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Competency in ECG Interpretation Among Medical Students

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Data Collection B
Statistical Analysis C
Data Interpretation D
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Background: Electrocardiogram (ECG) is commonly used in diagnosis of heart diseases, including many life-threatening disorders. We aimed to assess skills in ECG interpretation among Polish medical students and to analyze the determinants of these skills.

Material/Methods: Undergraduates from all Polish medical schools were asked to complete a web-based survey containing 18 ECG strips. Questions concerned primary ECG parameters (rate, rhythm, and axis), emergencies, and common ECG abnormalities. Analysis was restricted to students in their clinical years (4^{th}–6^{th}), and students in their preclinical years (1^{st}–3^{rd}) were used as controls.

Results: We enrolled 536 medical students (females: n=299; 55.8%), aged 19 to 31 (23±1.6) years from all Polish medical schools. Most (72%) were in their clinical years. The overall rate of good response was better in students in years 4^{th}–5^{th} than those in years 1^{st}–3^{rd} (66% *vs.* 56%; p<0.0001). Competency in ECG interpretation was higher in students who reported ECG self-learning (69% *vs.* 62%; p<0.0001) but no difference was found between students who attended or did not attend regular ECG classes (66% *vs.* 66%; p=0.99). On multivariable analysis (p<0.0001), being in clinical years (OR: 2.45 [1.35-4.46] and self-learning (OR: 2.44 [1.46–4.08]) determined competency in ECG interpretation.

Conclusions: Polish medical students in their clinical years have a good level of competency in interpreting the primary ECG parameters, but their ability to recognize ECG signs of emergencies and common heart abnormalities is low. ECG interpretation skills are determined by self-education but not by attendance at regular ECG classes. Our results indicate qualitative and quantitative deficiencies in teaching ECG interpretation at medical schools.

MeSH Keywords: Electrocardiography • Learning • Students, Medical

Abbreviations: ECG – electrocardiogram; IP – internet protocol

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Background

Interpretation of electrocardiogram (ECG) is an essential skill in cardiology, as well as in family, internal, and emergency medicine [1]. The 12-lead ECG is commonly used for screening and diagnosis of heart diseases, including many life-threatening disorders [2,3]. The benefits of correct interpretation of ECG has been clearly demonstrated in patients with cardiac arrest or acute myocardial infarction, in which ECG signs directly determine appropriate treatment [4,5].

Several studies have highlighted deficiencies in ECG interpretation among medical students and residents from different countries [6]. In Poland, the Ministry of Science and Higher Education standards for medical faculties specify that medical graduate should be able to perform and interpret standard resting ECG. However, little is known whether current education in medical schools guarantees competency in ECG interpretation.

Despite a variety of educational resources available, there is still a common belief among Polish medical students and physicians that ECG interpretation is one of the most challenging parts of the final exams in medical schools and in the specialization exams in internal medicine or cardiology. We hypothesized that this difficulty may result from ineffective education in ECG interpretation in medical schools.

Therefore, we aimed to assess the basic skills in the interpretation of ECG among Polish medical students. We also analyzed whether the skills are developed during the process of medical education.

Material and Methods

Study design

We developed an anonymous internet survey aiming to investigate the ECG interpretation skills of Polish medical students. Questionnaire design prevented multiple responses by the same person by prohibiting the use of a single Internet Protocol (IP) address more than once. Before starting the survey, participants were informed about the topic and the purpose of the study. They were also instructed how to complete the questionnaire.

Study population

Undergraduates from all 12 medical schools in Poland were asked to complete the questionnaire, available online from April 4th to May 20th, 2015. The survey was distributed by members of the Student's Scientific Group at the Jagiellonian University Medical College using social media, mailing lists, discussion groups, and online medical students' media to reach the largest number of recipients. Students of all years were allowed to complete the questionnaire, but final analysis was restricted to students in clinical years (4th–6th), and students in preclinical years (1st–3rd) were used as controls to assess the effect of studying medicine on competency in ECG interpretation.

