OPEN ACCESS

ISSN: 2835-9496

Hassan MM, et al. (2024): 519
DOI: 10.47991/2835-9496/AJCMR-146

Research Article

American Journal of Clinical and Medical Research

Electrocardiogram Competency Among Undergraduate Medical Students in Malaysia

Muhammad Mujibuddin Hassan[1], Rawan Jad[1], Ng Lee Mei[1], Ou Kai Qi[1], Muhammad Amir Ashraf Zakaria[1], Nisar Ahmed Mir[2], Poh Kok Wei[3], Sherreen Elhariri[4*]

[1]Medical graduates, International Medical University (IMU), Malaysia.
[2]Department of Orthopaedics, IMU, Clinical Campus, Kluang.
[3]Department of Internal Medicine, IMU, Clinical campus, Seremban, Malaysia
[4]Department of Surgery, IMU, Clinical campus, Seremban, Malaysia.

[*]**Corresponding author:** Sherreen Yehia Zakaria Elhariri, Department of Surgery, International Medical University (IMU), clinical campus, Seremban, Malaysia. E-mail: sherreenelhariri@imu.edu.my; Tel: (+60)1137778327.

Citation: Hassan MM, Jad R, Mei NL, Qi OK, Zakaria MAA, et al. (2024) Electrocardiogram Competency Among Undergraduate Medical Students in Malaysia. Ameri J Clin Med Re: AJCMR 146.

Received Date: 23 June, 2024; **Accepted Date:** 29 July, 2024; **Published Date:** 05 August, 2024

Abstract

Background: *Accurate interpretation of electrocardiogram (ECG) abnormalities is a core competency for medical school graduates to be able to identify basic abnormalities that are commonly seen in clinical practice.*

Methods: *A cross-sectional survey was conducted at International Medical University, medical students from third to fifth years were given an online-based questionnaire to evaluate the Electrocardiogram Competency level and its correlation with other factors such as seniority, future specialty interest, attendance of formal ECG classes, and self-study of ECG. The validity and the standard-setting of pass marks for the questionnaire were determined using the Angoff method by a panel of five qualified doctors from the medical department.*

Results: *The total number of students that took part in the research was 150 (74 male,76 female). The students were able to interpret the primary ECG parameters such as identifying sinus rhythm, calculating the rate, and identifying the cardiac axis with percentages of 58%, 70%, and 60% respectively. For common ECG emergencies 88%, 84%, and 81% of students were able to accurately identify Hyperkalaemia, Ventricular Tachycardia, and ST elevation myocardial Infarction (STEMI)respectively, however, only 39% were able to identify hypokalaemia, 50% Ventricular Fibrillation, and 58% of 3rd-degree Atrioventricular (AV) block. For common non-emergencies, more than half of the participants were able to identify all ECGs correctly. The students achieved a score equivalent to or higher than the standard pass mark relevant to their semester with a significant P-value ($P < 0.05$).*

Conclusion: *The study showed that a higher reported scale of confidence levels was directly associated with better competency in ECG interpretation skills among medical students, which is determined by many factors like self-directed learning, future specialty interests, web-based training, and attendance at formal ECG training via lectures or small group teaching.*

Keywords: *Electrocardiogram, ECG Competency, Medical Students, Malaysia.*

Introduction

Electrocardiogram (ECG) is commonly used in the diagnosis of different heart diseases, including many life-threatening conditions, accurate interpretation of ECG abnormalities is an essential skill for medical graduates [1]. ECG Interpretation Competencies are the ability to identify basic abnormalities that are commonly seen in clinical practice and the ability to classify them into urgent, non-urgent, or routine medical interventions.

Antiperovitch et al, 2018 published a guideline for designing an ECG curriculum for undergraduate trainees [2], based on the initial draft of proposed ECG interpretation competencies developed at Queen's University in Ontario, Canada in which ECG patterns are divided into 4 categories: common ECG emergencies, common nonemergency patterns, uncommon ECG emergencies, and uncommon nonemergency ECGs. The milestone indicating sufficient ECG interpretations is when medical students can recognize with a certain degree of accuracy most of the emergency patterns of ECG such as myocardial infarction, ventricular tachycardia, etc., by the end of the undergraduate study [2].

