The level of competency of emergency residents to interpret the electrocardiogram in Riyadh regions, Saudi Arabia: A cross-sectional study

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Abstract

Introduction: An electrocardiogram (ECG) is a simple test that can be used to assess the rhythm and electrical activity of the heart. Continuous 24-hour ECG monitoring, in addition to the usual 12-lead ECG and 24–48-hour ECG Holter, can detect arrhythmias undetected by 12-lead ECGs and Holters.

Aim: This study aimed to assess the level of competency of emergency room residents to interpret the ECG in the Riyadh region, Saudi Arabia.

Methods: This is a multicenter cross-sectional study conducted among emergency residents in Riyadh, Saudi Arabia. A self-administered questionnaire was sent to the targeted residents of the emergency department using an online survey. The questionnaire includes basic demographic data (i.e., age, gender, hospital, etc.) and a 12-item questionnaire assessing the level of competency using a different scenario. All statistical analyses were carried out using SPSS version 26.

Results: Of the 96 emergency residents involved, 63.5% were aged between 25 and 27 years old. Overall, the level of competency was average among 63.5%; 24% were considered to have high levels, and only 12.5% were considered to have low levels. The mean score of competencies was 7.80 (SD 2.21) out of 12 points. Factors associated with increased competency included working in King Abdulaziz Medical City, having more than 5 years of working experience in emergency care, and attending electrocardiography training courses.

Conclusion: The level of competency among emergency medicine residents in reading electrocardiograms was deemed adequate. Residents who had more years of experience in emergency care and had attended courses and training related to ECG reading tended to increase their competency levels more than the other emergency residents. More research is needed to establish the competency level of emergency residents in our region.

Categories: Cardiology, Emergency Medicine, Internal Medicine

Keywords: Riyadh city, competency, ECG interpretation, emergency residents, electrocardiogram (ECG)

Introduction

An electrocardiogram (ECG) is a fast test to check the heart's electrical activity and rhythm. Continuous 24-hour ECG monitoring, in addition to the standard 12-lead ECG and 24-48-hour ECG Holter, can detect arrhythmias undetected by 12-lead ECGs and Holters. As technology progresses, the quality of ECG monitoring facilities, the size of ECG recorders, and the length of recording time all improve. Continuous ECG recording is now generally available. Patients with known or suspected arrhythmias can now monitor their health with smartwatches and fitness bracelets. The kind and frequency of symptoms are essential factors in determining the type of ECG recording equipment and recording time [1]

Some electrocardiograms are carried in ambulances, emergency rooms, operating rooms, intensive care units, and as part of standard checks for middle-aged and older persons. ECGs are also carried out in the operating room when there has been a possible heart attack, syncope, or abnormal vital signs. Since people over 65 have a higher chance of developing heart disease, medical personnel need to understand ECGs and the significance of early identification of cardiovascular disorders. [2]

In a cross-sectional and comparative descriptive study, Rahimpour and Shahbazi (2021) aimed to compare electrocardiogram (ECG) interpretation competency among emergency nurses and EMS personnel. In this study, 170 participants in northwest Iran, including 105 emergency nurses and 65 EMS personnel, Rahimpour and Shahbazi found that the mean score was 6.65 ± 2.16 out of 10 for emergency nurses and 4.87 ± 1.81 for EMS personnel's ECG interpretation competency ($p < 0.05$) [3].

In another article named Electrocardiogram Interpretation Competency Among Paramedic Students Mobrad (2020) aimed to determine the ECG interpretation competency of paramedic students. The study took place at a single center [Prince Sultan College for Emergency Medical Services (PSCEMS) at King Saud University]. It included all students of PSCEMS, and 137 of 248 paramedic students completed the questionnaire (55% response rate). Mourad found that 88 students (64.2%) scored more than 7.5 points, which means most paramedic students were found to be competent in ECG interpretation, grade point average (GPA) (above 3.5). [4]

There was also c cross sectional study conducted on emergency nurses' competence in electrocardiographic interpretation in Spain. This study aimed to show the current level of competence in electrocardiographic interpretation among nurses in emergency departments. No significant differences between nursing and hospital experiences observed. Nurses who had received training within the previous five years scored significantly higher than those who had not (P = 0.031) [5]

An article published in 2015 entitled Competency in ECG Interpretation Among Medical Students aimed to assess the electrocardiographic interpretation skills of Polish medical students and analyze the determinants of these skills. The overall percentage of correct answers was higher among 4th and 5th year students than among 3rd year students (66% vs 56%; $p < 0.0001$).The ability to interpret ECG was higher among students who reported self-study ECG (69% vs 62%; $p < 0.0001$), but no difference was observed between students who participated and did not participate. As a result, it demonstrates that self-education, rather than regular ECG class attendance, determines ECG interpretation skills [6].

