

# Electrocardiographic interpretation skills of family practice residents

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**Abstract**--Electrocardiography is one of the most commonly used tools for cardiac investigation in primary care and accurate electrocardiogram (ECG) interpretation is one of the skill residents have to achieve during training. An ECG can show the first indicators of many emergent conditions and only their accurate interpretation can support a doctor's clinical decisions. However, there is no data documenting the competency of ECG interpretation skills among family medicine physicians. Our study evaluated the ability of family medicine residents to interpret a variety of common and emergent ECGs and determine if the interpreting ability improved from the postgraduate year. Based on the frequency and potential for clinical significance, we chose common findings (sinus rhythm, acute myocardial infarction, a left bundle branch block, right bundle branch block, left ventricular hypertrophy, atrial fibrillation, ventricular tachycardia and incorrectly placed electrodes. ECGs were then distributed to 100 residents. Residents were given one point for the correct identification of each ECG finding and were scored based on the number correct out of a total of 11. Two cardiologists independently established the correct diagnoses. 49 residents from all four years of residency returned their questionnaires (49 %). The overall diagnostic accuracy was 72.5%. Three (6.1%) residents did not interpret half of the ECGs accurately. All residents recognized acute myocardial infarction and six (12.2%) could not recognize ventricular tachycardia. There was no statistically significant difference among the residents from different years of residency. According to the analysis, the majority of the residents recognized key clinical recordings of the chosen electrocardiograms. We found that residents were strong in identifying acute myocardial infarction and ventricular tachycardia. Weaknesses of identification included interpretation of a normal sinus rhythm interpretation and atrial fibrillation. These identified areas of strengths and weaknesses may help guide resident educational interventions for ECG interpretation. Research is needed to find optimal methods to improve electrocardiogram competency.

**Index Terms**-- ECG, family medicine resident, diagnosis

## I. INTRODUCTION

The electrocardiogram (ECG) is one of the most popular cardiovascular diagnostic aids and an important tool in physician clinical practice [1], [2]. An ECG is a graphical recording of electrical activity on the body surface that results from currents of cardiac electrical activity. The electrical activation of the heart causes differences in the transmembrane

voltages of the cardiac muscle, which generates electrical currents that propagate to the surface of the body, where they are measured [2]. An ECG is clinically crucial in diagnosing patients with acute coronary syndrome and is most accurate for identifying intraventricular conduction abnormalities and arrhythmias. Proper interpretation can lead to the recognition of electrolyte imbalances, especially with changes in the concentration of potassium and calcium. With a high probability, it allows for identification of valve disease, cardiomyopathies, pericarditis, myocarditis, hypertensive heart disease. If the specialist has enough skill, it even allows for an interpretation of certain forms of genetic cardiac abnormalities. The ECG is routinely recorded at preventive examinations and in preoperative examinations. Due to its widespread use, a systemic approach to ECG analysis is of the utmost importance, so that significant abnormalities are not overlooked. The American College of Cardiology and the American Heart Association have issued standards for the acquisition and maintenance of appropriate competency in ECG interpretations. They have advised 500 interpretations of ECGs under supervision in initial education and at least 100 ECG readings per year to maintain knowledge and competency [1].

An ECG is a simple diagnostic test and is used regularly in the daily practice of a family medicine physician: it gets recorded at 2-3.5% of all visits. In 30% to 38% of the recordings, the ECG will be abnormal [1], [3]-[5]. So, interpreting ECG recordings is complex and requires knowledge, skills, and experience [5].

