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IMPROVING ECG LEARNING AND COMPETENCE AMONG MEDICAL AND POSTGRADUATE TRAINEES: SCOPING REVIEW OF AVAILABLE EVIDENCE

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ABSTRACT

Background: **Electrocardiogram (ECG) is an important non-invasive tool for cardiac disease evaluation, both for routine cardiac evaluation or in life-threatening emergency settings. Cardiovascular diseases remain the most common cause of death worldwide. It is therefore important that medical doctors should be proficient in ECG interpretation. This scoping review therefore sets out to identify approaches to improving ECG learning and competence among medical and postgraduate trainees.**

Methods: **We performed this review using the preferred reporting items for systematic reviews and meta-analysis guidelines/checklists. The following databases were searched; PubMed, Scientific Electronic Library Online (SciELO), and African Journals Online (AJOL), and all articles investigating the methods of improving ECG learning and competence among medical students and postgraduate trainees published between 1st January 2000 and 31st December 2022 were included. Data was screened and extracted by at least three independent reviewers**

Results: **A total of 25 articles (19 randomized control trials, one cohort studies and 5 cross-sectional studies were identified. Most studies were from Europe while 20% of them were from the United States.**

Various modalities of ECG learning were identified which varied from traditional lecture based or electronic learning, formative vs summative methods, multiple integrated/ blended methods, internet versus non-internet methods, computer-simulated program or traditional teaching leads and so on.

Conclusion: **We concluded that no single method of ECG learning is superior, however, a combination of conventional and electronic methods works better than either one as a standalone. Therefore, trainers should identify and adopt the most effective methods to enhance ECG competence among their trainees.**

Keywords: Echocardiogram, Electrocardiography, Resident doctors, Medical students

INTRODUCTION

An electrocardiogram (ECG) remained an important tool for evaluating cardiac patients since it was first introduced over a century ago.[1] The ECG is one of the most widely used tools in medicine today - nearly 200 million ECGs are recorded annually worldwide.[2] While the ECG tracing itself has remained relatively unchanged since its inception, the ability to leverage the "humble" ECG to detect and diagnose various pathologies continues to evolve.[3] ECG is important in the clinical diagnosis of cardiovascular diseases such as coronary syndrome, cardiac arrhythmias, risk stratification of sudden cardiac death and the selection of patients for medical device therapy and implantable cardiac devices etc. and this singular diagnostic tool can make a difference in the management and outcome of such cardiac patients.[3] ECG has also remained an important diagnostic tool because of its noninvasiveness, ease of accessibility, affordability and availability.[2]

Cardiovascular diseases have remained one of the leading causes of death all over the world. Hence, all healthcare providers must be skilled in making prompt and accurate diagnoses using ECG. The reliance on ECG to identify life-threatening arrhythmias and acute myocardial infarction has become so widespread and critically important that it has become part of the core curriculum for undergraduate and postgraduate medical trainees. This is of utmost importance because

misinterpreting the ECG result can lead to misdiagnosis thereby delaying the appropriate treatment. It then becomes important that every healthcare provider is competent with not only performing ECG but also accurate interpretation of its result as this can make a whole lot of difference in the patient's life. Moreover, improving the competency of ECG interpretation among trainees who work in emergency settings is a potential patient safety issue and could minimize interpretation errors during emergencies.[4,5]

Notwithstanding that ECG is important during undergraduate and postgraduate medical training, interpretation competence is not optimal and teaching or knowledge transmission is difficult.[6-8] Other studies have found poor competency in specific area of ECG knowledge such as ECG of emergencies.[9] The rapidly expanding undergraduate and postgraduate medical curriculum also bring to the fore the need for efficient ways to improve ECG learning and attainment of competence and proficiency for trainees.[8,10] There are evidence globally to suggest that competence in ECG interpretation is poor in medical students although worse when compared to postgraduate medical trainees, which also further varies among cardiology residents compared to non-cardiology residents.[11-13]

There is a need for a comprehensive understanding of effective methods to enhance ECG interpretation competence among medical students and postgraduate trainees. By addressing these gaps, this scoping review will provide valuable insights for educators, clinicians, and policymakers to develop targeted strategies for improving ECG interpretation competence among medical trainees, ultimately enhancing patient care, safety, and outcomes.