Web-based survey

The survey was divided into 4 blocks:

- Block I included 5 open-ended questions concerning personal information (gender, age, name of university, year of study, membership in a cardiology students' scientific group) and 5 closed-ended questions concerning the history of education in ECG interpretation (students were asked whether they attended regular ECG classes, whether they learned ECG by themselves, whether ECG interpretation was included in the final exams in internal medicine in their medical schools, and how they assessed their competency in ECG interpretation);
- Block II contained 3 open-ended questions regarding selected ECG scans and aimed to assess the ability to interpret the primary ECG parameters (heart rate, the origin of heart rhythm, and electrical axis of the heart);
- Block III contained 6 open-ended questions regarding selected ECG scans presenting: atrial fibrillation, asystole, third-degree atrioventricular block, ST-elevation myocardial infarction, ventricular tachycardia, and ventricular fibrillation. This block aimed to assess the competency in diagnosing emergency cardiovascular states;
- Block IV contained 9 multiple-choice closed-ended questions regarding selected ECG scans presenting: right atrium hypertrophy, first-degree atrioventricular block, atrial flutter, left bundle branch block, left ventricular hypertrophy, myocardial ischemia, right ventricular hypertrophy, inferior wall myocardial infarction, and left atrium hypertrophy. Five possible answers were suggested for each question, but only 1 was correct. This block aimed to assess the ability to recognize common ECG abnormalities.

Each question concerning the interpretation of a single ECG strip had a response time limit of 90 seconds. Each question was displayed independently, without the possibility to return to the previous one. If the time limit was exceeded, the next question was automatically displayed.

ECG selection

Nineteen ECGs were selected by the authors from the ECG textbooks, with permission of the editor [7,8]. After the ECG selection, 7 cardiology consultants were asked to independently interpret the ECG strips and complete the questionnaire. Agreement between the consultants and authors in ECG

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Table 1. Characteristics of the study group.

	All	1st–3rd year	4th–6th year	P value
Gender				
Male	237 (44%)	69 (46%)	168 (43%)	0.54
Female	299 (56%)	80 (54%)	219 (57%)	
Age (years) mean ± SD	23±1.6	22±1.6	24±1.2	<0.001**
Year of study				
1	8 (1%)	8 (5%)	–	
2	53 (10%)	53 (36%)	–	
3	88 (17%)	88 (59%)	–	
4	171 (32%)	–	171 (44%)	
5	139 (26%)	–	139 (36%)	
6	77 (14%)	–	77 (20%)	
Attendance in regular ECG interpretation classes				
Yes	366 (68%)	94 (63%)	272 (70%)	0.11
No	170 (32%)	55 (37%)	115 (30%)	
ECG interpretation as a part of final exam				
Yes	482 (90%)	138 (92%)	344 (89%)	0.20
No	54 (10%)	11 (8%)	43 (11%)	
Self-learning of ECG				
Yes	294 (55%)	78 (52%)	216 (56%)	0.47
No	242 (45%)	71 (48%)	171 (44%)	
Membership of cardiology students' scientific group				
Yes	128 (24%)	30 (20%)	98 (25%)	0.21
No	408 (76%)	119 (80%)	289 (75%)	
Self-assessed ECG interpretation skills				
Good	164 (31%)	36 (24%)	128 (33%)	0.04*
Bad	372 (69%)	113 (76%)	259 (67%)	
Amount of ECG classes				
Too little	432 (81%)	114 (77%)	318 (82%)	0.14
Adequate	101 (19%)	33 (22%)	68 (18%)	
Too much	3 (<1%)	2 (1%)	1 (<1%)	

ECG – electrocardiogram; SD – standard deviation; P value – calculated for preclinical *vs.* clinical years; * statistically significant in χ^2 test; ** statistically significant in Student's t-test.

interpretation must have been 100% to include the ECG into the final questionnaire. During this consultation, 1 ECG strip was excluded and 18 were left in the questionnaire.

Answers evaluation

For the multiple-choice closed-ended questions, the correct answers were identified automatically. For the open-ended questions, a list of acceptable diagnoses was provided before

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Table 2. Comparison of students' competency according to medical school.