Moreover, a multidisciplinary study in 2022 aimed to assess electrocardiogram interpretation competency among healthcare professionals and students at Ardabil University of Medical Sciences, Iran including 323 staff and students. The results revealed that many participants' ECG interpretation ability was low. Therefore, consistent, regular training and education are advised. Additionally, managers and educators in the healthcare system should consider how experience in ECG interpretation and positive self-assessment might help staff and students become more professional ECG interpreters [7]. A similar study was done in South Africa using a targeted questionnaire, and prospective cross-sectional research of emergency medicine residents and recently graduated emergency physicians and carried out between August 2008 and February 2009. This research discovered that the average ECG interpretation score was 46.4% (95% confidence interval [CI]: 41.5-51.2%). It finds that there was an improvement in interpreting ECGs with higher seniority in this prospective cross-sectional research of Emergency Medicine residents and freshly qualified emergency physicians. [8]

A cross-sectional study published in 2021 entitled Assessment of Electrocardiography Knowledge Among Doctors Working in Emergency Department, on the general practitioners (GPs), emergency residents (ERs), emergency physicians (EPs) and cardiology physicians interpreted a total of 40 ECG samples in non-cardiac pathologies, arrhythmias, conduction disorders, and myocardial infarctions. It found that the general practitioners in emergency departments have insufficient ECG knowledge. During their professional careers in the emergency department, doctors' understanding of ECG should be continually updated with in-service training commencing in medical school. [9]

Lastly, Hamam AH, AlNofaiey YH and AlAlayani AM conducted a study in Saudi Arabia to assess ECG reading skills and knowledge for emergency medicine residents which showed an alarmingly low result compared to other international programs residents, despite the improvement in the interpretation competency observed with clinical experience. Therefore, programs need to implement new methods of teaching ECG reading to improve the resident's proficiency. [10]

Methods

This cross-sectional multicenter study evaluated emergency medicine residents' clinical competence in interpreting electrocardiograms in Riyadh region, Saudi Arabia. It will be conducted from March to May 2022 using an online, self-administered, pre-validated, two-part questionnaire consisting of a professional profile and 12 questions (2 theoretical questions and ten questions on practical cases with an electrocardiographic register [readout]) to be filled out by the participants, who are junior emergency medicine residents in Riyadh. Participants signed informed consent forms and completed the questionnaire after hearing about the study's goals and methodology. All participants were invited to complete the questionnaires in a controlled atmosphere and return them to the researcher to actively supervise their completion and improve the study's accuracy. Inclusion criteria involved any ER junior residents who are currently working. Exclusion criteria applied to any ER junior residents who were not willing to participate in the research. The sampling for this study was non-probability convenience sampling; the reliability of the questionnaire was further evaluated on a subsample using an intraclass correlation coefficient with a 95% confidence interval. The sample size was 96, according to the sample size computation. We check continuous data for normality and comparing means using parametric or nonparametric tests. The Statistical Package for the Social Sciences (SPSS) software analyzed the data. The data will be presented as frequency. In tables, Chi-Square was used to attain a P-Value between categorical data dependent and independent of estimating the association, where a P-Value ≤ 0.05 was considered significant. The data will be kept confidential and only used for the purposes described in the study objectives.

Statistical analysis: The assessment of emergency room residents' competency to interpret the electrocardiogram was assessed using a 12-item questionnaire where the correct answer for each has been identified, marked, and coded with 1, while the incorrect answer was coded with 0. The total competency score was calculated by adding all 12 items. A score range of 1 to 12 points was generated, indicating that the higher the score, the higher the competency to interpret the electrocardiogram. By using 50% and 75% as cutoff points to determine the level of competency, residents were considered to have low competency if the score was below 50%, 50% to 75% was supposed to show average competency, and those above 75% were believed to have high competency levels. Categorical variables were shown as numbers and percentages (%), while continuous variables were summarized as mean and standard deviation. The differences in the score of competencies according to the socio-demographic characteristics of the residents was performed using the Mann-Whitney Z-test and the Kruskal-Wallis H-test. Statistical collinearity was tested using the Shapiro-Wilk test and the Kolmogorov-Smirnov test. Based on the overall distribution, the competency score follows an abnormal distribution. Thus, the nonparametric tests were applied. The cutoff for statistical significance was p 0.05 in two-tailed analyses. All data analyses were performed using the Statistical Package for Social Sciences, version 26 (SPSS, Armonk, NY: IBM Corp., USA).

