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Teaching the interpretation of electrocardiograms: Which method is best?

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Abstract

Background: Electrocardiogram (ECG) interpretation is poorly performed at undergraduate and post-graduate level. Incorrect ECG interpretation can lead to serious clinical error. Despite the incorporation of computerized ECG interpretation software into modern ECG machines, the sensitivity and specificity of current technology remain poor, emphasizing the on-going need for doctors to perform ECG interpretation accurately.

Purpose: This is the first review in this important area and aims to critically evaluate the current literature in relation to the optimal format and method of teaching ECG interpretation at undergraduate and postgraduate level.

Conclusions: No single method or format of teaching is most effective in delivering ECG interpretation skills; however, self-directed learning appears to be associated with poorer interpretation competence. Summative in preference to formative assessment is associated with improved interpretation competence. Web-based learning offers a promising modern approach to learning ECG interpretation, though caution must be exercised in accessing user-uploaded content to supplement learning.

Keywords: Electrocardiogram; Teaching; Interpretation

Introduction

Since its clinical development by Einthoven over a century ago, the electrocardiogram (ECG) remains one of the most commonly used and important diagnostic tests in cardiology and mastering its interpretation requires considerable time and effort. ECG interpretation is traditionally taught at medical school and beyond in the form of didactic teaching and self-study, though time allocation, faculty training and teaching format vary considerably [1].

Though ECG interpretation accuracy improves with time and practice, a number of studies have shown performance in ECG interpretation using ECGs independently verified by qualified cardiologists to be poor among both medical students [2] and doctors of different grades and specialties [3,4]. Ability to correctly identify potentially life-threatening conditions was 57% in a group of US graduating medical students [2] and 46.4% in a group of South African Emergency Medicine trainees [3].

Computerized ECG interpretation software is now built into many modern ECG machines which aims to automate the process. Contemporary data on the diagnostic accuracy of computerized ECG interpretation in determining cardiac rhythm were recently demonstrated to be 88% overall, with 95% correct identification of sinus rhythm, but poor interpretation of non-sinus rhythm at only 53.5% [5]. Computerized ECG interpretation in a pre-hospital setting has been shown to be 58% sensitive and 100% specific for diagnosis of ST-segment elevation myocardial infarction (STEMI) [6]. This contrasts with sensitivity and specificity rates of predicting STEMI among emergency medical personnel of 99.6% and 67.6% respectively [7]. From these data, it is clear that the current generation of computerized ECG interpretation technology should not be solely relied upon and its interpretation should be independently verified by an appropriately qualified individual [8]. Nevertheless, it is inevitable that computerized ECG technology will improve and may one day even supersede expert interpretation. In addition, the increasing availability of imaging modalities such as echocardiography and magnetic resonance imaging is providing better estimates of parameters such as ventricular hypertrophy which previously were diagnosed using ECG.

Inaccurate ECG interpretation may lead to adverse patient outcomes. A 2004 study retrospectively analyzed ECGs performed on 1085 patients where computerized ECG interpretation software

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interpreted the rhythm to be atrial fibrillation. They found that 382 patients' ECGs (35%) had been incorrectly interpreted by computerized ECG interpretation and, of these, the incorrect interpretation was not identified by the requesting physician in 92 patients leading to inappropriate anti-arrhythmic and anti-coagulant prescription in 39 patients (3.6% overall) [9]. Although it is difficult to accurately estimate the overall true number of adverse clinical events due to incorrect ECG interpretation, one paper suggested that 10,000 deaths annually in the USA alone would be a conservative figure [10]. It is acknowledged that this a crude estimate and, in that in real-world practice, making a diagnosis seldom relies on interpretation of a single ECG. More commonly, ECGs are interpreted by multiple medical personnel or the diagnosis may by means of an alternative investigation.

This worrying pattern of sub-standard ECG interpretation led to the publication of American College of Cardiology guidelines on requisite knowledge and minimum necessary teaching to attain clinical competency [11] and standardized approach to ECG interpretation [12]. The former of these guidelines recommends that in order to be deemed clinically competent in ECG interpretation, a reader should either be a qualified cardiologist, have interpreted 500 ECGs under the supervision of an expert electrocardiographer or achieve accreditation by way of passing a standardized ECG exam [11]. In practice, it may in fact require far more than 500 interpreted ECGs for a reader to reach competency. As part of a quality assurance process, it is recommended that all ECGs are reviewed by an appropriately qualified reader, with a turnaround of less than 24 hours and a means of emergency notification if a serious abnormality is detected [10].

