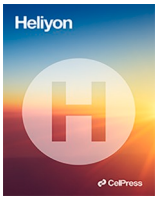
Heliyon 9 (2023) e22617

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Can Orthopaedic Surgeons adequately assess an Electrocardiogram (ECG) trace paper? A cross sectional study

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ARTICLE INFO

Keywords:
Electrocardiogram interpretation
Orthopaedic surgeons
ECG
Diagnosis
Cardiovascular complications

ABSTRACT

Objectives: The primary objective was to evaluate the ECG trace paper evaluation current knowledge level in a group of Orthopaedic surgeons divided into juniors and seniors according to M.D. degree possession.

Methods: A cross sectional study through self-administered questionnaires at a university hospital Orthopaedic and Trauma Surgery Department. The questionnaire included five sections: 1-Basic participants' characteristics, 2-Participants' perception of their ECG evaluation current knowledge level, 3-The main body of the questionnaire was an ECG quiz (seven); the participant was asked to determine if it was normal and the possible diagnosis, 4-Participants' desired ECG evaluation knowledge level, and 5-Willingness to attend ECG evaluation workshops.

Results: Of the 121 actively working individuals in the department, 96 (97.3 %) finished the questionnaire, and 85 (77.3 %) were valid for final evaluation. The participants' mean age was 30.4 ± 6.92 years, 76.5 % juniors and 23.5 % seniors. 83.5 % of the participants perceived their current ECG evaluation knowledge as none or limited. For participants' ability to evaluate an ECG, higher scores were achieved when determining if the ECG was normal or abnormal, with a mean score percentage of 79.32 % ± 23.27. However, the scores were lower when trying to reach the diagnosis, with a mean score percentage of 43.02 % ± 27.48. There was a significant negative correlation between the participant's age and answering the normality question correctly ($r = -0.277$, $p = 0.01$); and a significant positive correlation between answering the diagnosis question correctly and the desired level of knowledge and the intention to attend a workshop about ECG evaluation, $r = 0.355$ ($p = 0.001$), and $r = 0.223$ ($p = 0.04$), respectively. Only 56.5 % of the participants desired to get more knowledge, and 81.2 % were interested in attending ECG evaluation workshops.

Conclusion: Orthopaedic surgeons showed sufficient knowledge when determining the normality of ECG trace papers; however, they could not reach the proper diagnosis, and Junior surgeons performed slightly better than their senior peers. Most surgeons are willing to attend ECG evaluation and interpretation workshops to improve their knowledge level.

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[1] www.svu.edu.eg.

https://doi.org/10.1016/j.heliyon.2023.e22617
Received 7 July 2023; Received in revised form 10 November 2023; Accepted 15 November 2023
Available online 20 November 2023

1. Background

Electrocardiogram (ECG) interpretation ability is undoubtedly integral to certain medical specialties such as cardiology and intensive care. However, the importance of knowing how to read and interpret an ECG from a surgical point of view arises from the fact that postoperative cardiovascular complications such as myocardial infarction (MI), pulmonary embolism (PE), arrhythmias like atrial fibrillation (AF), and even cardiac arrest (CA) [1–8], are not uncommon after orthopedic surgeries, especially in the elderly and in those with preexisting cardiac problems [8–12]. Therefore, the first step in managing these possible complications is suspecting them promptly and reaching a timely proper diagnosis [4,13].

A bad reputation accompanied surgeons, in general, and Orthopaedic surgeons, in particular, regarding their competency in accurately detecting and diagnosing changes in ECG trace papers, with the famous dogma that "Two surgeons and an ECG constitute a double-blind study" [14]. Various studies in the literature evaluated the difference between specialized and non-specialized physicians regarding their ability in ECG evaluation and assessment knowledge [15–18]. Furthermore, the competency difference between seniors and juniors (different experience levels) within the same medical specialty was evaluated [19–22]. However, the literature on the ability and accuracy of surgeons, including Orthopaedic surgeons, in evaluating and interpreting ECGs is deficient [14,23,24].

An Orthopaedic surgeon could be the first to face a patient with postoperative cardiac complications, and early detection and a provisional diagnosis of this possible complication will help start the proper management and call for help. So, the current study's primary objective was to evaluate the current ECG trace paper evaluation knowledge level in a group of Orthopaedic surgeons working in a university hospital by examining their ability to detect ECG abnormalities and achieve a proper diagnosis. The secondary objectives were first to distinguish if there is a difference between junior and senior surgeons working within the same department and second to check their willingness to get more knowledge through attending ECG assessment and evaluation workshops.