Discussion

Table 1: Socio-demographic characteristics of emergency residents (n=96)

Study Data	N (%)
Age group	
25 – 27 years	61 (63.5%)
>27 years	35 (36.5%)
Gender	
Male	80 (83.3%)
Female	16 (16.7%)
Hospital	
Prince Mohammed bin Abdulaziz hospital	14 (14.6%)
King Fahad Hospital	24 (25.0%)
Prince Sultan Military Medical City	10 (10.4%)
King Abdullah University hospital	02 (02.1%)
King Abdulaziz Medical City	17 (17.7%)
King Khalid University Hospital	10 (10.4%)
King Saud Medical City	10 (10.4%)
King Faisal Specialist Hospital	09 (09.4%)
Working experience in emergency care	
<1 year	42 (43.8%)
1-5 years	49 (51.0%)
6-10 years	02 (02.1%)
11-20 years	03 (03.1%)
Did you do any training courses in electrocardiography?	
Yes	72 (75.0%)
No	24 (25.0%)
When was the last course? (n=72)	
1 year or less	36 (50.0%)
Between 2-5 years	33 (45.8%)
More than 5 years	03 (04.2%)
How was the course taken? (n=72)	
Online	41 (56.9%)
Face-to-face	22 (30.6%)
Partial face-to-face	09 (12.5%)
How many hours was the course? (n=72)	
Less than 10 hours	56 (77.8%)
10-20 Hours	14 (19.4%)
More than 20 hours	02 (02.8%)

This study involved 96 emergency room residents. Table 1 presents the socio-demographic characteristics of the residents. 63.5% were aged between 25 and 27 years old, with males being dominant (83.3%). Residents who were working at King Fahad Hospital constituted 25%. Regarding work experience in emergency care, 51% reported having 1-5 years of experience. The proportion of residents who attended training courses in electrocardiography was 75%, and half of them (50%) attended the course last year, mostly online (56.9%), in approximately less than 10 hours (77.8%).

Table 2: Assessment of emergency residents' competence to interpret the electrocardiogram (n=96)

Statement	N (%)
What is the correct order of ECG waves and intervals?	
P wave, QRS complex, T wave, PR interval, ST interval, U wave *	78 (81.3%)
T wave, P wave, QRS complex, PR interval, ST interval, U wave	02 (02.1%)
QRS complex, P wave, PR interval, T wave, ST interval, U wave	13 (13.5%)
I do not know	03 (03.1%)
If the p wave does not appear in an ECG, what is your first thought?	
There is a conduction problem between the ventricles	44 (45.8%)
There is a conduction problem between the atriums *	48 (50.0%)
It is normal, it does not have to appear in an ECG	04 (04.2%)
I do not know	0
You perform an ECG and observe this register. What do you think it might be?	
A third-degree heart block	01 (01.0%)
An atrial flutter *	87 (90.6%)
A supra-ventricular tachycardia	07 (07.3%)
I do not know	01 (01.0%)
You perform an ECG and observe this register. How would you act?	
Ask for help without leaving the patient alone because it is ventricular fibrillation *	74 (77.1%)
Ask for help without leaving the patient alone because it is an atrial fibrillation	19 (19.8%)
Perform another ECG because it looks like there may be interference	02 (02.1%)
You do not know how to act but you know it must be a serious problem	01 (01.0%)
A patient comes to the Emergency Department due to respiratory distress. He has 140 beats per minute. You perform an ECG and observe the following:	
It is atrial tachycardia	13 (13.5%)
It is atrial fibrillation *	51 (53.1%)
It is atrial extra-systole	30 (31.3%)
I do not know	02 (02.1%)
A patient comes to the Emergency Department with precordial pain for more than 8 hours. You perform a 12-branch ECG. After observing the ECG, what catches your attention?	
You can see pathological pauses	09 (09.4%)
You can see pathological Q waves *	61 (63.5%)
The patient has a low cardiac rhythm	19 (19.8%)
I do not know	07 (07.3%)
What pathology do you think the patient with this ECG has?	
A first-degree heart block	29 (30.2%)
He does not have any pathology	06 (06.3%)
A third-degree heart block *	56 (58.3%)
I do not know	05 (05.2%)
A hospitalized patient who had surgery due to an AMI is transferred to the emergency department to be monitored because his vital signs are unstable. You perform an ECG and observe the following:	
The patient presents with ventricular tachycardia *	77 (80.2%)
The patient presents a supra-ventricular tachycardia	18 (18.8%)
The patient presents an atrial tachycardia	0
I do not know	01(01.0%)