Medical school	Number of students	Overall score	95% CI (%)
1	31	63%	(59–67)
2	50	74%	(71–77)
3	30	59%	(55–63)
4	49	63%	(60–66)
5	102	62%	(60–64)
6	32	61%	(57–65)
7	74	60%	(57–53)
8	35	65%	(61–69)
9	37	61%	(57–65)
10	32	63%	(59–67)
11	30	63%	(59–67)
12	34	72%	(68–76)

P value for χ^2 test <0.001; CI – confidence interval.

starting the study. Only the answers that matched the pre-specified diagnoses were considered as correct.

Statistical analysis

The proportions of correct answers to individual questions were calculated by dividing the number of correct answers to a question by the total number of answers to this question. The proportion of correct answers to a single block of questions was calculated by dividing the number of correct answers to all questions from this block by the total number of questions in this block.

Categorical variables were described as counts and percentages and continuous variables as means ± standard deviations. We used the chi-square test to compare differences in ECG interpretation skills according to pre-specified criteria: gender, year of study, self-directed learning, attendance at regular ECG classes, and self-reported competency in ECG interpretation. Continuous variables were compared using Student's t-test.

To assess which factors significantly influenced competency in ECG interpretation, we used the multivariable logistic regression model. The outcome variable was the correct answer to at least 15 questions, which is consistent with competency greater than 80%; this is a commonly-used threshold for a good grade on exams. The following independent variables were included in this model: gender, being in clinical years, ECG self-learning, membership in cardiology students' scientific groups, and attendance at ECG classes. The significance level was set at $p < 0.05$. Statistical analysis was performed with Statistica PL software (StatSoft, Inc. (2010) STATISTICA (data analysis software system), version 9.1. Tulsa, USA (*www.statsoft.com*).

Results

Group characteristics

A total of 536 medical students (females: n=299, 55.8%; males n=237, 44.2%), aged 19 to 31 (23±1.6) years from all Polish medical schools participated in our survey. Most students (n=387; 72%) were in clinical years 4th–6th. Most of them (70%) declared to have attended regular classes on ECG interpretation, but the majority (82%) assessed the number of such classes as too small. More than half of students (55%) declared self-education of ECG. Characteristics of the study group are presented in Table 1. Only 164 (31%) participants assessed their ECG interpretation skills as good; these were more often students in their clinical rather than preclinical years (Table 1). Students' competency in ECG interpretation according to medical school is presented in Table 2.

Competency in ECG interpretation

Most students of clinical years (86%) were able to correctly interpret the primary ECG parameters such as heart rate, heart rhythm, and electrical axis of the heart; 69% of them were able to recognize ECG emergencies and only 58% were able to recognize common ECG abnormalities such as ischemia, rhythm disorder, and cardiac chambers hypertrophy (Figure 1). The overall rate of correct responses was 66%. As shown in