Concerns about the rate of misdiagnosis involving life-threatening ECGs continue to rise resulting in inappropriate management decisions with adverse and sometimes fatal patient outcomes [2]. Studies show that the outcomes of missed high-risk ECG abnormalities that the patients did not receive ideal treatment due to misdiagnosis were 21% less likely to receive aspirin, 20% less likely to receive beta-blockers, and 48% less likely to receive reperfusion therapy due to misinterpretation by junior doctors [3]. Unfortunately, various research on residents, physicians, and surgeons reported a low level of competency to

accurately interpret ECGs and low confidence among residents in their level of ECG proficiency [3-5].

Studies on ECG competency among medical students are limited and universal research has reported suboptimal proficiency levels of ECG interpretation among them [1,6].
Multiple factors such as lack of training, future specialty interest, and clinical exposure contributed to those findings. A recent study in Poland found that Polish students were able to identify basic ECG parameters such as cardiac axis, heart rate, and heart rhythm, but their ability to recognize emergency ECGs and common arrhythmias was insufficient **[**6].

At International Medical University Malaysia (IMU), pre-clinical students are taught basic ECG parameters, common arrhythmia, and emergency ECGs. When students enter the clinical phase, they are taught in-depth ECG knowledge by clinical professors and required to complete advanced cardiac life support (ACLS) certification before their final year.

Therefore, the study aimed to evaluate the ECG competency of medical students, and to correlate their performance with self-reported confidence and adequacy of ECG training.

Methods

1. Study population:

Students in the MBBS program from years 3,4 &5 were enrolled on an online-based questionnaire on the IMU e-learning portal. The performance of junior students (3rd, and 4th years) was compared with senior students (5th year). Our Inclusion Criteria were Current third, fourth, and fifth years IMU, medical students. Exclusion criteria were first and Second-year students, other students who do not consent to participate in the study, or not from IMU.

1. Web-based survey:

The online questionnaire consisted of two sections. The first section gathered data related to demographics that included gender, age, and seniority defined by the current year not by age to be classified as either Junior or senior students. Future specialty interest (the students can choose more than one specialty). The participants were asked if they had attended any formal ECG-related classes (including university-taught classes, formal training special courses, and ECG workshops) by answering yes or no, if yes, we will ask them if they feel these formal ECG classes were sufficient. Using a Likert scale from 1 to 10 (1 is insufficient,10 is sufficient), what are the numbers of formal ECG classes they attended?
They were asked if these formal ECG-related classes would be enough to pertain to their knowledge of ECG using a Likert scale (from 1 to 10). Also, asked about self-directed learning (self-study) of ECG (the answer was yes/no). Finally, they were asked how confident they were in ECG? using a Likert scale (1 is unconfident,10 is confident). Then statistically evaluate the effect of advanced grade level and the correlation between other factors including gender, seniority, and future specialty interest. etc.,
The second section assessed the student's ability to recognize normal, abnormal, and critical ECGs that require immediate medical attention via a questionnaire. There are a total of 20 strips and the student will be allocated two minutes to evaluate a single strip. The first three questions will show an ECG strip, and he is asked to assess its heart rate, rhythm, and axis deviation, for each question the student will be given 4 choices. He will pick the choice that would best describe the abnormalities represented by the ECG.

2. Study design:

This was a cross-sectional study. The design of the ECG was guided by ECG interpretation competencies developed at Queen's University in Ontario, Canada, which classified the ECG into common and uncommon patterns of ECG. and put the list for each group. Group of Common ECG emergencies. This group contains ECG findings that require recognition within minutes to deliver potentially lifesaving care [2]. For this reason, undergraduate medical education programs should prioritize mastering the common conditions to minimize the risk of misdiagnosis and late recognition. A group of common non-emergency ECG patterns represent common findings that are seen daily in patients who are not acutely ill and may impact patient care in a clinically appropriate context. The group of uncommon ECG conditions represents the less common findings that are not seen every day.