We hypothesized that Orthopaedic surgeons have limited ECG evaluation and assessment knowledge, and thus, they would like to improve their knowledge by attending teaching courses and workshops.

2. Methods

After obtaining the ethical committee approval, we performed a cross sectional study through self-administered questionnaires at an Orthopaedic and Trauma Surgery Department at a university hospital. To guarantee transparency and avoid manipulation, the study was conducted during the department's monthly meeting (in March 2022), which most surgeons attended. For those who did not attend, one of the authors delivered the questionnaire to them personally and immediately collected the completed questionnaire sheet. Surgeons were not allowed to participate remotely, and questionnaire answers delivered by email or social media apps (such as WhatsApp) were not accepted for evaluation.

The main outcome of interest was evaluating the ability of orthoapedic surgeons to identify an ECG trace paper as showing normal or abnormal findings and, if it was abnormal, would the surgeon be able to detect (diagnose) this specific type of abnormality? Followed by evaluating the surgeon's desire to gain more knowledge.

The questionnaire was formulated after an extensive discussion among the authors; it included five sections (supplementary file 1):

Table (1)
Characteristics of studied participants.

	N = 85 (%)
Age: Mean ± SD (range)	30.40 ± 6.92 (24–55)
Qualification	
-Juniors (Before M.D.)	65 (76.5 %)
-Seniors (After M.D.)	20 (23.5 %)
The current level of knowledge about ECG	
1. None	46 (54.1 %)
2. Limited	25 (29.4 %)
3. Moderate	12 (14.1 %)
4. Advanced	2 (2.4 %)
5. Expert-level	0 (0.0 %)
(1 and 2) Not knowledgeable	71 (83.5 %)
(3,4 and 5) Knowledgeable	14 (16.5 %)
Desired level of knowledge about ECG	
1. Not interested	23 (27.1 %)
2. To gain limited knowledge	14 (16.5 %)
3. To gain Moderate knowledge	20 (23.5 %)
4. To gain Advanced knowledge	14 (16.5 %)
5. To gain Expert-level knowledge	14 (16.5 %)
(1 and 2) Not interested in gaining knowledgeable	37 (43.5 %)
(3,4 and 5) Enthusiastic to gaining more knowledgeable	48 (56.5 %)
Willing to attend a workshop about ECG	
-Not willing	16 (18.8 %)
-Maybe	44 (51.8 %)
-Will attend	25 (29.4 %)

1 Basic characteristics of the participant (age and current position).
2 Participants' perception of their ECG trace paper evaluation and assessment of current knowledge level. Before starting to answer the ECG quiz, the participants were asked about their perception of their ECG knowledge level using a 5-point Likert scale, where "1″ is no knowledge and "5″ is an expert level of knowledge (Table 1).
3 The main body of the questionnaire was an ECG trace paper quiz prepared by one of the authors, a cardiology consultant. This section of the questionnaire included seven different ECG trace papers; one was normal (Normal sinus rhythm (NSR), and the remaining six were abnormal. The types of abnormalities were selected based on the most common and possible postoperative cardiac complications, which included (sinus tachycardia, sinus bradycardia, atrial fibrillation, ventricular tachycardia, ventricular fibrillation, and myocardial infarction). The included ECG trace papers were selected from the cardiology department teaching library (from real clinical situations) to ensure their good quality and clarity, and two other cardiology consultants volunteered to confirm their readability and clarity (to ensure that these ECGs had only one possible diagnosis) before carrying out the current study. The final selected ECGs were also tested on a group of junior cardiology residents. In this ECG quiz, the participants were asked to answer two questions on each ECG trace paper: if it is normal or abnormal, and second, what is the possible abnormality or diagnosis?
4 Participants' desired level of knowledge in evaluating ECG trace papers: After answering the ECG quiz, the participants were asked what level they would like to achieve in evaluating ECG trace papers, using a 5-point Likert scale, where "1″ is not interested and "5″ is willing to achieve an expert level of knowledge (Table 1).
5 Willingness to attend an ECG evaluation and assessment workshop. Finally, all participants were asked if they would like to attend an ECG evaluation and assessment workshop, and the answers were either yes, maybe, or no.

Four questionnaire forms were designed, each with a different order of the ECGs in the quiz part, to avoid copying answers between participants. After finishing the questionnaire, two of the authors collected the data and entered it into an Excel sheet after coding. An independent statistician performed the final analysis.