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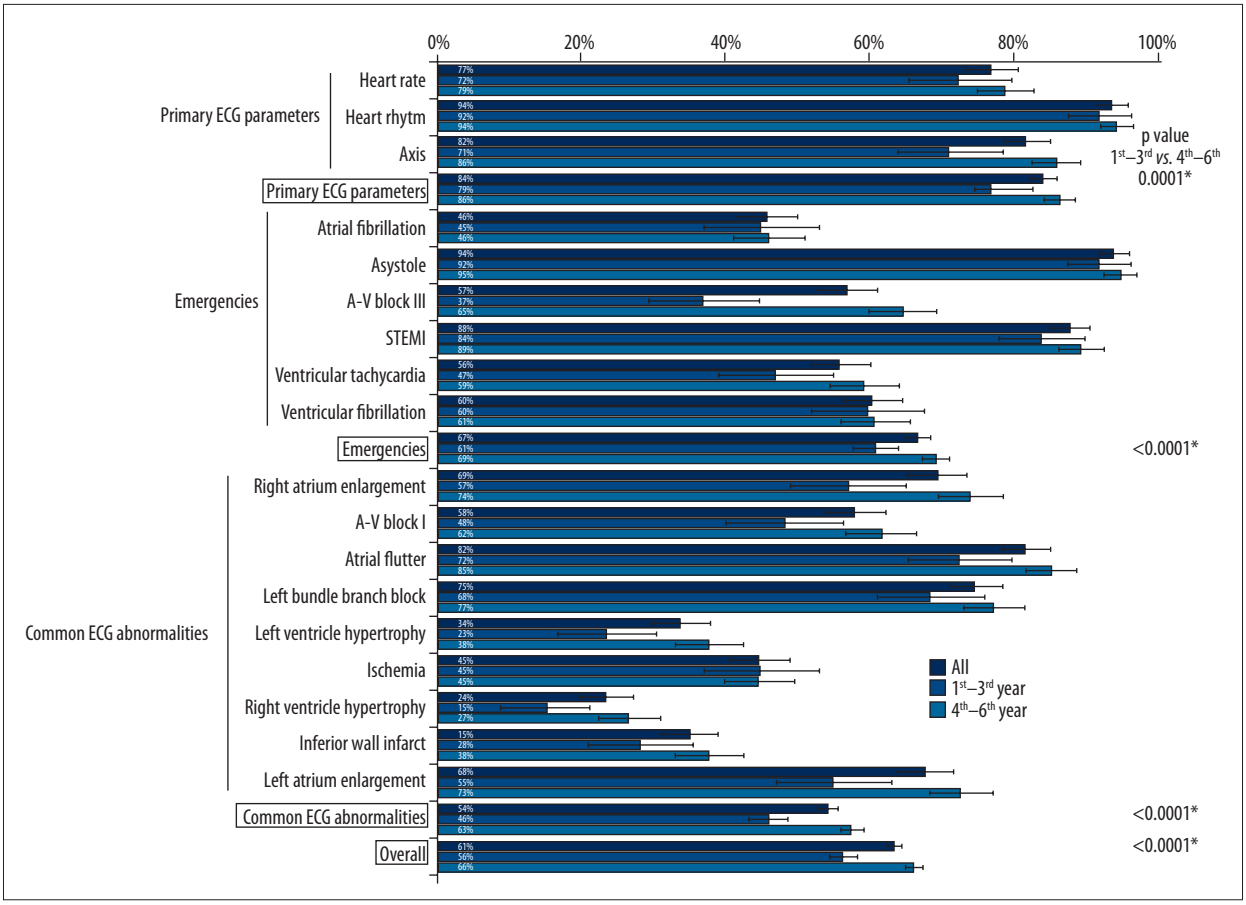

Figure 1. Competency in interpretation of electrocardiogram by year of study.

Figure 1, competency in ECG interpretation was higher in students in their clinical years than in preclinical students. There were no significant differences between 4th-, 5th-, and 6th-year students with respect to competency in interpreting primary ECG parameters (88%, 84%, and 88%, respectively), emergencies (69%, 69%, and 69%, respectively), other common ECG abnormalities (57%, 58%, and 59%, respectively), and overall competency (66%, 66%, and 67%, respectively).

Determinants of competency in ECG interpretation.

Overall accuracy of ECG interpretation in students in their clinical years was similar in men and women, but male students were better trained in interpretation of primary ECG parameters (Figure 2A). Competency in ECG interpretation was higher in students who reported self-learning of ECG interpretation than in those who did not learn ECG by themselves (Figure 2B), but we did not find any relationship between attending regular ECG classes and the competency in ECG interpretation (Figure 2C). Students usually could estimate their ability to interpret ECGs correctly. Those who assessed their skills as good had overall rate of correct responses of 69%, as compared to those who assessed their skills as bad (61%, p<0.0001).

Logistic regression analysis (Table 3) showed that being in the clinical years and self-learning of ECG interpretation determined competency in ECG interpretation in medical students.

Discussion

In this cross-sectional study,we have shown that Polish medical students in their clinical years have a good level of competency in interpreting the primary ECG parameters such as heart rate, the origin of heart rhythm, and electrical axis of the heart. However, their ability to recognize ECG signs of life-threatening disorders and common heart abnormalities is low.

We have also shown that the competency in ECG interpretation is determined mainly by self-education, while attendance at regular ECG classes fails to affect most of the ECG interpretation skills, including recognition of ECG signs of emergencies.