This scoping review sought to synthesize the available evidence of methods of improving ECG learning and competence among medical students and postgraduate trainees.

METHODS

Study Design

This study and report were based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guideline/checklist (Figure 1).[14,15]

Review Questions

This study addressed the following principal questions: (i) What are the evidence of traditional and novel methods of improving ECG learning and competence among medical students and postgraduate trainees? (ii) What are the usefulness of these methods of improving ECG learning and competence among medical students and postgraduate trainees?

Literature Selection Criteria

The inclusion or exclusion of literature into these scoping review was based on the criteria listed below:

Inclusion Criteria

1. All articles investigating the methods of improving ECG learning and competence among medical students and postgraduate trainees.
2. Articles in which their full texts are accessible.
3. Relevant articles published between 1st January 2000 and 31st December 2022

Exclusion Criteria

1. Product literatures was excluded.
2. Observational studies that merely evaluated the profile and prevalence of traditional methods of ECG competence.

Literature Search Strategy

The literature search was based on the PICO framework, which is made up of population [p], Intervention [i], context [c] and outcome [d] (Table 1). The following databases were searched: PubMed, Scientific Electronic Library Online (SciELO), and African Journals Online(AJOL)(Table 2, Figure 1). The following search terms were employed electrocardiogram, competence, proficiency, medical students, postgraduate trainees, resident doctors. The combination of relevant search terms, aided by Boolean operators and truncations, and without year limiters, was used to retrieve relevant literature published within the duration in the inclusion criteria. English, French, and Portuguese-language articles were all included, and there were no geographic restrictions on them.

Deduplication of Literature

The details - titles, year of publication, and author- of each article found were entered into Excel spreadsheets. These outputs obtained were manually searched to remove duplicates.

Literature Screening and Selection

The screening process was two-staged, with at least three independent reviewers: two reviewers screened all the deduplicated literature, while the third reviewer, who is more experienced, resolved any conflicts in the screening decisions made by the other two reviewers as a consensus. The first stage consists of title and abstract screening, while the second stage consists of full text screening.

Data extraction, data summary, and data analyses

The information extracted from literature search was arranged in tables.

Table 1: PICO (population, intervention, concept or context, outcomes) framing research question for the study.

Population
• Medical students • Resident doctors
Intervention
• Instruction/methods used to teach the analysis and interpretation of ECGs
Concept or Context
• Any comparative ECG teaching method/means of instruction among undergraduate or postgraduate trainees
Outcome
• ECG educational intervention's effectiveness/competence improvement
Study
Any study design including • Randomised controlled trial, or • Cohort study, or • Case-control study, or • Before-and-after study, or • Cross-sectional research

Ethical Considerations

Since this study is a review, ethical approval is not necessary because the study used information from a public research repository.

RESULTS

Overall this review identified many teaching modalities (traditional lecture-based or electronic learning), assessment methods (formative versus summative) and multiple integrated(Blended) methods such as e-learning with face-to-face learning and mode of delivery (internet versus non-internet based methods or lecture based or flipped classes), practice methods (self-generated answers versus multiple choice answers, and instructional or learning modalities (providing schema, expert based versus learner-based , active versus passive learning , computer simulator program versus traditional teaching methods)(Table 3).