At the time of the study, 121 individuals (surgeons) of different positions and rankings were actively working in the department. We divided them into those who had not obtained a Medical Doctorate (M.D.) degree yet, i.e., Juniors (residents, specialists, assistant lecturers), and those who had finished their M.D., i.e., Seniors (lecturers, associate professors, professors, and consultants). The M.D. degree is our country's highest specialization in Orthopaedic and Trauma Surgery.

2.1. Statistical analysis

Data analysis was performed using a statistical package for the social science (IBM-SPSS) version 26.0 software. Categorical data were presented in the form of frequencies and percentages. All numerical variables were tested before evaluation to determine the normality of data by the Shapiro–Wilk test and means ± S.D. were used to express numerical data. An Independent Sample T-test was used to compare the mean knowledge score between two independent groups. Spearman's correlation was used to identify the correlation between knowledge score and other variables. Significant variables in bivariate analysis (Independent Sample T-test and Spearman correlation) were entered in a multivariate linear regression analysis adjusted with age. The level of significance was considered at a P value < 0.05.

Table (2)
ECG knowledge among the participants.

ECG Diagnosis	N = 85 (%)	
	Answering the normal vs. abnormal questions correct	Answering the diagnosis question correct
Sinus bradycardia	55 (64.7 %)	28 (32.9 %)
Sinus tachycardia	58 (68.2 %)	32 (37.6 %)
Atrial fibrillation	77 (90.6 %)	47 (55.3 %)
Myocardial infarction	71 (83.5 %)	40 (47.1 %)
Ventricular tachycardia	77 (90.6 %)	26 (30.6 %)
Ventricular fibrillation	78 (91.8 %)	27 (31.8 %)
Normal sinus rhythm	56 (65.9 %)	56 (65.9 %)
The total score of Answering the normal vs. abnormal questions correct		
-Mean ± SD	5.55 ± 1.62 (0–7)	
-Mean score %	79.32 % ± 23.27 (0–100)	
The total score of Answering the diagnosis question correct		
-Mean ± SD	3.01 ± 1.92 (0–7)	
-Mean score %	43.02 % ± 27.48 (0–100)	

The score was created by asking 7 questions, if the ECG trace paper is normal or abnormal, and the possible diagnosis. Responses were given a score of 1 for a correct answer and a score of 0 for an incorrect answer or did not know. The scores of the 7 questions were summed. So, each participant took a score from 0 to 7, and a mean knowledge score was calculated; a higher score indicated better knowledge, and the mean score percent was calculated as score/optimal score × 100. Cronbach's alpha for the reliability of the normal or abnormal score and for the diagnosis score were 0.711 and 0.700, respectively.

3. Results

Of the 121 actively working individuals in the Orthopaedic Department, 110 were available to participate in the study. Fourteen surgeons refused to participate, and 96 (97.3 %) finished the questionnaire. Incomplete questionnaires (n = 11) were eliminated, leaving 85 (77.3 %) valid questionnaires for the final evaluation.

Our cohort's mean age was 30.4 ± 6.92 years, where 65 (76.5 %) were juniors having a mean age of 27.67 ± 2.93, and 20 (23.5 %) were seniors having a mean age of 45.14 ± 6.78. The vast majority of our participants (83.5 %) perceived their current ECG evaluation knowledge as none or limited, while 16.5 % considered themselves as having good knowledge, but none considered themselves experts (Table 1).

Regarding the participants' ability to evaluate an ECG trace paper (Table 2), higher scores were achieved among all participants when determining if the ECG trace paper was normal or abnormal, with a mean score of 5.55 ± 1.62 (0–7), and a mean score percentage of 79.32 % ± 23.27 (0–100). However, the scores were lower when trying to reach the correct diagnosis (if an abnormality was detected), with a mean score of 3.01 ± 1.92 (0–7) and a mean score percentage of 43.02 % ± 27.48 (0–100).

We evaluated the association between various study variables and the ability to get a correct answer in both the normality and diagnosis questions (Table 3). Although juniors were better than seniors in both aspects, the difference was insignificant (p = 0.077 and 0.339). Lastly, we found that there was a significant negative correlation between the participant's age and answering the normality question correctly (r = −0.277, *P*-value = 0.01); furthermore, a significant positive correlation was detected between answering the diagnosis question correctly and the desired level of knowledge and the intention to attend a workshop about ECG evaluation, r = 0.355 (*P*-value = 0.001), and r = 0.223 (*P*-value = 0.04), respectively (Table 4). Furthermore, multivariate linear regression analysis adjusted with age found that the significant predictor associated with the participants' increased ECG diagnosis knowledge was the participants' desired knowledge level (β = 6.063, *P*-value = 0.004) (Table 5).