To the best of our knowledge, this is the largest published study on ECG interpretation skills among medical students. Previous studies focused mostly on residents of various specialties like cardiology [9], emergency medicine [10], pediatrics [11],

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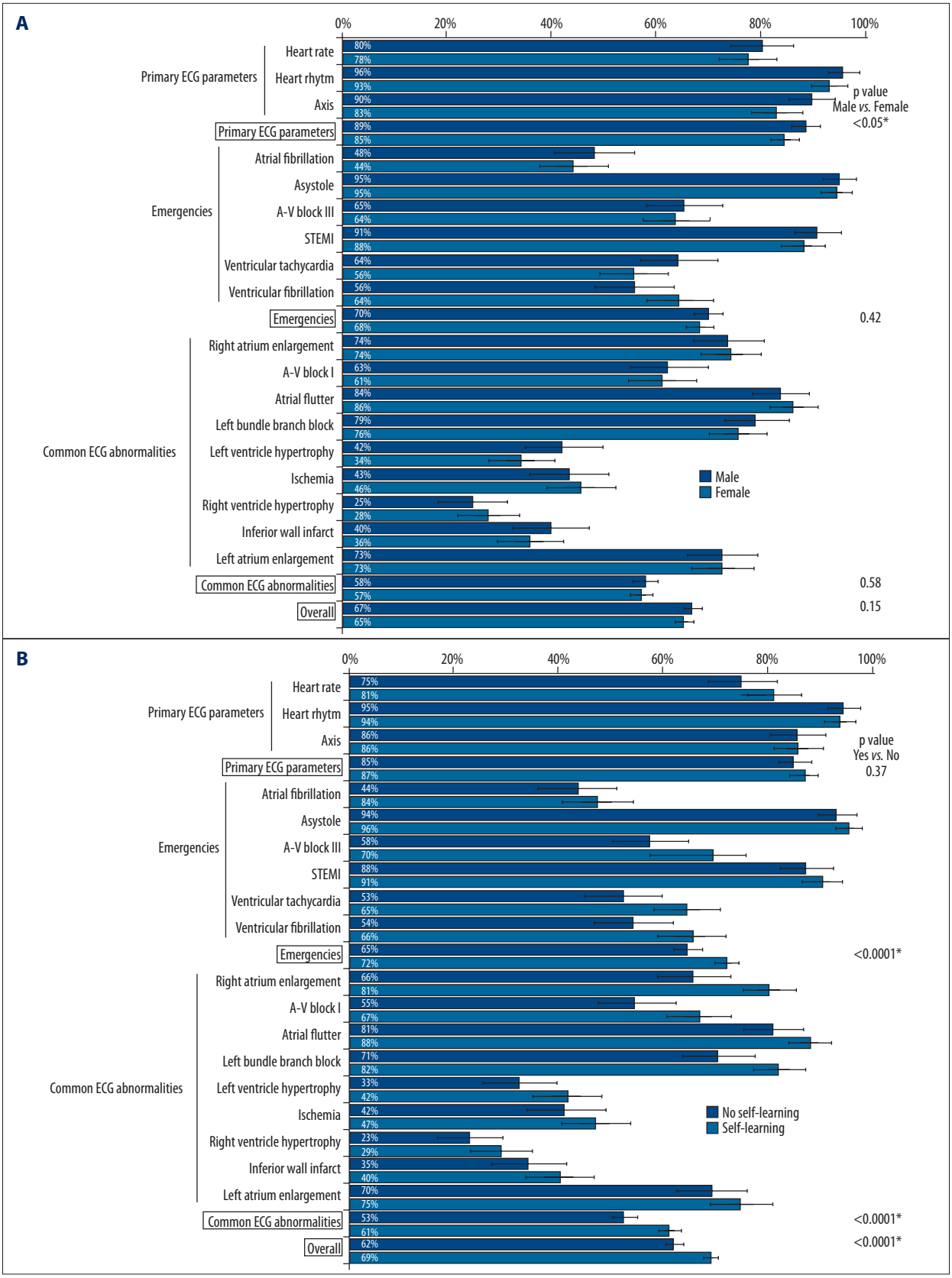