Table 2: Table showing the databases and search queries

Database	Search queries
PubMed	((((Medical students) OR (trainee)) OR (resident doctors)) AND (ECG competence)) OR (ECG interpretation) "Full text, Clinical Study, Clinical Trial, Observational Study, Randomized Controlled Trial, from 2000 - 2022" "((((""students, medical""[MeSH Terms] OR (""students""[All Fields] AND ""medical""[All Fields]) OR ""medical students""[All Fields] OR (""medical""[All Fields] AND ""students""[All Fields]) OR (""trainee""[All Fields] OR ""trainee s""[All Fields] OR ""trainees""[All Fields]) OR ((""internship and residency""[MeSH Terms] OR (""internship""[All Fields] AND ""residency""[All Fields]) OR ""internship and residency""[All Fields] OR ""residencies""[All Fields] OR ""residency""[All Fields] OR ""reside""[All Fields] OR ""resided""[All Fields] OR ""residence""[All Fields] OR ""residence s""[All Fields] OR ""residences""[All Fields] OR ""residency s""[All Fields] OR ""resident""[All Fields] OR ""resident s""[All Fields] OR ""residents""[All Fields] OR ""resides""[All Fields] OR ""residing""[All Fields]) AND (""doctor s""[All Fields] OR ""doctoral""[All Fields] OR ""doctorally""[All Fields] OR ""doctorate""[All Fields] OR ""doctorates""[All Fields] OR ""doctoring""[All Fields] OR ""physicians""[MeSH Terms] OR ""physicians""[All Fields] OR ""doctor""[All Fields] OR ""doctors""[All Fields]))) AND ((""electrocardiography""[MeSH Terms] OR ""electrocardiography""[All Fields] OR ""ecg""[All Fields]) AND (""compete""[All Fields] OR ""competed""[All Fields] OR ""competences""[All Fields] OR ""competencies""[All Fields] OR ""competently""[All Fields] OR ""competents""[All Fields] OR ""competes""[All Fields] OR ""competing""[All Fields] OR ""mental competency""[MeSH Terms] OR (""mental""[All Fields] AND ""competency""[All Fields]) OR ""mental competency""[All Fields] OR ""competence""[All Fields] OR ""competency""[All Fields] OR ""competent""[All Fields]))) OR ((""electrocardiography""[MeSH Terms] OR ""electrocardiography""[All Fields] OR ""ecg""[All Fields]) AND (""interpret""[All Fields] OR ""interpretability""[All Fields] OR ""interpretable""[All Fields] OR ""interpretating""[All Fields] OR ""interpretation""[All Fields] OR ""interpretation s""[All Fields] OR ""interpretational""[All Fields] OR ""interpretations""[All Fields] OR ""interpretative""[All Fields] OR ""interpreted""[All Fields] OR ""interpreter""[All Fields] OR ""interpreter s""[All Fields] OR ""interpreters""[All Fields] OR ""interpreting""[All Fields] OR ""interpretive""[All Fields] OR ""interpretively""[All Fields] OR ""interprets""[All Fields]))) AND ((clinicalstudy[Filter] OR clinicaltrial[Filter] OR observationalstudy[Filter] OR randomizedcontrolledtrial[Filter]) AND (fft[Filter]) AND (2000:2022[pdat]))" 488 0:40:52
Scielo	(*• Medical students) OR (Resident doctors) OR (Trainees) AND (ECG competence) OR (ECG interpretation)
AJOL	medical students, resident doctors,. trainees, ECG competence, ECG interpretation