It must be recognized that there cannot be one method for teaching ECG interpretation to suit the wide-ranging needs of all healthcare professionals using ECG for a multitude of clinical applications. It is neither feasible nor necessary for every practicing doctor or healthcare professional to be an expert in ECG interpretation. However, by graduation medical students need to achieve basic competency both to allow on-going recognition of potentially life-threatening conditions and as a foundation for those needing to master the skill later in their careers (Table 1).

Review

The review attempts to assess the optimal method for the acquisition of ECG interpretation skills, by addressing which teaching method was employed, the seniority and expertise of the person or persons responsible for the teaching and how acquisition of knowledge was tested. The papers included in the review assess the teaching of ECG interpretation at undergraduate level, primarily as few if any studies at postgraduate level exist. It is unclear, therefore, whether poor performance in ECG interpretation at postgraduate level results from to a failure to achieve an adequate level during undergraduate training or is indicative of failings in teaching beyond graduation. A 2005 US survey of Clerkship Directors in Internal Medicine revealed the most frequent format for teaching ECG interpretation to medical students was lectures (75%) followed by teaching rounds (44%) [13] but are these approaches the most effective?

A large 2011 study randomized 223 US medical students to receive either workshop-based, lecture-based or self-directed learning (SDL) and assessed performance in a baseline pre-course, immediate post-course and one-week post course ECG 'retention' interpretation test [14]. In order to standardize the content and quality of teaching materials, each group covered the same content, used identical example ECGs and were given the same learning objectives. All teaching materials were created and delivered by the same educators to ensure they were of equivalent quality. The workshop and lecture-based groups received two hours of teaching and the SDL group was provided with a course manual and instructed to study for two hours. The same university instructor was responsible for delivery of teaching, though their precise seniority and expertise were not explicitly stated. No statistical difference was found between the three groups in the baseline test, but in the immediate post-course tests, scores in the workshop and lecture groups were significantly better than the SDL group with mean scores of 57.3%, 56.8% and 48.8% respectively (p-value 0.003) with a similar, significant effect also being present in the retention test [14].

Web-based ECG learning packages are widely available and have been shown to be a popular resource for medical students [15]. The usefulness of one such Web-based learning program for medical students was assessed by a group of Swedish researchers. They invited a cohort of 32 students to complete a Web-based ECG interpretation package in addition to traditional lecture based teaching and tested performance in an ECG interpretation exercise five months later. They compared their results to a control group of 30 students who received the same lecture based teaching, but were not given access to the package [16]. The mean score for those who completed the Web based learning package (n = 17) in an eight-question interpretation exercise

Table 1
Summary of different teaching formats reviewed in this paper.

Teaching Format	Features
Self-directed learning	Learners can progress in own time and at own pace Reliant on learner engagement Reliant on learners to access support when needed
Workshop-based teaching	Interactive and face to face Can be tailored to learner level and understanding Can be time-intensive
Lecture-based teaching	Standardizes content for all learners Can be difficult to assess engagement and learning
Web-based learning	Accessible at learners own time and pace Limited in ability to provide feedback and facilitation Learner engagement may vary
User-generated video sharing	Popular and easy to access Often free Non peer reviewed sources may not be accurate
Contrastive teaching method	Encourages learner to compare differences in ECG appearances across different diagnoses May facilitate pattern recognition and allow accurate diagnosis Acquisition dependent on exposure to specific patterns
Non-contrastive teaching method	Teaches different ECG diagnoses individually and sequentially Logical and systematic approach May be less effective

was 61% versus 51% in the control group ($n = 25$) (p-value = 0.03) [16]. However, there were significant confounding factors which may have influenced this difference, including self-selection bias and a small cohort of participants. In addition, the control group without access to the package received additional teaching on cardiac physiology which included some ECG interpretation. Interestingly, however, the test of ECG interpretation was administered five months after commencing the course, which could indicate that this method of teaching is associated with a sustained benefit in learning.

Though Web-based packages offer a potentially useful learning opportunity, caution must be exercised as to the quality of material accessed. A recent study analyzed 119 videos on the video broadcast Website 'YouTube' offering tutorials on ECG interpretation in the context of ten common ECG diagnoses [17]. All of these videos were watched by an expert panel of two physicians who graded each video against pre-specified criteria in terms of usefulness, source and characteristics. This revealed that while 47.1% were deemed 'very useful' and 39.5% as 'useful', 13.4% were felt to be 'misleading' and contained inaccurate information [17]. Of the videos classified as 'very useful', 90% were uploaded by universities or hospitals and only 45% were uploaded by individuals [17]. The study demonstrated how popular this resource is with each of the 119 videos having been viewed an average of 12,197 times; however, given that there was no difference in number of views or number of 'likes' and 'dislikes' by viewers between 'very useful' and 'misleading' videos [17], it would seem that viewers are unable to discriminate between useful and misleading content themselves. Although clearly of benefit in some cases, this highlights the potential dangers associated with non peer-reviewed uploaded content.