Surprisingly, only 56.5 % of the participants showed their desire to get more knowledge, and only 16.5 % were willing to reach an expert level of knowledge. Interestingly, participants who desired to achieve a higher knowledge level were significantly better at achieving correct answers to the diagnosis question (*P*-value = 0.003). In answering the fifth question in the questionnaire, 81.2 % were interested in attending an ECG evaluation and assessment workshop (Table 1 and Fig. 1).

4. Discussion

Most of the participants in the current study admitted that their ECG interpretation and evaluation knowledge and skill were limited or deficient, and over half showed interest in improving their knowledge. Over two-thirds of the surgeons could identify an ECG as normal or abnormal; however, less than 50 % could reach the proper diagnosis. Furthermore, the junior surgeons performed better than their senior counterparts. Moreover, we found that participants who showed better knowledge were more interested in improving their knowledge level. So, our hypotheses were partially disputed, as surgeons showed an acceptable knowledge level regarding determining the ECG normality; however, the scores were less when trying to reach an accurate diagnosis. Furthermore, over 80 % of the participants were willing to attend ECG evaluation and interpretation workshops.

Cardiac-related medical conditions, either acutely or post-surgery, could be a serious emergency necessitating rapid and proper diagnosis and management; this could be achieved by careful clinical examination and obtaining an ECG, which is considered a rapid and bedside investigation [2,13,25–27]. The importance of ECG for diagnosing such possible cardiac conditions provoked many authors to evaluate how physicians are variable in their ability to assess an ECG trace paper based on their specialty and seniority level [17,28,29]. On the contrary, this issue was rarely discussed or investigated within different surgical specialties.

Furthermore, to the best of our knowledge, only three studies are the ones that evaluated surgeons' abilities to evaluate ECGs [14,23,24]; however, they are limited by the small numbers of included participants and the way by which questionnaires were distributed and answers were collected. In the current study, we tried to overcome these limitations by increasing the number of participating surgeons and delivering the questionnaire in a way that guarantees transparency and reliability.

Table (3)
Association of total normality, total diagnosis scores of ECGs assessment, and other variables.

	The total score of the normality question of ECG	The total score of the diagnosis question
Qualification		
-Juniors (Before M.D.)	5.78 ± 1.31	3.12 ± 1.9
-Seniors (after M.D.)	4.80 ± 2.26	2.65 ± 1.98
P-Value*	0.077	0.339
The current level of knowledge about ECG		
-Not knowledgeable	5.50 ± 1.67	2.84 ± 1.8
-Knowledgeable	5.78 ± 1.42	3.85 ± 2.34
P-Value*	0.562	0.072
Desired level of knowledge about ECG		
-Not knowledgeable	5.43 ± 1.6	2.32 ± 1.54
-Knowledgeable	5.64 ± 1.65	3.54 ± 2.03
P-value*	0.553	**0.003**

Data were expressed as mean ± SD.
*Independent Sample T-test was used to compare the mean between groups.

Table (4)
Correlation between total normality, total diagnosis score of ECGs, and other variables.

	The total score of the normality question of ECG		The total score of the diagnosis question	
	r	*P*-value	r	*P*-value
Age	−0.277	**0.01**	−0.144	0.188
The current level of knowledge	0.049	0.653	0.169	0.121
Desired level of knowledge	0.084	0.446	0.355	**0.001**
Workshop about ECG	0.169	0.123	0.223	**0.04**

r:Spearman Correlation coefficient.

Table (5)
multivariate linear regression analysis for factors associated with total knowledge score for diagnosis ECG.

	The total knowledge score of the ECG diagnosis question			
	β	95 % CI		*P*-value
		lower	Upper	
	$R^2 = 0.161$			
Age	−0.53	−1.33	0.27	0.194
Desired level of knowledge	6.063	1.98	10.13	**0.004**
Workshop about ECG	5.114	−3.35	13.58	0.233

R^2 (R square).
β: beta coefficient.
95 % CI: 95 % confidence interval (lower-upper).
Multivariate linear regression analysis adjusted with age of participants.