3. ECG selection:

ECG strips were selected by the authors from our university teaching materials, after the ECG strips selection, a panel of five consultants was asked to independently interpret the ECG strips and review the questionnaire, then agree to include the ECG in the final questionnaire. We modified our questionnaire so that it had a one-time response, the student will be allocated two minutes to evaluate a single strip. Ensuring that the participants were unable to change their responses afterward and making our research foolproof.

4. **Competency level**: the competency level of the participants was defined as achieving a score equivalent to or higher than the standard pass mark relevant to their study year (junior vs. senior) which was placed by our specialist panel.
5. **The validity and the standard-setting**: The passing mark for the ECG questionnaire, was determined using the Angoff method by a panel of five IMU professors, they were asked to identify the credible pass mark for juniors and seniors students after going through the 20-item ECG test and imagining a group of borderline students (those who are not good enough to pass but not bad enough to fail the examination) for each question. They then predicted the percentage of these borderline students that would get each question correct. The average sum was used to set two passing grades for juniors and seniors respectively.
6. **The sample size** was calculated via OpenEpi, Version 3, an open-source calculator.
7. **Statistical analysis:**

The proportion of correct answers to an individual question was calculated. *P* value <0.05 is statistically significant. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS). The marks of each group were compared versus the standard pass mark set for their respective level, and junior students were compared versus seniors as well as using the student's t-test. Continuous variables were described as means ± standard deviations. The presence of an association between the demographics data (age, gender, year in

medical school, future specialty interest, attendance of formal ECG classes, self-study of ECG, and self-reported confidence in ECG interpretation) and its effect on ECG proficiency was analyzed using the student chi-square. Univariate logistic analysis was used to identify predictive factors for a pass mark, significant variables will be used in a multivariate regression model to identify co-dependency.

Results

Characteristics of the Study Group:

The total number of students that took part in the research was 150 (74 male,76 female). The baseline characteristic is shown in (Table 1). Future specialty interest was also considered. The most popular future specialty interests were Internal Medicine (IM), Surgery, Accident & Emergency(A&E), and Paediatrics respectively (Table III). The participants were asked if they had attended any formal ECG-related classes (including university-taught classes, formal training special courses, and ECG workshops), and 134 students answered yes with most of them being juniors (88 students). They were asked about the number of formal ECG classes they attended the reported average number was only 1.99 classes (Juniors attended 1.74 classes and Seniors attended 2.51 classes). They were asked if these formal ECG-related classes would be enough to pertain to their knowledge of ECG the mean scale given by students was 5.58(juniors scale 5.24, seniors 6.29). They were asked about self-study, and 104 students answered yes, (69 students were juniors while 35 were seniors). Finally, they were asked a question about how they were confident in ECG interpretation. The mean scale given by students was 4.65(juniors scale 4.24, seniors 5.51).

Table 1: Characteristics of the Study Group.

	Junior	Senior	Total
Male	42	32	74
Female	59	17	76
Total	101	49	150
Age (Years) SD	23 ± 0.999	24.06 ± 1.107	23.35 ± 1.10

Competency in ECG interpretation:

The students in the clinical year were able to interpret the primary ECG parameters such as identifying sinus rhythm, calculating the rate, and identifying the cardiac axis at rates of 58%, 70%, and 60% respectively. ECG abnormalities were then classified based on 2 main classes: common (emergencies, and non-emergencies), and uncommon (emergency and non-emergencies) (Table 2).

Common ECG patterns:

Six common ECG emergencies: were included in this questionnaire: Hypokalaemia, Hyperkalaemia, STEMI, 3rd-degree Atrioventricular (AV) block, Ventricular tachycardia (VT), and Ventricular fibrillation (VF). 88%, 84%, and 81% of students were able to accurately identify Hyperkalaemia, VT, and STEMI respectively; there were no significant disparities between junior clinical students in interpreting them. However, only 39% were able to identify hypokalaemia, 50% VF, and 58% 3rd-degree AV block. Furthermore, the most significant difference between junior and senior students in interpreting those ECG was in identifying 3rddegree AV block (46% vs 84%) and VT (77% vs 98%).