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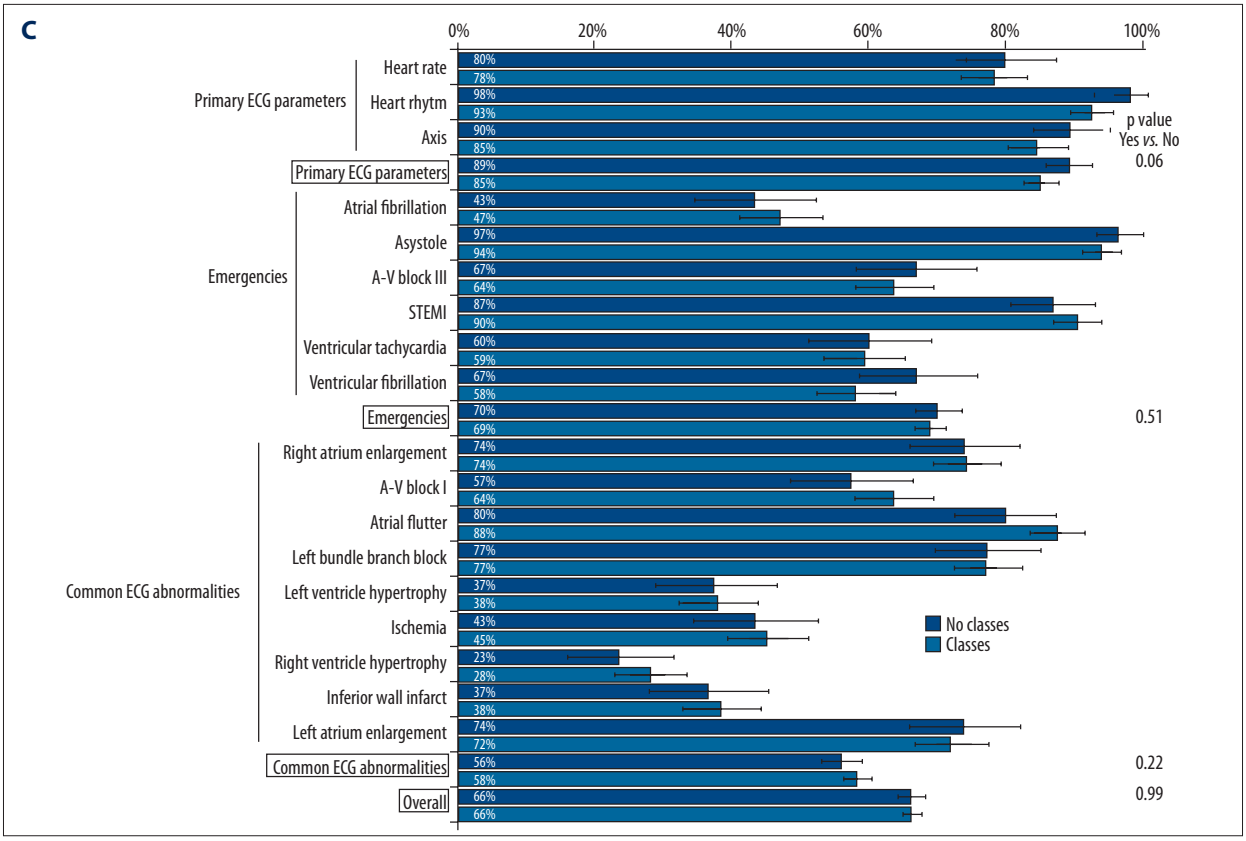

Figure 2. (**A**) Competency in interpretation of electrocardiogram by gender. (**B**) Competency in interpretation of electrocardiogram by reported self-learning. (**C**) Competency in interpretation of electrocardiogram by attendance in ECG interpretation classes. Only data from students of 4th to 6th years are presented.

Table. 3. Determinants of competency in ECG interpretation. Results of multivariable logistic regression model.

Factor	OR	p	95% CI
Self- learning	2.44	0.001*	(1.46–4.08)
Member of students' scientific group	1.37	0.229	(0.82–2.27)
Male gender	1.27	0.302	(0.81–2.00)
Attendance in regular classes	0.79	0.321	(0.49–1.27)
Being at clinical years	2.45	0.003*	(1.35–4.46)

P value for model <0.0001*; OR – reported odds ratios; p – p value of test statistic; CI – confidence interval; * statistically significant variable.

or internal medicine [12]. One study on ECG interpretation among Polish medical students only analyzed data from a single university [13].

