RESEARCH LETTER

Twelve-lead versus rhythm strip electrocardiogram interpretation skills among medical students

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Introduction Electrocardiogram (ECG) interpretation is one of the core competencies in undergraduate medical curricula.[1] The ability to accurately interpret 12-lead ECG is a crucial learning outcome as well as a challenging skill among medical students. Despite the fact that most students can accurately interpret ECG of myocardial infarction, they do not perform well in the elucidation of different classification of heart blocks especially third-degree heart block and tachyarrhythmias.[2] The reason behind this is poorly understood. The ability to accurately detect such life-threatening ECG abnormalities is vital, especially in emergency situations. A complete 3-dimensional electrical activity can be recorded using a 12-lead ECG, which is a standard recommended assessment tool for diagnosing myocardial ischemia and infarction.[3] The rhythm strip is a single-lead long strip recorded to show the rhythm. Both heart block and tachyarrhythmia may be read on 12-lead ECGs or rhythm strips of a single lead. However, it is essential not to make any diagnosis from a single lead. The study was done to compare medical students' competence in interpreting 12-lead ECG versus rhythm strip in the diagnosis of various types of atrioventricular (AV) blocks and tachyarrhythmia.

Patients and methods A cross-sectional study was conducted to compare the final scores of the ECG rhythm strips and 12-lead interpretation of heart block and tachyarrhythmias by using an ECG knowledge test. A convenience sampling method was used, and 220 third- to fifth-year medical students from University Malaysia Sabah (Kota Kinabalu, Malaysia) were enrolled in the study. ECG theory and its application had been taught as one of the major learning outcomes since the univeristy's ECG teaching curriuculum is designed to integrate spirally across all academic years (1st to 5th). At the university, "ECG interpretation" learning outcome is integrated in the teaching curriculum of every academic year. It is mainly taught using a traditional classroom teaching method where third- to fifth-year students are expected to use systematic approach to interpretation as follows: heart rate, rhythm, axis, P wave, QRS complexes, ST-segment, and T waves. Ethics approval was obtained through the university ethics board. Informed consent was obtained from each participant before the study. The participation was voluntary and anonymous.

To begin with, ECGs were sent to one national and one senior international cardiologist to review independently for content validity. After selecting the ECG questions, ECG-test class was created in Schoology, which is one of the popular online learning management systems. A total of 18 validated ECG questions (nine rhythm strips and nine 12-lead ECGs) were uploaded onto the platform. It consisted of four different single-lead AV block ECG rhythm strips and four 12-lead AV block ECG tracings, five different single-lead tachyarrhythmias ECG rhythm strips, and five different 12-lead tachyarrhythmias ECG tracings. No case scenarios were given to aid in ECG diagnosis, as clinical history influences diagnostic accuracy.[4] After all, computer-based ECG test was conducted under supervision.

Statistical analysis was carried out using SPSS 24.0 (SPSS, Inc., Chicago, Illinois, United States). The sample size was calculated using G*Power software (Version 3.1.7. Uiversität Kiel, Germany. 2013). The sample size was determined according to the power level, which will be 0.99, and the use of the conventional $\alpha = 0.05$ 2-tailed

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TABLE 1 Diagnostic accuracy of atrioventricular heart block and tachyarrhythmia on single rhythm strip and 12-lead electrocardiograms (n = 220)

ECGs	Points		Correct answer, n (%)		*P* value[a]
	Single-lead ECG	12-lead ECG	Single-lead ECG	12-lead ECG	
Atrioventricular block					
First-degree	1	1	71 (32)	78 (36)	0.4
Second-degree type I	1	1	82 (37)	84 (38)	0.5
Second-degree type II	1	1	83 (38)	93 (42)	0.3
Third-degree	1	1	130 (59)	73 (33)	<0.001
Total score	4	4	366 (42)	328 (37)	0.04
Tachyarrhythmias					
Supraventricular tachycardia	1	1	112 (26)	94 (21)	0.09
Atrial fibrillation	1	1	107 (24)	91 (21)	0.14
Atrial flutter	1	1	104 (24)	56 (13)	<0.001
Ventricular tachycardia	1	1	117 (27)	80 (18)	<0.001
Torsade de pointes	1	1	157 (36)	102 (23)	<0.001
Total score	5	5	727 (55)	631 (48)	<0.001

a Inferential statistics calculated by paired *t* test

Abbreviations: ECG, electrocardiogram

criterion of significance. *P* values of less than 0.05 were set to be significant. On this basis, 220 students were required. Effect sizes were calculated as, resulting in large effect size (Cohen's d = 0.38). ECG test score was displayed as mean (SD) and categorical data were described as numbers and frequency. Paired *t* test was used for comparison of knowledge test score by the same participants.