Table 3: Summary of studies included in the scoping review

Serial number	Authors	Year of publication	Sample size/Number of participants	Country of study	Study design	Study population Students/residents 1. University	Strategy for skill improvement	Major findings
1.	Barthelemy *et al.*[6]	2017	39	France	Randomized control trial	First and second year Residents, La Roche sur Yon Hospital, Saint Nazaire Hospital, Chateaubriant Hospital, Nantes University Hospital,	lecture-based courses versus e-learning courses	ECG interpretation score was 40% before intervention and 55%, P=0.0002. Electronic learning program may be an effective tool for enhancing ECG interpretation skills among ED residents.
2.	Waechter, *et al.*[16]	2019	314	Canada	Cohort study	1st year Medical students, McGill University and University of Calgary	Short course and workshop on online ECG learning, assessment and computer algorithm feedback.	Deliberate practice of many ECG on an average of 34 cases in 112 minutes will produce 75% increased accuracy in diagnostic exam.
3.	Montassier *et al.*[17]	2016	98	France	Randomized control, non-inferior study	5th year medical students	lecture-based course versus e-learning course	e-learning was non-inferior to lecture-based course. Therefore e-learning course is an effective tool for the acquisition of ECG interpretation skills by medical students.
4.	Bojsen *et al.*[18]	2015	203	Denmark	Randomized study	4th year and 5th year medical student. University of Copengagen	web-based ECG tutorial	A standalone web-based ECG tutorial can be an effective means of teaching ECG interpretation skills to medical students. The newly acquired skills are, however, rapidly lost when the intervention is not repeated.
5.	Antiperovitch, *et al.*[8]	2021	48	Canada	Randomized Study	Medical students and Residents. London Health Sciences Centre, Western University, London, Ontario, Canada	Multiple-choice (MCQ) or self-generation (SG) format,	Practicing ECG interpretation using self-generation of diagnoses improved immediate post-test performance and fluency.
6.	Pavo *et al.*[19]	2021	1315	Austria	Observational Study	4th-grade Medical University of Vienna	online Moodle-based ECG quiz	Gender-related differences already described for non-online based examinations are similarly observable in e-learning-based testing
7.	Thach *et al.*[20]	2020	65	Canada	Randomized Study	first year. McMaster University,	Incorporating Salient or discriminatory features in worked examples	Instruction with worked examples improved diagnostic performance regardless of whether salient or discriminatory features were highlighted.
8.	Davies *et al.*[21]	2015	39	United Kingdom	Randomized controlled trial	second year	Near-peer teaching and electronic learning (e-learning)	Near-peer teaching led to superior scores in the final assessment.
9.	Blissett S *et al.*[22]	2014	57	Canada	Randomized study	medical students	expert versus learner-generated schemas in novice learners	Participants generating their schemas perform similarly to those using expert-generated schemas despite reporting higher cognitive load.

Table 3 cont'd

10.	Rui *et al.*[10]	2017	181	China	Randomized controlled study	Junior medical students	flipped classroom versus Lecture-Based Learning	Flipped classroom teaching can improve medical students' interest in learning and their self-learning abilities. This can in turn be applied to the learning of ECG.
11.	Staal J *et al.*[23]	2022	42	The Netherlands.	Randomized controlled trial.	First-year general practice residents	Usage of diagnostic checklists	Checklist use improved confidence, accuracy and calibration. Time taken to make ECG diagnosis was also reduced.
12.	Raupach *et al.*[24]	2016	493	Germany	Partially randomised and single-blinded trial	Four consecutive cohorts of fourth-year medical students	Different levels of teaching intensity and different types of examination consequences on medium- term retention of ECG interpretation skills. Afterward summative versus formative assessment.	Summative assessments are substantially more effective drivers of student ECG learning than state-of-the-art instructional methods that are grounded in theory. Summative assessments increase medium-term retention of ECG interpretation skills, irrespective of instructional format
13.	Greb *et al.*[25]	2022	42	USA	Observational study	1. University of California, Irvine, School of Medicine 2. USA	Active learning using KardiaMobile 6lead devices and Apple iPads in small learning group.	Student preference for hands-on, small group learning activities and this active learning session helped understanding of ECGs
14.	Raupach *et al.*[26]	2013	534	Germany	Six-group (two sets of three), partially randomized and single-blinded trial	1. Fourth-year medical students Göttingen Medical School	3 levels of teaching intensity at the individual, lecture and small-group peer-facilitated teaching One of the two groups on each level of teaching intensity was assessed in a formative, the other in a summative written	Summative assessments drive student learning to a much greater extent than innovative instructional formats that were deliberately designed to enhance student learning.
15.	Mahler *et al.*[27]	2010	223	USA	Prospective randomised study	1. Fourth year medical students 2. Louisiana State University Medical School, Shreveport, Louisiana	Teaching ECG interpretation using one of three teaching formats: workshop, lecture or self-directed learning(SDL). Each format covered the same content and utilised identical practice ECGs and learning objectives.	Medical students taught using workshop and lecture-based formats were able to correctly interpret more ECGs than students who studied using SDL
16.	Nickerson *et al.*[28]	2019	100	USA	Blinded randomized control trial	1. Year 2-4 resident doctors New York City Emergency Medicine Residencies	A checklist of clinically important syncope-related pathology commonly seen and diagnosed on ECGs.	No significance difference with competency in interpreting ECGs between those without a checklist and those that used checklists and those with checklist may over-read ECGs.
17.	Fent *et al.*[29]	2016	168	UK	Randomized control trial	UK medical students from 2 separate medical schools in their 3rd, 4th or 5th year of study and a group of junior doctors in their 1st year of postgraduate training.	Use of ECG simulator teaching for 85 participants while the rest 83 were taught in the lecture group	There is insufficient evidence to suggest that ECG simulator programs are superior to traditional teaching.
18.	Southern & Arnsten[30]	2009	105	USA	Quasi randomized trial	1. Sa 2. internal and emergency medicine residents 3. USA	Use of concealed stack of handouts; some contained an erroneous computer interpretation of the ECG (citing acute ischemia), and some contained no computer interpretation.	Erroneous computer interpretation of ECG reading did not significantly affect how resident physicians interpreted ECGs, although it had a profound effect on management recommendations.