Our observation of the relatively poor competency in ECG interpretation among medical students is consistent with previous studies. Nigel et al. [14] reported only 52% accuracy in interpreting various ECGs among 52 final-year medical students from New Zealand; they used open-ended questions in their survey, which are more difficult to analyze than closed-ended questions. In another study, Jablonover et al. [15] found 37% accuracy in ECG interpretation among 231 graduating medical students. Although these results seem even worse than ours, there are major difficulties in comparing different studies concerning ECG interpretation since electrocardiograms and methodologies used in those studies were very diverse. It may explain the high discrepancy in the accuracy (17% to 63%) in ECG interpretation by students described by Salerno et al. [6] in his systematic review of papers published between 1996 to 2002.

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Because medical students develop clinical skills mainly during years 4th to 6th, we compared their competency in ECG interpretation with students in preclinical years (1st to 3rd) and observed that their overall score rose from 56% to 66%. This phenomenon was previously shown in medical students [15], and in pediatric [11] and emergency medicine residents [10], and was considered to result from "ECG exposure", defined as accumulation of ECG interpretation skills during medical education, and may be explained by the "memory store models" theory [16]. Interestingly, we found that competency in ECG interpretation did not improve between the 4th, 5th, and 6th years. Pudlo et al. [13] reported a similar finding, but their study mostly focussed on the knowledge of ECG criteria but not ECG interpretation skills. Their study and our observations suggest that the ability to list ECG criteria of some cardiac disorders does not necessarily reflect ability to identify them on an ECG strip.

We have shown that among students in their clinical years, self-learning significantly improved their skills in this field. De Jager et al. [10] found that self-learning was the most frequently used technique of ECG interpretation learning among 96 emergency medicine residents. However, contrary to our results, a randomized prospective study by Mahler et al. [17] found that self-learning was less effective than formal teaching.

Unexpectedly, we found that regular classes that focused on ECG interpretation failed to improve ECG interpretation skills. Additionally, most students reported that the amount of ECG classes during medical education was too small. This suggests qualitative and quantitative deficiencies in teaching ECG interpretation at Polish medical schools. Currently, there is a paucity of data about the best possible method of ECG interpretation teaching. The above-mentioned studies of Mahler et al. [17] stressed the importance of formal ECG training via lectures or seminars with small groups of students. Nilsson et al. [18] found that ECG competency can be improved among medical students by a web-based ECG training. However, a recent review on ECG learning by Fent et al. [19] did not specify which learning method is most effective.

It should be stressed that in our study one-third of students were not able to recognize the ECG signs of life-threatening disorders, such as ventricular fibrillation, tachycardia, or advanced atrioventricular block. Similar results (40% accuracy) were reported by Berger et al. [12] with regard to AV block in internal medicine and emergency medicine residents. Sibbald et al. [9] showed 48% accuracy in diagnosis of atrial fibrillation among cardiology residents, which is similar to our results.

Strengths and limitations

Our study has several strengths. First, the respondents were enrolled from all medical schools in Poland, thereby making the results generalizable to the entire Polish medical education system. Second, we specified the areas in ECG interpretation skills that need to be improved. Finally, we showed the impact of current ECG education in medical schools on competency in ECG interpretation.

There are also several limitations to this study that should be considered. Participation in our survey was voluntary; therefore, our sample may not be representative of all Polish medical students. We believe that students interested in ECG interpretation accounted for most of the respondents; therefore, the level of competency in ECG interpretation might be overrated in our study. Students completed they survey without supervision; therefore, they could have used additional resources to answer the questions and might have repeated the survey many times to get the best result. We think, however, that this is unlikely as the survey was anonymous, we did not reward good responses, and the time for each response was limited. Additionally, the survey could have been sent only once from a specific computer IP address.

Conclusions

Polish medical students in their clinical years have a good level of competency in interpreting the primary ECG parameters. However, their ability to recognize ECG signs of life-threatening disorders and common heart abnormalities is insufficient. Competency in ECG interpretation is determined mainly by self-education, while attendance at regular ECG classes failed to affect the ECG interpretation skills. New evidence-based educational methods should be applied when teaching medical students.

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Conflict of interest

The authors do not declare any conflict of interest with regard to the study.

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