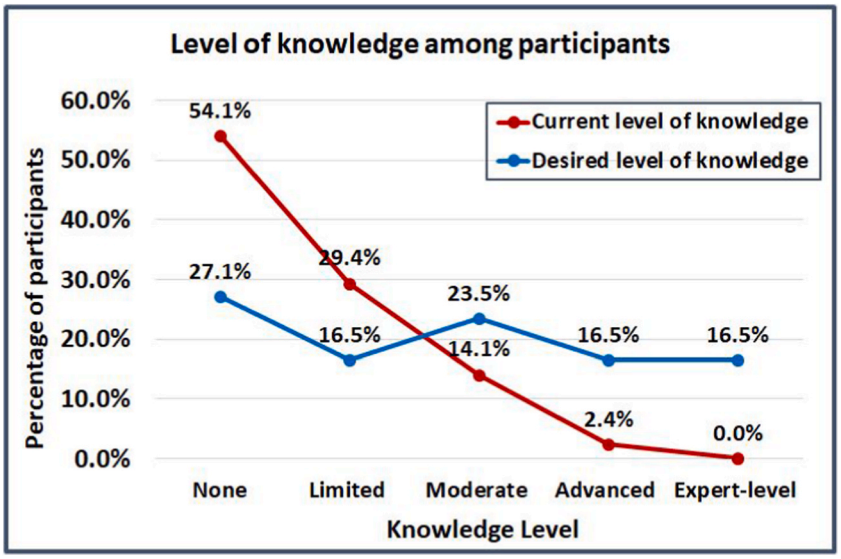

Fig. 1. Current and desired level of ECG knowledge among studied participants.

In a systematic review by Cook et al. to evaluate literature published on physicians' accuracy in ECG interpretation, 78 studies were included; the pertaining accuracy was 54 %, which improved to 67 % after training. The accuracy improved with increasing seniority level, 42 % for medical students, 55.8 % for residents, 68.5 % for practicing physicians, and 74.9 % for cardiologists. The authors concluded that even after training, physicians are deficient in correctly interpreting ECGs [17]. Our results differed from what was previously mentioned by Cook et al. as we found that the junior surgeons performed slightly better than the seniors when evaluating ECGs; however, we did not assess before and after obtaining specific ECG evaluation training.

Orthopaedic surgeons participating in the current study showed acceptable scores when evaluating the normality of an ECG and partial awareness when trying to reach a proper diagnosis; the same findings were reported in a study by Ulf Martin Schilling, who included 20 surgeons (12 Orthopaedic and eight abdominal surgeons) who assessed a set of five ECGs (eight items with a final score of 40), the mean final score was 25.3 (38–20), where abdominal and orthopedic surgeons had a mean score of 27.6, and 23.7 points ($p = 0.09$), respectively. The overall accuracy ranged from 95 % to 50 %. Although the author did not report the ECG assessment details, it

was mentioned that none of the participants accepted an ECG showing MI changes as normal, and all participants could diagnose MI changes in the ECG, which made the author refuses the dogma that surgeons are incapable of evaluating ECGs [14]. Contrary to our study, Ulf Martin Schilling found that seniors got a slightly higher score than juniors [14]; however, the difference was insignificant, but we found that juniors were overall better than their seniors.

In the current study, about 43 % of the participants could reach the correct diagnosis. The same finding was reported in a study by Raheel et al. who included different specialties doctors, 22 surgical (11 orthopedic surgeons) and 16 non-surgical, an electronic questionnaire containing four ECGs with different diagnoses, participants were asked to comment on the rate and rhythm and suggest a diagnosis. Overall, the scores from surgeons were lower than their colleagues from non-surgical specialties. Regarding the diagnosis, about 77 % of the physicians got the correct answer compared to 47 % of the surgeons. Interestingly, Orthopaedic surgeons were slightly better than other surgical specialties; however, the difference was insignificant [23].

On the opposite side, proof that surgeons are very deficient regarding ECGs assessment was reported in a study by Montgomery et al. who included 117 doctors of different specialties (including ten surgeons); participants were asked to identify the *P*–R interval and to define what a small square in an ECG trace paper represents, 64 % could not define the PR interval, and 41 % were unable to define the time interval represented by the small square, interestingly, the included ten general surgeons failed in all questions [24].