The family medicine physician or an emergency physician often has to interpret ECGs promptly, in challenging circumstances, often without previous ECGs available and without the help of a cardiologist. Incorrect interpretation can lead to incorrect care and treatment of the patient [4]-[7], [12]-[15]. Numerous studies have been conducted comparing the ability to interpret ECGs of non-cardiologists (especially emergency care physicians) compared to cardiologists, who were set as the gold standard. Correct diagnoses by non-cardiologists ranged from 36% to 96% [7], [9], [12]-[15]. Little is known about ECG interpretation skills in family medicine specialists [5]. In 1981, Pinkerton et al demonstrated that family medicine residents missed electrocardiographic findings such as acute myocardial infarction and left ventricular hypertrophy in 20% of the cases. Findings such as reversed electrodes, pericarditis, and right ventricular hypertrophy, remained

unidentified in 60% of the cases [6]. Sur et al conducted a similar study in 2000, which confirmed that family medicine residents misinterpreted ECG recordings in 33% of the cases, and 21% missed acute myocardial infarction [7]. The survey was repeated a year later in the United Arab Emirates and comparable results were obtained [8]. In Denmark, Jensen et al compared the sensitivity of the interpretation of an abnormal ECG, finding that the computer performed better than the family medicine physician, with a rate of 84.4 vs 69.9%; in comparison the specificity in the interpretation of an abnormal diagnosis, the physician performed better, 85.7% vs. 75.6% [9]. How did cardiology residents, who represent the future gold standard of correct ECG interpretation, perform in the tests? In 2014, 29 cardiology residents were tested in Canada; they had correct diagnostic interpretation of the ECG recordings in their tests at 58%. Six ECG cases indicating potentially life-threatening conditions were missed in 36% of the cases, most commonly hyperkalaemia (81%), prolonged QT interval (51.7%), and complete AV block (34.5%). Myocardial infarction with the ST-segment elevation was missed by 26.2%. In literature, this type of accuracy ranges between 87% and 100% [10], [11], [13]. In addition, residents misinterpreted 40% of normal ECGs, which could mean exposing the patient to unnecessary diagnostics and treatment. A Canadian examination of cardiology residents revealed a lack of knowledge of ECG interpretation in critical diagnoses, showing that the knowledge of residents does not improve over the years of their specialization [10].

The analysis performed by Snoey et al [11] among Paris emergency physicians and cardiologists compared the interpretations of 300 ECGs and showed an incorrect interpretation of emergency care physicians in 154 recordings (51%), of which 9 (3%) had significant clinical value. Images of all 12 patients (4%) who had an acute myocardial infarction were appropriately identified by emergency physicians. The most commonly missed findings were repolarization abnormalities, bundle branch blocks and hemiblocks. Premature beats, axis and rhythm abnormalities were best identified. Among the clinically most important missed findings were: Wolff-Parkinson-White syndrome, prolonged QT interval and atrial fibrillation [11]. Berger et al compared knowledge from the interpretation of 12 ECGs between residents in internal medicine and emergency medicine, between which there were no significant differences. Their knowledge has been assessed as lacking, which may have important implications for patient treatment [12].

When an ECG interpretation knowledge test was performed on medical students in England, it turned out that only 1 in 50 correctly measured the PR and QT intervals. When testing this knowledge with cardiologists, surgeons, cardiac surgeons, anaesthesiologists, and emergency physicians, 142 (90%) of the 158 failed the test [13].

Studies that followed the patient after misidentification of the ECG diagnosis showed less than 1% had a worse treatment outcome, or potentially fatal outcome as a result of incorrect ECG interpretation. There is a higher incidence of interpretation errors in non-cardiologists than in cardiologists, but they clearly have a minimal effect on morbidity or mortality. An important

limitation of the conducted research is that it was mostly conducted in emergency medicine departments [12]–[15].

Interpretation of the ECG is a skill that us physicians of various specialties need in our work, and research shows a global lack of knowledge in this respect. There is little evidence of quantitative standards for acquiring or maintaining adequate knowledge of correct interpretation [15]. It is important for a family doctor to be aware of the sensitivity and specificity of his skills of interpreting ECGs, in order to properly treat the patient or to timely refer them to the secondary level [11].

The purpose of this study was to verify the correctness of the interpretation of the electrocardiogram in family medicine residents. Specifically, the aim was to find out how often family medicine residents correctly interpret an ECG recorded in general and emergency conditions that they encounter in their work and to identify differences in the knowledge of ECG interpretation based on the year as of residency training.