Table 3 cont'd

19.	Nikendei *et al.*[31]	2009	168	Germany	Group control design study	1. 2007 2. University of Heidelberg Medical Hospital in Germany	Comparison of the effects of an on-ward PAL programme on self-assessed clinical competencies	Introduction of a Peer assisted learning programme on internal medicine wards with final year students as peer tutors is practical and leads to increased self-assessed competencies in important areas of medical education.
20.	Rubinstein J *et al.*[9]	2009	15	United States	Blinded crossover trial.	3rd year Medical student	Puzzle based teaching versus traditional ECG interpretation	Puzzle session are more interactive and relaxing, and warrant further investigations on larger scale. The two methods are however comparable.
21.	Nilsson, *et al.*[32]	2008	32	Sweden	semi-structured interview	1. 6th Semester 2. Karolinska University Hospital 3. Stockholm, Sweden	Web-based ECG-interpretation programme	1. There are benefits with added web-based ECG-learning programme over only conventional teaching of ECG
22.	Zeng R *et al.*[7]	2015	200	China	Prospective randomized controlled study	Medical students	Traditional teaching group and an innovative teaching group	The graphics-sequence memory method was found to be a useful method for ECG teaching.
23.	Hartman *et al.*	2016	113	United States	Multicenter, prospective study	1. 2015 2. Postgraduate year (PGY) 1–4 residents at five EM residency programs 3. United States	An assessment tool was created that asks the physician to identify either the ECG diagnosis or the best immediate management.	An assessment tool that asks the physician to identify either the ECG diagnosis or the best immediate management which was noted to improve ECG interpretation.
24.	Rabbitt *et al.*[33]	2020	104	Ireland	Pragmatic randomised controlled trial (RCT)	Final-year medical students from a 5-year undergraduate program in an Irish university	Say-All-Fast-Minute-Every-Day Shuffled (SAFMEDS) methodology - A flashcard-type behavioural instructional methodology used to assist learners in developing fluency in a behaviour using one-minute timed learning trials that function both as practice and assessment	Medical students trained in ECG interpretation using SAFMEDs for a relatively short duration showed significantly greater accuracy in electrocardiogram interpretation than students who received teaching as usual without SAFMEDS.
25.	Tsai *et al.*[34]	2003	30	USA	randomized, controlled trial	internal medicine residents Academic medical center, the University of Pittsburgh Medical Center	Comparing computer interpretation versus without computer interpretation	Computer decision support systems typically enhance the interpretive accuracy of internal medicine residents when analysing EKGs. However, incorrect advice significantly influenced the subjects, reducing the overall effectiveness of computer-generated advice.