Antiperovitch et al. discussed the lack of formal protocol for teaching principles of ECG evaluation and interpretation for both undergraduates and postgraduates as the reason for the deficient knowledge; they suggested that the first step for management always starts with identifying an ECG as normal or abnormal, then abnormality differential diagnoses should be suggested, upon which an immediate treatment should be initiated if the patient is unstable or having an emergency condition, and a consultation from a senior health professional if needed must be asked in timely fashion [19]. In the current study, we formulated the ECG quiz based on the previous study recommendations, as the first question was to identify the ECG normality followed by the possible diagnosis; however, we did not include any suggestion regarding the treatment plan.

According to our institution's Orthopaedic and Trauma Surgery residency teaching curriculum, understanding and evaluating ECGs is not an integral part of the curriculum; however, this was taught during the internship year, where the intern had to spend two obligatory months in the intensive care unit. The importance of training and attending specialized courses was reported in a study by Al Mousa et al. who evaluated 373 medical interns (juniors), and all have finished advanced cardiac life support courses; 91.7 % of the participants could identify the essential ECG elements and normal patterns [28].

Although we did not profoundly investigate why junior surgeons performed relatively better than their senior peers, however, we speculated that this could be due to some factors including but not limited to: first juniors are usually in close contact with post-operative cases where they are more likely to face patients with cardiac complications. Second, juniors have recently had their internship year with mandatory training in the intensive care unit, where they might be subjected to evaluating ECGs. Third, in recent years, there have been modifications in the medical school curriculum, emphasizing more clinical practice than theoretical knowledge and introducing mandatory basic life support (BLS) courses during the internship period.

However, we admit that our study has some inherent limitations. First, it was carried out on a single surgical specialty (Orthopaedic and Trauma Surgery) in a single center, making the results' generalizability questionable. Second, no clinical data accompanied the ECG quiz, which in real scenarios is mandatory for reaching the proper diagnosis [30]. Third, this was a single-group study with no comparative group from other medical or surgical specialties. Fourth, we did not perform a before and after ECG training evaluation, which could reflect the effect of education on the ECG interpretation improvement.

5. Conclusion

Orthopaedic surgeons showed acceptable knowledge when deciding on the normality of ECG trace papers; however, they lacked the ability to reach the proper diagnosis, and Junior surgeons performed slightly better than their senior peers. Most surgeons are willing to attend ECG evaluation and interpretation workshops to improve their knowledge level. Appropriate identification of ECG abnormalities, mainly in the postoperative period, where there is a higher possibility of cardiac complications, will assist in proper patient management or even timely asking for assistance from other medical specialties. Adding formal ECG evaluation and assessment training to the Orthopaedic and Trauma Surgery residency curriculum, besides initiating courses, workshops and providing online educational materials, is advisable. Lastly, another multicenter and multi-surgical specialty is planned to be carried out.

Ethics approval and consent to participate

This article does not contain any experimental studies with human participants or animals performed by any of the authors, and the ethical committee of our institution approved it: Faculty of Medicine, Assiut University, Egypt (IRB no.: 17300634) (Telephone, Fax: +20882332278, ethics-committee12@yahoo.com, IRB-Asyut@aun.Edu.eg, http://afm.edu.eg).

Study setting

Orthopedic and Trauma Surgery Department, Assiut University Hospitals, Assiut, Egypt.

Consent for publication

Verbal informed consent was obtained from all participants to use the data for publication of this article; no identification of the

participant's identity is present neither in the manuscript nor in the images or tables.

Availability of data and materials

Data associated with this study has been deposited at https://www.kaggle.com/datasets/ahmedakhalifa/can-orthopaedic-surgeons-adequately-assess-ecg.

Funding

This research received no specific grant from public, commercial, or not-for-profit funding agencies.

CRediT authorship contribution statement

Ahmed A. Khalifa: Conceptualization, Supervision, Writing – original draft, Writing – review & editing. **Shimaa S. Khidr:** Data curation, Investigation, Methodology, Visualization. **Ahmed Abdelazim A. Hassan:** Data curation, Methodology, Resources, Validation. **Heba M. Mohammed:** Data curation, Formal analysis, Project administration, Software, Validation, Visualization. **Mohammad El-Sharkawi:** Conceptualization, Supervision, Writing – review & editing. **Amr A. Fadle:** Data curation, Investigation, Methodology, Project administration, Visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

None.

List of abbreviations

Electrocardiogram (ECG)
Myocardial infarction (MI)
Pulmonary embolism (PE)
Atrial fibrillation (AF)
Cardiac arrest (CA)
Medical Doctorate (M.D.)
Basic life support (BLS)

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e22617.

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