Nine common non-emergencies were included in this questionnaire**,** 1stdegree AV block, Paroxysmal SVT, Sinus Tachycardia, Complete Left Bundle Branch Block (LBBB), Right Bundle Branch Block (RBBB), Left Ventricular Hypertrophy (LVH), Atrial fibrillation (AF), Atrial Flutter, Wolf-Parkinson-White Syndrome (WPW). More than half of the participants were able to identify all ECGs correctly, with the highest percentage of them being able to correctly recognize LVH (81%). However, in general, there was a vast difference between the ability of juniors versus seniors to incorrectly identify the ECG, with more seniors being able to do so. The difference in values when comparing the ability of junior students is shown in (Table 2). The largest disparities were prominent when it came to identifying 1st-degree AV block (58% vs 90%) and AF (52% vs 88%).

Uncommon ECG patterns were included in this questionnaire; Right Ventricular Hypertrophy (RVH) and only 33% of students were able to identify it (34% juniors vs. 33% seniors). Also, Ventricular Bigeminy and 60% of students were able to recognize it (52% juniors vs. 76% seniors).

Table 2: Competency in the interpretation of electrocardiogram by seniority.

Correct answers for each ECG					
ECG Questions		Junior N:101 (%)	Senior N:49 (%)	Total N:150(%)	*p**
1	Rhythm	54 (53)	33 (67)	87 (58)	0.106
2	Rate	72 (71)	33 (67)	105 (70)	0.621
3	Cardiac axis	59 (58)	31 (63)	90 (60)	0.57

Common emergencies pattern					
4	Hypokalemia	42 (42)	17 (35)	59 (39)	0.418
5	Hyperkalemia	87 (86)	45 (92)	132 (88)	0.314
6	STEMI	81 (80)	41 (84)	122 (81)	0.608
7	3rd Degree AV block	46 (46)	41 (84)	87 (58)	0.001
8	Ventricular Tachycardia	78 (77)	48 (98)	126 (84)	0.001
9	Ventricular Fibrillation	48 (48)	27 (55)	75 (50)	0.384
Common non-emergencies pattern					
10	1st Degree AV block	59 (58)	44 (90)	103 (69)	0.000
11	Paroxysmal SVT	53 (52)	42 (86)	95 (63)	0.000
12	Sinus Tachycardia	58 (57)	38 (78)	96 (64)	0.016
13	Complete LBBB	66 (65)	34 (69)	100 (67)	0.622
14	RBBB	77 (76)	39 (80)	116 (77)	0.645
15	LVH	80 (79)	42 (86)	122 (81)	0.337
16	Atrial Fibrillation	53 (52)	43 (88)	96 (64)	0.000
17	Atrial Flutter	70 (69)	48 (98)	118 (79)	0.000
18	Wolf-Parkinson-White (WPW) pattern	72 (71)	38 (78)	110 (73)	0.416
Uncommon pattern					
19	RVH	34 (34)	16 (33)	50 (33)	0.902
20	Ventricular Bigeminy	53 (52)	37 (76)	90 (60)	0.007
*P -value comparison between Junior &Senior groups.					

The competency level of the participants:

The mean marks for the juniors were (59.74%,60.93% &66.31%) respectively, so more than the standard pass mark for them which was set at 41.65%.

The mean marks for the seniors were (71.2%, and 79.37%), more than the standard pass mark for them which was set at 53.7%. The overall competency level showed that both junior and senior medical students have achieved a competent level. The mean score was increased as the seniority of the semester increased which correlated to semester 6 having the lowest average (59.74%) versus semester 10 scoring the most (79.38%).

Competency level between junior vs senior:

The failure numbers are 17 out of 150 (16 are junior &1 senior) with a P value 0.01, so the competency level between juniors and seniors was significant ($P < 0.05$).

Table 3: Chi-square test &Student T-test of Comparison of competency level with baseline characteristic.