Table 2: Assessment of emergency residents' competence to interpret the electrocardiogram (n=96) - continued

Statement	N (%)
You are in triage and call a patient who reports medium-intensity precordial pain. He tells you that the pain appeared after leaving an important meeting two hours ago. He is 52 years old and hypertensive, and a few months ago he was diagnosed with Diabetes Mellitus II. You perform a 12-branch ECG and observe the following:	
It is a supra-ventricular tachycardia	04 (04.2%)
It is an acute myocardial infarction *	44 (45.8%)
It is an acute myocardial infarction with a pathological Q wave	47 (49.0%)
I do not know	01 (01.0%)
A 24-year-old male comes to the emergency department. He is athletic and slim. He reports feeling a pricking sensation in the left area of his chest since he finished doing exercise (3 hours earlier). You perform an ECG and observe the following:	
It is an atrial bradycardia	31 (32.3%)
He has conduction problems	23 (24.0%)
It is a normal ECG *	41 (42.7%)
I do not know	01 (01.0%)
A patient with digital intoxication comes from a hospitalization ward. Before monitoring him, you perform an ECG and obtain the following:	
You observe an atrial extra-systole	03 (03.1%)
You observe a ventricular extra-systole *	69 (71.9%)
You observe that he is carrying a pacemaker	11 (11.5%)
I do not know	13 (13.5%)
A 30-year-old woman comes to the emergency department reporting palpitations, chest tightness, and dyspnea. You perform an ECG and observe the following:	
It is a ventricular tachycardia	07 (07.3%)
It is an atrial extra-systole	19 (19.8%)
It is an atrial tachycardia *	63 (65.6%)
I do not know.	07 (07.3%)
Competence score (mean± SD)	7.80 ± 2.21
Level of competency	
Low	12 (12.5%)
Average	61 (63.5%)
High	23 (24.0%)

In Table 2, residents were confident to identify the P wave, QRS complex, T-wave, PR interval, ST interval, and U wave (81.3%). Half of them (50%) were aware that if the p wave does not appear, there is a conduction problem between the atriums. Nearly all (90.6%) were confident in their ability to distinguish an atrial flutter, and (77.1%) knew what to do in the case of ventricular fibrillation. More than half (53.1%) were confident in their ability to detect atrial fibrillation in a patient who had respiratory distress, while nearly two-thirds (63.5%) knew how to read pathological Q waves in patients with precordial pain for more than 8 hours. Approximately (58.3%) indicated that they are adept at reading a third-degree heart block in an ECG, while a great proportion (80.2%) expressed that they knew how to read ventricular tachycardia in patients who had an incidence of AMI. However, only (45.8%) of respondents knew how to read an acute myocardial infarction in a patient with medium-intensity precordial pain, and a similar proportion (42.7%) knew how to read a normal ECG in a patient who reported a feeling of pricking in the left area of his chest. Regarding a patient with digitalis intoxication, (71.9%) showed confidence in reading the ECG, which is related to ventricular extra-systole. Finally, approximately two-thirds (65.6%) knew how to read a case of palpitations, chest, tightness, and dyspnea, which is atrial tachycardia. Based on the above statements, the overall competency score was 7.80 (SD 2.21), with low, average, and high competency levels found among 12.5%, 63.5%, and 24%, respectively.

Table 3: Differences in the score of competencies in relation to the Socio-demographic characteristics of emergency residents (n=96)