## II. MATERIAL AND METHODS

A cross-sectional survey was conducted from May to November 2016 among current family medicine residents. Participation was voluntary and anonymous. The time to complete the survey was limited to 30 minutes. The participants were not allowed to use aids to facilitate their completion of the survey.

The exclusion criterion was a completed specialization in family medicine. The surveys were distributed to 100 family medicine physicians in training. The surveys were distributed to all family medicine residents of the Health Centre Novo Mesto, all rotating family medicine residents of the General Hospital Novo Mesto in the mentioned period, residents of the 17th and 18th modular groups and family medicine residents in the joint training called Useful ECG in October 2016. In the analysis of the research, the residents were classified according to gender, duration of their residency and their involvement in the on-call service.

The survey consisted of two parts. In the first part, the participants filled in a questionnaire about gender, year of residency, and their involvement in the on-call service. This was followed by questions relating to individual ECG recordings. Based on the frequency and potential for clinical significance, we chose common findings (sinus rhythm, acute myocardial infarction, a left bundle branch block, right bundle branch block, left ventricular hypertrophy, atrial fibrillation, ventricular tachycardia and incorrectly placed electrodes). Based on the frequency of findings on the ECG recordings in everyday practice or their clinical significance, and according to similar studies performed, 10 ECG recordings were selected. Two ECG recordings were copied with permission from the Canadian Journal of Cardiology, the article *Electrocardiographic Interpretation Skills of Cardiology residents: Are they competent?* [10] Three ECG recordings were copied with the permission of the author and publisher from the book *ECGs for the Emergency Physician 1* [22]. The remaining ECGs were obtained from patients from the author's own outpatient work. ECG recordings with one pathology were included in the study, and the survey questions required targeted answers. ECG recordings were accompanied by brief

descriptions of the patient's age, symptoms, or vital signs. Participants were asked questions about rhythm, axis, ischemic heart changes, structural heart changes, malignant arrhythmias, and technical errors. The survey was first reviewed by a cardiologist with many years of work experience, before being conducted.

1 point was given for each correct identification of ECG recording abnormalities. A total of 11 points could be scored. It was necessary to identify the left axis. In a technically poor image, it was necessary to identify sinus rhythm. Then, the key finding was acute myocardial infarction (AMI) where it was necessary to identify the involvement of both posterior and lower heart walls with AMI. It was also necessary to identify the left and right bundle branch blocks and hypertrophy of the left ventricle. When asked a question that required a full interpretation of the ECG recording, a point was awarded to each participant who noted that it was atrial fibrillation. Supraventricular tachycardia and ventricular tachycardia had to be identified in the ECG recording of tachyarrhythmia for it to count as a correct response. In the ECG recording, where the two main electrodes were reversed, it was necessary to mark the offered option for a re-recording of ECG, in order for it to count as the correct answer.

The statistical analysis was divided into two parts. In the first part, a univariate analysis was performed in which the answers to individual questions were reviewed and showed results according to gender and year of residency. A point was awarded for each correct answer. A new variable was created, namely the number of correct answers expressed as a proportion of all possible points, which was used in the second part.

The second part of the statistical analysis was based on bivariate analysis. Using the method of one-way analysis of variance (one-way ANOVA), I checked whether there are differences in the average knowledge of ECG recording interpretation according to the number of years of residency and according to the duration of years of involvement in the on-call service. Next, using an analysis of variance, it was checked whether the observed differences were also statistically significant at the 0.05 level.

The research was approved by the Republic of Slovenia National Medical Ethics Committee at its session in May 2016, letter number 0120-526/2015-3.

### III. RESULTS

49 family medicine residents (49.0%) responded to the survey out of 100 distributed surveys, representing four different groups according to their year of residency (Table I) and representing six groups according to the time they were involved in the on-call service.

TABLE I. PARTICIPATING RESIDENTS BY YEAR OF RESIDENCY.

