the Saudi EMRTP to those in the international programs worldwide.

Despite the results showing that our residents fall way below the international competency scores of other programs, we have observed an improvement trend in the reading competency as we go from junior residents to senior residents. This has been demonstrated previously by Gillespie et al in 1996 as he tested the ECG reading skills of junior house officers against those of senior house officers, he found that the seniors were better [13].

Limitations

Our study has the following limitations:

1. ECG competency and reading ability can be affected by tiredness, post night duty and such. Having done the study at the end of an academic activity, the participants might have been mentally exhausted.
2. Imposing a time limit of each ECG might have given the residents a tight time to write down their observations, and thus some slow writing residents might have left some ECG answers blank simply due to time constraints and not due to lack of knowledge.
3. The extent of ECG training of each subject was not taken into consideration. Some residents might have had more intensive ECG teaching than others.
4. A large number of residents were inaccessible, and that could have had a profound effect on the results
5. The ECGs were given to the subjects without any clinical history, which in most cases is essential for the diagnosis, however only a differential diagnosis was requested.
6. While our scoring system has been used before [14] , there were alternate ways of scoring the data that would have given a different result.
7. ECG diagnoses used in this study, although were taught in the emergency medicine curriculum, were substantially more difficult than the ECGs used in previous studies.

CONCLUSIONS

The level of ECG reading competency among the residents of the Saudi Arabian Emergency Medicine Residency Training Program is way below the international levels of residents enrolled in international programs. Despite an improvement that was observed across increasing program years, the overall level was still low. No region singled itself out from the others, and the inability of the residents to identify potentially

lethal ECG diagnoses points to the need to implement new methods of teaching ECG reading throughout the program, coupled with the possibility of creating a competency exam for the graduating residents, as this is a serious problem that needs to be remedied.

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