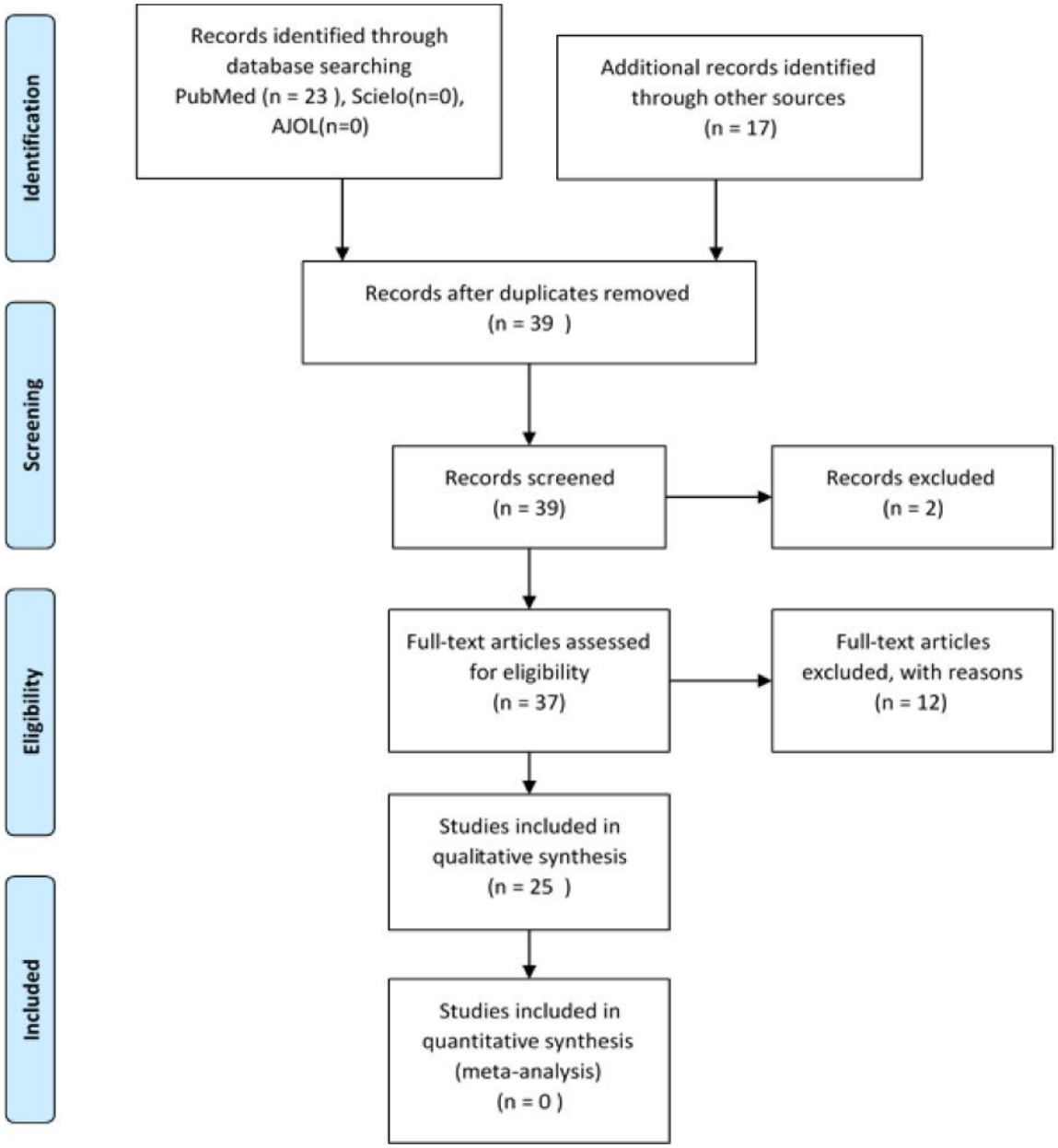

Figure 1: PRISMA 2009 flow diagram for improving ECG learning and competence among medical students and postgraduate trainees: scoping review of available evidence

The review yielded 25 articles which included randomized control trials[19], cohort studies[1], cross-sectional studies.[5] Most were from European countries. While United States as a country has five of such studies (20%)(Table 3).