Factor	Competency Score (12) Mean ± SD	Z/H-test	P-value
Age group			
25 – 27 years	7.85 ± 1.95	Z=0.471	0.638
>27 years	7.71 ± 2.63		
Gender			
Male	7.87 ± 2.31	Z=0.512	0.608
Female	7.44 ± 1.63		
Hospital			
Prince Mohammed bin Abdulaziz hospital	6.07 ± 2.02	H=33.008	<0.001 **
King Fahad Hospital	7.04 ± 0.20		
Prince Sultan Military Medical City	9.10 ± 2.47		
King Abdullah University hospital	6.50 ± 0.71		
King Abdulaziz Medical City	9.41 ± 1.80		
King Khalid University Hospital	7.30 ± 2.16		
King Saud Medical City	8.30 ± 1.64		
King Faisal Specialist hospital	8.33 ± 3.67		
Work experience in emergency care			
<1 year	7.14 ± 2.03	H=10.663	0.005 **
1-5 years	8.16 ± 2.08		
>5 years	9.80 ± 3.27		
Did you do any training courses in electrocardiography?			
Yes	7.37 ± 2.09	Z=3.579	<0.001 **
No	9.08 ± 2.06		

a. P-value has been calculated using Mann Whitney Z-test.
b. P-value has been calculated using Kruskal Wallis H-test.
** Significant at p

When measuring the differences in the score of competency in relation to the socio-demographic characteristics of the residents (Table 3), it was observed that a higher competency score was more associated with residents working in King Abdulaziz Medical City (H=33.008; p<0.001).

Discussion

This study investigated the level of competency in reading ECGs among emergency medicine residents in Riyadh, Saudi Arabia. The findings of this study showed that there was a sufficient level of competency in reading ECG results among our residents working in the emergency department. Nearly two-thirds (63.5%) were categorized as average levels, 24% were high, and only 12.5% were categorized as low levels of competency (mean score: 7.80; SD 2.21, out of 12 points). These findings are consistent among paramedic students in Riyadh [4]. According to reports, 64.2% of the students were found to be competent in ECG interpretation. This is in line with the study conducted in Spain [5], wherein a high level of electrocardiographic knowledge was seen among emergency nurses. However, several papers reported insufficient competency levels, whether they were healthcare professionals and students [7], emergency residents [8], emergency doctors [9], or internal medicine and emergency medicine residents [10]. However, in a prospective cross-sectional study done in South Africa [9], they found that although there was an improvement in the interpretation of ECGs with increased seniority, but still, a low level of accuracy exists for many of the critical ECG diagnoses. The mean score of 46.4% reported in the study was lower than other international studies from other regions where emergency medicine is a well-established specialty. A lack of knowledge about ECG interpretation is detrimental to a patient with a cardiac condition. Hence, continuous education is necessary to update their knowledge about ECG reading. The data in this study suggests that increasing years of experience are associated with increasing competency levels. Also, we found that the name of the hospital-specifically, those working in King Abdulaziz Hospital showed a significantly higher score in competency than residents working in other hospitals. These findings are almost consistent with the study of Amini et al. [7]. According to their reports, they estimated that variables such as education level, self-assessment of electrocardiogram interpretation competence, work experience, and type of hospital were able to predict the competence of ECG interpretation. However, age and gender had no significant influence on competency levels in our study. This is in contrast with the study of Rahimpour et al. [3], wherein female nurses working in the emergency unit showed higher ECG interpretation competency than male nurses (p = .042). However, they mentioned that the type of hospital participants worked in was an important factor in predicting a high competency score, which was also seen in our results. Moreover, we have learned that most of our residents attended ECG courses (75%), with half of them attending in the current year (59%), mostly online (56.9%), and for less than 10 hours (77.8%). Furthermore, attendance at ECG courses was estimated to be one of the most important predictors of increased competency levels. The impact of participating in ECG-related courses on increased competency levels in reading ECG results has been proven in the literature, specifically among healthcare practitioners or paramedic students [3,5]. On the contrary, Mobrad et al. [4], revealed that there was no significant difference in the number of points earned in regard to the time since the last course was attended, the mode of the course delivery (in-class vs. online), or the length of the course. The importance of education about ECG interpretation is vital among emergency personnel. Thus, higher authorities should encourage their staff to attend ECG-related courses to strengthen their competency levels and provide the best quality of care. Concerning the specific assessment of emergency residents' competency in reading ECG through various scenarios, we found that only two out of twelve scenarios resulted in residents scoring poorly on the correct answers, namely ECG interpretation after performing 12-branch ECG on a 52-year-old patient with hypertension and type 2 diabetes (45.8%) and reading ECG on a healthy person with pricking sensation in the left area of his chest after doing exercise (42.7%) while on the other hand, most of our emergency residents exhibited adequate competency levels among the rest of the scenarios (10 out of 12 scenarios) as they were able to correctly identify the correct answers such as determining an atrial flutter (90.6%), interpretation of ECG waves and intervals (81.3%), determining ventricular tachycardia on a patient with AMI (80.2%), action to be taken in case of ventricular fibrillation (77.1%), determining a ventricular extrasystole n patient with digitalis intoxication (71.9%), determining atrial tachycardia in patient reporting palpitations, chest tightness and dyspnea (65.6%), determining pathological Q waves after performing a 12-branch ECG (63.5%), determining a third-degree heart block (58.3%), determining atrial fibrillation on a patient with respiratory distress (53.1%), and determining conduction problem between atriums (50%). The competency levels of our residents fared better than those of Iranian healthcare professionals and students [7]. Based on the reports, a considerable number of participants couldn't determine normal sinus rhythm (77.3%), acute myocardial infarction (63.8%), or pathological Q waves (62.2%). Citing low competency levels, the author suggested training and education among their healthcare professionals as well as future ones. Another study carried out among American internal medicine and emergency medicine residents [10], indicated that internal medicine residents who had expressed interest in a cardiology career scored higher than those who did not (17.3 vs. 14.1, p=0.003). When interpreting the most critical diagnoses, they found that the mean score for ventricular tachycardia was 1.6 of 2.0, for myocardial infarction was 1.3 out of 2.0, and for complete heart block was 0.8 9 of 16 out of 2.0, adding that more than half felt their electrocardiogram training was insufficient, which necessitates more education.