According to gender and age.					
Demographics		All	Incompetent	Competent	p
Gender	Male	74	7	67	0.475
	Female	76	10	66	
Age (years) ± SD		23.35 ± 1.141	23.35 ± 1.145	23.35 ± 1.101	0.98

Seniority	Junior	101	16	85	0.00
	senior	49	1	48	
According to future specialty interests					
Internal Med		59	6	53	0.72
Surgery		57	7	50	0.774
A&E		29	4	25	0.642
Paediatrics		29	2	27	0.401
O&G		25	1	24	0.205
Ophthalmology		22	3	19	0.712
Psychiatry		19	2	17	0.905
Orthopaedic		18	3	15	0.447
Family Med		17	0	17	0.117
ENT		7	0	7	0.333
Attend ECG class	Yes	134	16	118	0.497
	No	16	1	15	
Suggested enough numbers of class (mean) ± SD		5.58 ± 2.352	5.06 ± 2.384	5.65 ± 2.349	0.334
Number of formal classes (mean) ± SD		1.99 ± 1.293	1.76 ± 0.97	2.02 ± 1.328	0.349
According to Class attendance and Self-study.					
Self-study	Yes	104	10	94	0.318
	No	46	7	39	
Confidence scale (mean) ± SD		4.65 ± 1.956	3.18 ± 1.94	4.84 ± 1.882	0.001

Table 4: Multivariable regression model.

Covariate	B	S.E.	Wald	df	p-value	Exp (B)	95% C.I. for EXP (B)	
							Lower	Upper
Seniority	1.703	1.073	2.52	1	0.112	5.492	0.67	44.981
Scale confidence	0.367	0.148	6.176	1	0.013	1.443	1.081	1.927

Table 3&4 showed competencies in ECG interpretation were largely affected by seniority. In this research, we found out that medical students with higher confidence levels tend to have better competency in ECG interpretation, regardless of their seniority. Since the results showed the presence of more than one independent factor that may influence ECG interpretation proficiency, we used a multivariable regression model to identify which factor was more vital. Interestingly, after using the multivariable regression model, the scale of confidence proved to be more significant than seniority.

Table 5: Chi-square test of confidence level based on multiple characteristics. For the competent (passed students).

A) According to gender and age				
	Demographics	**High confidence**	**Low confidence**	***P***
Gender	Male	48	19	0.128135
	Female	39	27	
Age (years)	Older	40	14	0.082551
	Young	47	32	
B) According to future specialty interest				
Selected Top future specialties interest	Internal Medicine	34	19	0.80323
	Accident & Emergency	4	25	0.641752
	Family Medicine	0	17	0.1175
	Paediatrics	2	27	0.019881
Attend ECG class	Yes	83	35	0.00081
	No	4	11	
Number of formal ECG classes attended	A high number of classes	65	11	0.00
	A low number of classes	22	35	
Self-study	Yes	65	29	0.159702
	No	22	17	

As shown in (Table 5) we used the Chi-square test to identify which characteristics influenced the scale of confidence level. Concerning the top 4 medical specialties chosen by the students, we found that confidence level was influenced by the future specialty of interest as internal medicine, A&E, family medicine& paediatrics, the number of ECG classes attended confidence level, showing that students have a better confidence level if they attended ECG classes compared to students that did not attend any ECG classes.

Discussion

ECG interpretation is one of the most challenging parts of the final exams in medical schools [6]. Several studies have highlighted incompetency in ECG interpretation among medical students from different countries [7]. There are major difficulties in comparing different studies concerning ECG interpretation since electrocardiograms and methodologies used in those studies were very diverse.

In our study, students were able to interpret the primary ECG parameters, up to 70%, in comparison to other studies by Getachew M et al, and Kopeć et al, which was 61.3%, and 86% respectively [6,8].