Factors other than teaching method have been shown to effect performance in ECG interpretation. Raupach et al. [18] recently performed an extensive and well-conducted study assessing the effects of both teaching format and type of assessment. A total of 534 fourth year medical students were divided into six groups (two sets of three) who received three differing levels of intensity learning; two SDL groups, two lecture groups (facilitated by expert electrocardiographer) and two small group peer teaching groups (where more advanced medical students facilitated sessions). One of each group type underwent formative assessment and the other underwent summative assessment, both assessments taking place after six weeks. A 'summative' assessment is often completed at the end of a block of study and a grade is given. It therefore counts more towards overall degree classification or career progression. In contrast, a 'formative' assessment is typically conducted during a block of study and checks a learner's progress to guide learning needs and often does not count towards degree classification or career progression. While no differences were found in performance (defined as obtaining at least 3/5 correct answers in an ECG interpretation exercise) attributable to intensity level of learning, a significant improvement was found in students undergoing summative rather than formative assessment (OR 5.14; 95% CI 3.26 to 8.09) [18]. Furthermore, the authors found that summative rather than formative assessment increased the likelihood of spending extra time studying as well as using additional learning material [18]. The old adage, 'assessment drives learning' appears to hold truth in this context with intensity level of learning seemingly less of a significant factor at undergraduate level, though whether this leads to a long-term sustained effect is unclear.

A 2003 paper assessed the effect of instructional format on the acquisition of ECG interpretation skills [19]. A total of 66 first year medical students were divided into two equal groups and received a two-hour teaching session covering ECG appearances in the following diagnostic categories; myocardial infarction, bundle branch blocks, pericarditis and ischemia. ECG interpretation was assessed immediately after the session. One group was encouraged to use a 'contrastive approach' where morphological ECG differences between the four categories are compared, whereas the other group used a 'non-contrastive' approach where the same ECG examples were presented in isolation. The facilitator for both groups was the same, however, their seniority or expertise was not stated by the authors. This showed significantly better performance in the contrastive group who attained 46% accuracy compared with the non-contrastive instructional format who attained 30% accuracy (p-value <0.05) [19].

Conclusions

The ECG remains a critically important diagnostic tool in medicine, and interpretation competence is often poor among undergraduate and postgraduates. Errors in ECG diagnosis can have serious implications for patient care. Computerized ECG technology aims to automate this process but sensitivity and specificity in the current generation of technology are inadequate to obviate the need for expert review. Future improvements to computerized ECG technology will undoubtedly bridge this gap, however.

There is no standard method for ECG interpretation acquisition teaching which is applied uniformly, although guidance is available for minimum standards. Learning commences during undergraduate study, and should continue into postgraduate practice. Methods described in the literature include tutorials, lectures, teaching rounds and self-directed learning. Web-based packages have risen to prominence in recent years, with their accessibility being the key underlying reason for this. There is a great deal of scope to expand and improve existing Web-based learning though ensuring content is accurate and of high quality represents perhaps the greatest challenge.

With the exception of the study assessing the effectiveness of a Web-based learning package where the ECG interpretation test was conducted five months after the start of the trial [17], the remainder of the studies assessed in this review share a common flaw in that testing occurred either shortly after or immediately after their intervention. A widely held principle of medical education is that for a teaching method to be considered effective, the observed effect should be 'retained' i.e. be present six to twelve months after the teaching in question took place, thus it remains unclear

whether any of the teaching methods in the studies evaluated in this review produce any long-term benefit.

Another area of uncertainty is whether any observed benefits of these teaching methods lead to transfer of acquired knowledge to the workplace and real-world improvement in ECG interpretation and reduction in adverse clinical events.

Notwithstanding, although studies to date have failed to demonstrate superiority of any single method of instruction, self-directed learning may be less effective. The use of summative assessment in preference to formative assessment does also appear to be a driver to stimulate learning.

Future areas for research in this area should aim to identify teaching methods for ECG interpretation which lead to a sustained benefit and aim to demonstrate measureable 'real world' benefit in the form of reduced adverse clinical events, both of which are lacking in current literature. Furthermore, none of the studies to date have assessed the impact of the seniority and expertise of the facilitator responsible for delivery of teaching. Teaching of ECG interpretation at postgraduate level has not been studied adequately and this may also be an area of focus for future research.

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