Limitations: The generalization of this study was subjected to some limitations. First, our sample size was small (n=96). It could be interesting to see a bigger sample that could generate better results, which could provide a clearer view of the competency level of the emergency medicine residents regarding ECG interpretations. We cannot generalize the comparison of competency levels between male and female residents because data on gender distribution was not collected equally. Furthermore, being cross-sectional by nature has drawbacks such as cause-and-effect relationships and bias.

Conclusion

The level of competency among emergency medicine residents in reading electrocardiograms was deemed adequate. Residents who had more years of experience in emergency care and who had attended courses and training related to ECG reading tended to increase their competency levels more than the other emergency residents. The accuracy with which ECG results are read is vital in determining the cause of the cardiac condition. Thus, residents working in emergency medical services should and must have a certain level of confidence to accurately diagnose both symptomatic and asymptomatic patients with possible cardiac conditions. More research is needed to establish the competency level of emergency residents in our region.

References

1. NHS. (n.d.). NHS choices. Retrieved February 8. (2022). https://www.nhs.uk/conditions/electrocardiogram/.
2. CEUFast Inc. (n.d.). ECG, ECG interpretation. Course | CEUfast Nursing Continuing Education. Retrieved February 8. (2022). https://ceufast.com/course/ecg-interpretation.
3. Rahimpour M, Shahbazi S, Ghafourifard M, Gilani N, Breen C: Electrocardiogram interpretation competency among emergency nurses and Emergency Medical Service (EMS) personnel: A cross□sectional and Comparative Descriptive Study. Nursing Open. 2021, 8:1712-9.
4. Mobrad A: electrocardiogram interpretation competency among paramedic students. Journal of Multidisciplinary Healthcare. 2020, 13:823-8.
5. Coll-Badell M, Jiménez-Herrera MF, Llaurado-Serra M: Emergency nurse competence in electrocardiographic interpretation in Spain: A cross-sectional study. Journal of Emergency Nursing. 2017, 43:560-70. 10.1016/j.jen.2017.06.001
6. Kopeć G, Magoń W, Hołda M, Podolec P: Competency in ECG interpretation among medical students. Medical Science Monitor. 2015, 21:3386-94.
7. Amini K, Mirzaei A, Hosseini M, Zandian H, Azizpour I, Haghi Y: Assessment of electrocardiogram interpretation competency among healthcare professionals and students of Ardabil University of Medical Sciences: a multidisciplinary study. BMC Medical Education. 2022, 22:1-0.
8. de Jager J, Wallis L, Maritz D: ECG interpretation skills of South African Emergency Medicine residents. International journal of emergency medicine. 2010, 3:309-14.
9. ÇANAKÇI ME, ÇETİN M, YILDIRIM ÖT, AYDİN MO, ALTUNTAŞ G, Nurdan AC: Assessment of Electrocardiography Knowledge Among Doctors Working in Emergency Department. Eskisehir Medical Journal. 2:103-10. 10.48176/esmj.2021.24
10. Adequacy of Electrocardiogram Reading and Interpretation Among Emergency Medicine Residents. (2022). https://www.arjonline.org/papers/arjeic/v1-i1/1.pdf.