The competency level of the participants was defined as achieving a score equivalent to or higher than the standard pass mark relevant to their semester (junior vs. senior). The overall mean average of ECG interpretation for common, uncommon& emergency ECG in our study for the semester 6,7, &8(juniors) were (59.74%,60.93% &66.31%) respectively, and for semester 9&10 (seniors) was (71.2%, and 79.37%). Like Kopec et al, the overall results were 66% for seniors & 56% for Juniors. Lever NA et al in New Zealand, reported only 52% overall accuracy [6,9], in contrast to Getachew et al in Ethiopia, who reported the overall average was 35.9%. Likewise, Jablonover et al found 37% accuracy in ECG interpretation [1,8]. It may explain the high discrepancy in the accuracy (17% to 63%) in ECG interpretation by students described by Salerno et al, in their systematic review of papers for medical students in preclinical & clinical years [7]. This phenomenon can be explained by ECG exposure as senior medical students have longer exposure to various ECG patterns as compared to juniors, hence allowing them to recognize common ECG abnormalities better, and it is logical to be affected by seniority.

In the current study, competency in ECG interpretation was higher in students who reported SDL, same results as Kopeć et al. Also, we observed that students who thought that they attended enough numbers of ECG classes showed a high confidence level, contrary to Kopeć et al, report that no difference was found between students who attended or did not attend regular ECG classes [6]. In the current study, SDL during the clinical years significantly improved the students' skills, same as the survey by Kopeć et al, and De Jager et al [6,10].

In contrast to those studies of Getachew et al. 2020, and a randomized prospective study by Mahler et al 2015, found that SDL was less effective than formal teaching via lectures or small group classes [8,11]. Nilsson et al, found that ECG competency can be improved among medical students through web-based ECG training [12].

In our study, the ability to detect common emergency ECG abnormalities of anteroseptal ST-segment elevation myocardial infarction was 81% in comparison to Getachew M, which was 42.6%. Antiperovitch et al, which was 87% [2,8]. In the diagnosis of atrial fibrillation, our results were 64% which was higher in comparison to Antiperovitch et al, which was 55%, Getachew et al, it was 39.1%, Sibbald et al, was 48%, [2,8,13]. In the first-degree atrioventricular block, our correct answers were 69% which was higher in comparison to Getachew et al, which was 32.1%, and in Berger et al, it was 40% [8,14]. In the Kopeć et al, study one-third of students were not able to recognize ventricular fibrillation, tachycardia, or advanced atrioventricular block [6].

We found out that medical students with higher confidence levels tend to have a better competency in ECG interpretation, regardless of their seniority, same as a survey done by Jablonover et al, and McAloon et al [1,15]. Dedicated teaching programs can improve students' self-confidence and competence in ECG interpretation. We found that confidence level was influenced by the future specialty of interest such as internal medicine, A&E, family medicine& paediatrics.

Conclusion

The medical students in IMU demonstrated a good level of proficiency in the interpretation of common and uncommon ECG abnormalities. We found that a higher reported scale of confidence levels was directly associated with better competency in ECG interpretation skills among medical students. Competency in ECG interpretation is determined by many factors like SDL, Self-confidence, web-based training, future specialty interests, and attendance at formal ECG training via lectures or small group teaching.

Our results highlighted that personal confidence level influenced by the amount of knowledge amassed by students remains the primary factor that determines their competency, regardless of seniority, and the augmentation of combined educational methods could lead to a wholesome, competent, medical personnel.

Strengths and limitations

Our study has several strengths. Firstly, all the respondents were enrolled in IMU, thereby guaranteeing that all the students who participated in the ECG research were medical students. We modified our questionnaire so that it had a one-time response, ensuring that the participants were unable to change their responses afterward and making our research foolproof.

However, there were still a few limitations that could be considered in this research; participation was still based voluntarily, hence, a limited number of respondents were obtained due to their restrictions. We only managed to gather respondents from one university, therefore our research study cannot reflect the overall competency of students throughout Malaysia.

The most important question. Is MCQ the best way to test ECG interpretation? As real-life interpretation is not an MCQ, it also reduces the number of options to 4 only, but maybe many possible abnormalities.

Acknowledgment

We would like to thank Dr. James Koh Kwee Choy, A/P Sethuraman Nagappan &A/P Rumi Khajotia. from the Internal Medicine department, Prof., Esha Das Gupta& Dr. Narayanan N. Sundram, from the Family Medicine Department. Special thanks to Prof. Teng Cheong Lieng & Prof. N Sivalingam for their help & support to our team.