DISCUSSION

This review identified a broad spectrum of activities that improve the competence of ECG interpretation among medical students and resident doctors. Overall these studies identified many teaching modalities. Such approach includes improvement of educational activities (instructional modalities, instructional methods, and interpretation approaches) and improvement of retention skills while overall the blend of traditional and electronic approaches appear to be superior than standalone approach.[6,8,10,18,19,22,24,26,27,29] The review also identified relevant teaching styles (electronic, non-electronic, near-peer), teaching tools, teaching strategies/teaching model (learner generated schema versus expert generated schema, flipped classroom versus lecture-based learning, self-directed learning) and teaching format to enhance ECG interpretative competence in medical students and resident doctors.[31] The utility of diagnostic check list during practice may also be beneficial although with mixed result.[23] The optimal way to acquire ECG interpretation skills for greater competency is still evolving however there are evidence to suggest certain activities are superior.[17]

i. Instructional modalities

Active learning with 12 lead or six leads does not appear to influence competence among medical students however the evidence for this is poor.[25] Similarly, there appears to be no difference in whether ECG simulator programs or traditional paper ECG materials in form of strip printouts affect same when used for teaching.[29] However, electronic learning(e-learning) materials with self-generating diagnosis practice training seem to be beneficial.[8] Although, what appear to be important is adequate or optimal exposure to improved learning and retention.

American Heart Association/American College of Cardiology guideline recommends interpretation of 500 ECG tracing down from 800 in 1995 and yearly interpretation of 100 under the supervision of a trained electrocardiographer for certification.[35,36] These recommendations are not based on any particular recommendation but rather what appears to be expert opinion.[37] Studies on minimum numbers of ECG learning material exposure or assessment of ECG learning curve are few therefore evidence for minimum number of ECG for optimal competence is very poor.[13] Although, Wacheter *et al.* found improve diagnostic accuracy among year one medical students with exposure to an average of 34 cases.[16] Overall it is relevant for more studies to provide insight.

ii. Instructional methods

Traditionally, workshops, lectures and self-directed learning (SDL) modules are the commonest instructional delivery methods in many medical students or resident training programs.[27] While SDL, commoner in residency training program may increase trainees' self-confidence and capacity for independent learning it appears that the method provide poor outcomes to improving ECG interpretation competence.[6,27] Additionally, medical students who are accustomed to pedagogical instruction may be resistant to SDL.[27] The influence on resident doctors may however be different since they are likely to be more motivated, mature, and have independent skill acquisition capacity.[33]

E-learning especially with web experience in isolation is well-suited for the healthcare field training because it addresses certain drawbacks of traditional lecture-based courses.[6,17,18] These drawbacks include limited teaching time and inadequate student-teacher interaction, especially in the setting of large enrollment classrooms. Furthermore, e-learning provides greater immediacy, improved visualisation and interactivity.[17] The high level of interactivity leads to successful e-learning of procedures.[17] Moreover, e-learning offers trainees and tutors the chance to engage in both synchronous and asynchronous interactive experiences. Furthermore, the rapid proliferation of mobile technologies, which are especially well-known among students, facilitates easier access to educational content.[17] The graphical nature of the ECG tracing enhances usability, providing an additional advantage. The e-learning approach also appear to be relevant for broad categories of specialist trainees.[6]

ECG teaching in electronic format also fulfills the three dimensions of Kirkpatrick's model, in term of learner satisfaction, learning outcome, and performance.[17] The Kirkpatrick Model created by Donald Kirkpatrick in 1959 is an internationally acknowledged approach for assessing the outcomes of training and educational programmes. Fewer studies notwithstanding provided contrary view that e-learning of ECG is not better than traditional methods and suggested more studies to provide better insight.[6,29] While other studies demonstrate that e-learning confers some superior benefits in term of ECG interpretation competence, as standalone e-learning tends to have lesser retention especially without repetition.[18]

The improved ECG competence seem to be optimal as a blended approach with the traditional methods among medical students or resident doctors.[10,16, 17,19,32] Even though the benefits of e-learning include ease of assessment, improve engagement and quality assurance it should not replace the traditional methods such as shop floor and workshop-based teaching or other classical or traditional way of passing instruction on ECG learning.[17] The higher benefit of blended approach may not be unconnected with the synergy the blend of approaches will provide. Fun way or other user friendly methods of knowledge delivery may also be useful.[9] For example, using puzzle session may be more interactive and relaxing compared to traditional methods.[7,9]