Characteristic		Number	Percent
Year of residency	1st year	7	14.3 %
	2nd year	14	28.6 %
	3rd year	20	40.8 %

	4th year	8	16.3 %
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The overall diagnostic accuracy for all 11 determinations (Table II) averaged at 72.5%. Values ranged from 34.7% – in the recognition of rhythm in a technically poor recording – to 98.0% in the recognition of acute myocardial infarction with the ST-segment elevation. Among the diagnoses, the most commonly missed were posterior heart wall affection following acute myocardial infarction (61.2%), right bundle branch block (30.6%), and atrial fibrillation (26.5%). Incorrectly placed electrodes remained unrecognized in 55.1% of cases. Residents had best results in identifying structural changes in the heart, left ventricular hypertrophy (93.9%), and tachyarrhythmia, paroxysmal supraventricular tachycardia (93.9%), and ventricular tachycardia (87.8%).

TABLE II. TOTAL OF CORRECT IDENTIFICATION OF INDIVIDUAL ECG RECORDINGS.

Question	Number and percentage of correct answers for each ECG
Axis	41 (83.3%)
Rhythm	17 (34.7%)
Findings	
AMI	48 (98.0%)
Affected wall	19 (38.8%)
LBBB	37 (75.5%)
RBBB	34 (69.4%)
LVH	46 (93.9%)
AF	36 (73.5%)
PSVT	46 (93.9%)
VT	43 (87.8%)
Incorrectly placed electrodes	22 (44.9%)

The average values of interpretation of ECG recordings between individual years of residents were: 76.9% for the first year, 65.7% for the second, 73.0% for the third and 78.6% for the fourth year. A review of the averages showed that those with four years of residency training had the highest knowledge of interpretation (correctness average of interpretation at 78.6%), while those with two years of residency training had the weakest knowledge of interpretation on average (correctness of interpretation at 65.7%). The knowledge of ECG interpretation among family medicine residents did not statistically significantly differ according to the length of residency training in our sample ( $F=1.787$ ,  $p=0.163$ ).

For work and length of involvement in the on-call service, on average, the residents with the longest work experience in the on-call service had the most knowledge of ECG recording interpretation (on average correct in 88.0% of cases, but the result was based only a sample of three residents). Residents with three years of work in the on-call service showed the least

knowledge (on average correct in 68.5% of the cases) and those with one year of work in the on-call service were correct on average in 68.9% of the cases. Residents who were not included in the on-call service were correct in 70.3% of the cases. The knowledge of ECG recording interpretation among residents did not statistically significantly differ according to the length of work in the on-call service ( $F=0.944$ ,  $p=0.462$ ).

Three (6.1%) residents did not correctly interpret half of the electrocardiograms.

#### IV. DISCUSSION

In our study, the overall diagnostic accuracy of all selected ECG recordings was 72.5%. Three respondents (6.1%), all in their second year of residency, did not interpret half of the ECG recordings correctly. In our sample, there were no statistically significant differences in the correct interpretation of the ECG recordings between the residents of different years. There were also no statistically significant differences in interpretation between residents who have been working for an on-call service for a long time or have never worked for an on-call service.

The knowledge shown by Slovenian family medicine residents is similar to published research from abroad. A systemic analysis published in 2003, which included 12 different articles on the topic of ECG recording interpretation capabilities of non-cardiac physicians, showed that the average correctness of ECG recording interpretations ranged between 36 and 96% [16], of which 4 to 33 % of ECG recordings had a significant clinical value. Despite a wide range of errors, research has shown that patient care would merely change from 0 to 11% if interpreted correctly [12], [15], [16]. Certain research has shown that the competence to correctly interpret ECG recordings improves during the training of internists and emergency medicine physicians, especially in residents who show greater interest in knowledge of cardiology [12], [17].