Conflict of interest

All authors have no conflict of interest to declare.

Source of funding: None

Ethical approval

This study was approved by the IMU Ethical -Joint Committee. This study complied with the Declaration of Helsinki and all participants gave signed informed consent.

References

1. Jablonover RS, Lundberg E, Zhang Y, Stagnaro-GreenA (2014) Competency in electrocardiogram interpretation among graduating medical students. Teach Learn Med 26:279-284. doi:10.1080/10401334.2014.918882.
2. Antiperovitch P, Zareba W, Steinberg JS, et al (2018) Proposed In-Training Electrocardiogram Interpretation Competencies for Undergraduate and Postgraduate Trainees. J Hosp Med 13: 185-193.doi:10.12788/jhm.2876.
3. Masoudi FA, Magid DJ, Vinson DR, et al (2006) Implications of the failure to identify high-risk electrocardiogram findings for the quality of care of patients with acute myocardial infarction: results of the Emergency Department Quality in Myocardial Infarction (EDQMI) study. Circulation114: 1565-1571.doi:10.1161/CIRCULATIONAHA.106.623652.
4. Eslava D, Dhillon S, Berger J, Homel P, Bergmann S (2009) Interpretation of electrocardiograms by first-year residents: the need for change. J Electrocardiol 42:693-697. doi: 10.1016/j.jelectrocard.2009.07.020.
5. Montgomery H, Hunter S, Morris S, Naunton-Morgan R, Marshall RM (1994) Interpretation of electrocardiograms by doctors. BMJ 309:1551-1552. doi:10.1136/bmj.309.6968.1551.
6. Kopeć G, Magoń W, Hołda M, Podolec P (2015) Competency in ECG Interpretation Among Medical Students. Med Sci Monit 21: 3386-3394.doi:10.12659/msm.895129.
7. Salerno SM, Alguire PC, Waxman HS (2003) Competency in interpretation of 12-lead electrocardiograms: a summary and appraisal of published evidence. Ann Intern Med138: 751-760.doi:10.7326/0003-4819-138-9-200305060-00013.
8. Getachew M, Beyene T, Kebede S (2020) Electrocardiography Interpretation Competency of Medical Interns: Experience from Two Ethiopian Medical Schools. Emerg Med Int. 2020; 2020:7695638. doi:10.1155/2020/7695638.
9. Lever NA, Larsen PD, Dawes M, Wong A, Harding SA (2009) Are our medical graduates in New Zealand safe and accurate in ECG interpretation? N Z Med J. 122:9-15.
10. de Jager J, Wallis L, Maritz D. ECG interpretation skills of South African Emergency Medicine residents. Int J Emerg Med. 2010; 3: 309-314.doi:10.1007/s12245-010-0227-3.
11. Mahler SA, Wolcott CJ, Swoboda TK, Wang H, Arnold TC (2011) Techniques for teaching electrocardiogram interpretation: self-directed learning is less effective than a workshop or lecture. Med Educ. 45: 347-353.doi:10.1111/j.1365-2923.2010. 03891.x.
12. Nilsson M, Bolinder G, Held C, Johansson BL, Fors U, Ostergren J (2008) Evaluation of a web-based ECG-interpretation programme for undergraduate medical students. BMC Med Educ. 8: 25.doi:10.1186/1472-6920-8-25.
13. Sibbald M, Davies EG, Dorian P, Yu EH (2014) Electrocardiographic interpretation skills of cardiology residents: are they competent? Can J Cardiol. 30:1721-1724. doi: 10.1016/j.cjca.2014.08.026.

14. Berger JS, Eisen L, Nozad V, et al (2005) Competency in electrocardiogram interpretation among internal medicine and emergency medicine residents. Am J Med. 118: 873-880.doi: 10.1016/j.amjmed.2004.12.004.

15. McAloon C, Leach H, Gill S, Aluwalia A, Trevelyan J (2014) Improving ECG Competence in Medical Trainees in a UK District General Hospital. Cardiol Res. 5:51-57. doi:10.14740/cr333e.