Results Of the 251 third- to fifth-year medical students, 220 consented to participate in this study (response rate, 88%). Students of different academic years participated in this study (year 3, n = 78 [35.5%]; year 4, n = 64 [29%]; year 5, and n = 78 [35.5%]) with a mean (SD) age of 22 (1.01) years. Most students (n = 159; 72%) were women. The total ECG test score on rhythm strips was higher than 12-lead ECG interpretation on rhythm strip (mean [SD], 4.37 [1.92]) vs 3.41 [1.85], *P* <0.001). The diagnostic accuracy of each type of AV block and tachyarrhythmia on single-lead and 12-lead ECG is shown in TABLE 1. In diagnosing AV blocks, the total score was higher with rhythm strips than 12-lead ECGs interpretation (mean [SD], 1.66 [1.16] vs 1.49 [1.22], *P* = 0.04). In diagnosing tachyarrhythmias, the total score was also higher with rhythm strips than 12-lead ECGs interpretation (mean [SD], 2.71 [1.65] vs 1.92 [1.34], *P* <0.001).

Discussion Our results highlight that students had higher ability to diagnose AV blocks and tachyarrhythmias using rhythm strip ECG compared with 12-lead ECG. It is consistent with previous studies. Little et al[5] demonstrated that there was a significant difference in the diagnostic accuracy using rhythm strip compared with 12-lead ECG (67% and 46%, respectively) among final year medical students. It is noteworthy that around two-thirds of the participants in our study failed to identify third-degree AV blocks using 12-lead ECG tracing. The ability to make a correct diagnosis of life-threatening ECGs such as heart block and tachyarrhythmia is crucial for immediate management. Misinterpretation of common cardiac emergencies can lead to poor patient outcome and higher mortality.

In our study, 12-lead ECG knowledge on AV blocks among students was shown to be generally poor. Only less than half of the students were able to correctly diagnose AV blocks (37% by 12-lead and 42% by rhythm strip ECG); for tachyarrhythmias, the respective percentages were 48% by 12-lead and 55% by rhythm strip ECG. Kopeć et al[2] also found that one-third of the students were not able to recognize the ECG signs of life-threatening disorders. Similar findings were also shown in a study looking at medical doctors, where Berger et al[6] reported an accuracy of 40% with regard to AV block in internal medicine and emergency medicine residents.

Our medical students were found to be better at interpreting ECG using rhythm strips than 12-lead tracings. We believe this is due to several reasons. The first one is because rhythm strips are usually taken from the ECG tracings that represent lead II, which is the lead that is almost parallel to the depolarization wave coming from the sinus node down to the ventricles. Therefore, it is arguably the best lead to look for P waves which denote atrial depolarization. This should help students identify the ECG rhythm by focusing on the regularity of the P waves and its association with the ventricular depolarization seen on the rhythm strip. Secondly, a 12-lead ECG carries much more information compared with a single-lead ECG. A 12-lead ECG uses different electrical perspectives of the heart to enable a more holistic outlook, which provides a more accurate representation of the heart's electrical activities compared with a single-lead ECG tracing.

Our study showed that there is an alarming need for clinical educators to enhance 12-lead ECG learning by employing new effective instructional methods such as collaborative e-learning[7] or gamified learning. A study by Kopeć et al[8] found that collaborative e-learning of ECG among fifth-year medical students resulted in a better outcome than self e-learning. Its effect was related to the theoretical knowledge of ECG gained throughout the course and to the level of students' activity. Additionally, gamification is the use of game design elements and game mechanics in non–game contexts. This idea has been used successfully in many web-based businesses to increase user engagement.[9] Ohn et al[10] highlighted the new platform for ECG learning to motivate students and enhance ECG interpretation skills.

It is essential to stress that a rhythm strip is simply a representation of one lead out of the usual 12 surface ECG leads. A methodical approach to 12-lead ECG interpretation is important to spot the abnormalities on ECG tracing, and this requires a thorough examination at each of the 12 leads in a systematic manner. Perhaps this complexity associated with 12-lead ECG interpretation is one of the reasons why students find it difficult to get the correct diagnosis in a timely manner. It is important that we recognize this as an area to focus on during ECG teaching. We suggest that, apart from using traditional textbook ECG teaching methods, constructive use of images in ECG teaching coupled with utilization of multimedia support may be useful to enhance students' ECG interpretation skills. An example would be to develop an ECG gamification platform to encourage ECG learning. For rhythm analysis, students should focus their attention on the rhythm strip on the 12-lead ECG first to confirm whether it is a sinus rhythm, and if not, determine the correct underlying rhythm. The use of an efficient and systematic approach to ECG interpretation could help strengthen the ability of students to make a correct diagnosis based on 12-lead ECG.

In conclusion, this study has shown that in the context of diagnosing AV blocks and tachyarrhythmias, there is a significant discrepancy between single-lead ECG and 12-lead ECG interpretation skills. Furthermore, the study confirmed that the skills in ECG interpretation are still poor among medical students. It is important to identify and address the reasons for this discrepancy during ECG teaching. For ECG rhythm analysis, we suggest that students focus their attention on the rhythm strip first, which usually corresponds to lead II on the 12-lead ECG to ascertain the rhythm before proceeding to other parts of the ECG recording.

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