iii. Interpretation approaches

The use of a diagnostic checklist among medical students and resident doctors improve confidence-accuracy calibration, though accuracy and confidence were not significantly affected.[23,38,39] Another study found that identifying cognitive bias or mobilising domain-specific knowledge had no overall effect on reducing diagnostic errors in ECG interpretation, despite the fact that they may help novices.[38] While computer decision support systems typically enhance the interpretive accuracy of resident doctors when analysing ECGs.[34] Other studies, suggest it does not have any benefit and it may give incorrect advice which may significantly influence the learners, thereby reducing the overall effectiveness of computer-generated advice.[30,34]

iv. Assessment approach

Previous review suggested formative assessment offers some superior benefit.[40] However, summative assessment appears to be better and it has been found to help increase medium-term retention of ECG interpretation skills, the instructional format notwithstanding.[24,26] Infact examinations or evaluations is more important and powerful drivers of student learning than mere provision of instructional format for that matter.[26]

Recommendation

While a blended approach to ECG training is the best there is need for repetition and experiential methods since this is essential for retention and it is the required approach for the attainment of competence.[8,41] Another feature that may help is self-generating choice in training sets instead of multiple choice responses in the electronic component.[8,16] Training modules with worked examples are also relevant whether the salient or discriminatory features of the ECG were highlighted.[20] The former provide deeper learning and long-term retention.[8] A good component also include using worked examples either with salient or discriminatory features which demonstrate to the trainees the logic behind the solution to improve diagnostic competence.[20] Improving competence encompasses instruction delivery, assessment and recertification. Also, there are differences between what works during training and during practice.

Overall, there is also a need for deliberate and repeated practice and feedback and not mere opportunistic learning during clinical posting.[16] Deliberate practice as against passive learning is widely cited as a key component of obtaining competence and mastery.[16] Furthermore, the electronic component should have computer algorithms providing automated feedbacks which help scalability, practicability and feasibility, as well as consistency in skill transfer.[40] There should also be a consideration for learning curve and a balanced blend of didactic theory impartation, with formalized structured ECG practice while efforts should be made for periodic objective assessments of ECG interpretation skills and competence.[16]

To supplement faculty efforts at effective ECG training, peer-learning can be introduced.[42] Given the congested nature of the modern medical curriculum, direct comparison of the efficacy of these methods may aid course design.[21] Near-peer or peer-assisted-learning sessions provide a supportive learning environment that benefits both the students and the tutor.[21,31]

Further direction

The optimal way to acquire ECG interpretation skills for greater competency is still evolving (17) There is a need to evaluate the best time to introduce learning, the duration of learning at each level of medical studentship or staggered through residency training, and the consistency of exposure with varying degree of complexity to ECG to ensure greater competence. There is also a need to explore various approaches such as puzzle-based learning, mnemonic techniques for pattern recognition, and YouTube e-learning in improving ECG interpretation competence.[43] Furthermore, there is also a need to develop new ways of delivering traditional methods especially for low-resource settings. Also, the relevance of small or large group approach to ECG learning should be explored.[25] For example, Say-All-Fast-Minute-Every-Day-Shuffled (SAFMEDS) methodology - A flashcard-type behavioural instructional methodology used to assist learners in developing fluency in a behaviour using one-minute timed learning trials that function both as practice and assessment.[33] Similar technologies or approaches should be evaluated to determine usefulness in the ECG training for mastery.[27]

Limitation

The assessment of competency is complex and multidimensional and these may have impacted on the methodology of the individual studies.[37] However, the diverse setting of the various studies reviewed as well as the consistent and rigourous methods used in this scoping review, are the strength of this study.

CONCLUSION

Overall, proficiency or competence in electro-cardiogram (ECG) interpretation is vital for diagnosing cardiac issues. It relies on pattern recognition and experience-driven knowledge. The best method for developing ECG interpretation skills for increased competency is still being studied, but data suggests, all things considered, a combination of conventional and electronic methods works better than either one standing alone. While it has been proffered that no single teaching strategy is effective in delivering ECG interpretation skills, trainers should look for newer but effective methods to enhance traditional ECG competence among trainees. Generally, improving competence require efforts at improving accuracy, confidence, speed, repeatability and retention.

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