Some ECG recordings represent conditions that the resident must immediately recognize and treat urgently. Among these are ventricular fibrillation, ventricular tachycardia, complete AV block, prolonged QT interval, pacemaker malfunction, and ST-segment changes in acute myocardial infarction [12]. These diagnoses require immediate, correct interpretation, as a misdiagnosis can have fatal consequences. Our study included ventricular tachycardia, which remained unrecognized in 12.2%, and acute myocardial infarction with ST-segment elevation. The diagnosis of AMI was made by all 49 residents (100%); however, 1 participant of the survey (2.0%) incorrectly identified it as AMI with ST-segment depression. Studies report similar numbers ranging between 83 and 100% in non-cardiologists [15]. Posterior wall involvement (61.2%) often remained unidentified with AMI. Posterior wall AMI is otherwise considered among the most common misdiagnoses in relation to myocardial infarction. The Gillespie et al study states that 50% of the younger hospital physicians have missed a posterior wall myocardial infarction [17]. Two ECG recordings that had already been used in the Canadian study were included in the survey with permission. The first ECG with AMI of the anterior and posterior wall, with ST-segment elevation, was correctly interpreted by 73.8% of Canadian cardiology residents, in comparison to 38.8% of the family medicine residents in this study. Comparatively, they recognized sinus

rhythm with tremor – 34.7% of family medicine residents, compared to 31.0% of cardiology residents [10]. In the technically poor recording, most interpreted the sinus rhythm as atrial fibrillation. Since family medicine residents, unlike Canadians, had clinical picture input data and a target question available, these results cannot be completely comparable.

Rutten et al monitored eight family medicine physicians for two years in a prospective study in 2000, in their indications for ECG recordings and their follow-up. The main indications (92%) to perform ECG recordings were: chest pain, collapse and palpitations, and dyspnea. 10% of the images turned out to be atrial fibrillation [4]. Atrial fibrillation is one of the most common arrhythmias and one of the main risk factors for a cerebrovascular event [19]. It remains worrisome that such a clinically important finding remained unidentified by 26.5% of the family medicine residents. The Registry of CVD patients is still being established in Slovenia. According to the National Institute of Public Health, it is estimated that 4,400 people are treated for stroke in Slovenia every year [18].

Left ventricular hypertrophy is an important prognostic indicator of morbidity and mortality in patients with arterial hypertension [20], [21] and it is important to actively look out for it from a preventive point of view. 93.9% of family medicine residents correctly identified left ventricular hypertrophy in the ECG recording. Residents performed equally well in identification of supraventricular tachycardia (93.9%).

##### 1) *Discussion of methodology*

The survey had a number of limitations. The survey was conducted on a small sample of residents who were not evenly distributed by year of residency.

The results may have been influenced by the fact that the survey was rejected by many residents or was chosen by those who may have felt more confident in the interpretation of the ECG recordings. The participating physicians had clinical data (main symptom) available in the study of the ECG recordings, which most closely mimics the environment of a family medicine physician in which ECG recording is made and interpreted. The questions asked were highly targeted, which facilitated participation. The question of incorrectly placed electrodes was asked very indirectly and did not even offer an answer as to whether the residents really identified the incorrectly placed electrodes, and it therefore remains irrelevant. It would be better if the ECG recording with incorrectly placed electrodes was available for an independent interpretation, without the possibility of multiple-choice answers.

ECG records were comparable to or identical to previously published studies from abroad [6, 9–14]. Due to clinical relevance, knowledge testing from the interpretation of atrioventricular blocks was lacking. They included the most common and urgent conditions and errors that family medicine physicians have or will certainly encounter.

ECG recordings were not equipped with computer interpretation, which is present in clinical work and which is known to improve the correctness of interpretation [7], [23], [24].

##### 2) *Improvement options*

An ECG recording is a commonly used device in a family medicine physician's office and its interpretation is an important skill to ensure good patient care. In Slovenia, this is the first research that tried to assess the skills of a family medicine resident in interpreting the ECG recordings and at the same time pointed out the common mistakes that family medicine residents make in their work.

In the process of education, standards for knowledge and skills should be set for an individual physician to know when it is necessary to take an ECG recording, to correctly identify normal and abnormal findings, to understand the criteria of therapy and further diagnostics with individual conditions.

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