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A new algorithm for arrhythmia interpretation

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Abstract

Background: Electrocardiogram (ECG) is an essential tool used to diagnose serious heart disease but its interpretation is challenging for undergraduate students and junior practitioners despite numerous methods that have been suggested to aid ECG interpretation. This paper aims to present a new algorithm for arrhythmia interpretation that is superior to current methods to be used as a supplement to lecture materials for medical students.

Methods: A new systematic algorithm is introduced in this paper. To evaluate the effectiveness of the proposed algorithm, a study was carried out in a medical university. Two groups of medical interns were educated via lecture and teaching rounds, either using the proposed algorithm or without using the algorithm. At the end of 1 month training, students of both groups were blindly evaluated.

Results: The group trained using the algorithm scored an average of 93% on the evaluation, while the group trained without it averaged 62%. This was found to be a statistically significant difference ($p < 0.01$).

Conclusion: The proposed method for education of arrhythmia interpretation can improve physicians' competency in ECG interpretation.

Keywords: Electrocardiogram; Arrhythmia interpretation; Algorithm; Education

Introduction

The electrocardiogram is a useful tool used to diagnose heart disease and ECG interpretation is known as an important clinical skill for quick diagnosis of potential life-threatening diseases. Therefore, physicians should have sound expertise in ECG interpretation.

The accuracy of ECG interpretation improves with practice and time and the performance of ECG interpretation should be evaluated by qualified and expert cardiologists. Analyses of the ability of a group of graduated medical students in the US and a group of emergency medicine trainees in South Africa showed that these students could correctly identify only 57% and 46.4% of life-threatening conditions, respectively [1,2]. This shows the poor ability of these groups, who were medical school trained, to interpret ECGs.

Previous studies have shown that in addition to medical students [3,4], physicians [5], internal medicine residents [6,7], pediatric residents [8], family practice residents [9–11] and emergency medicine residents [6] have difficulties with the interpretation of ECGs and cardiac rhythms.

Several methods have been suggested for training in electrocardiogram interpretation and arrhythmia. Methods using workshops and lectures [12,13], computer-assisted learning [14], a web-based ECG interpretation program [15], a computerized qualitative model (QM) and 'cardiac rhythm disturbances analysis learning tool' [16], a puzzle [17] and algorithms, have been used by practitioners to overcome the difficulties in interpretation of ECGs.

Statistical analyses undertaken by Mahler et al. [12] showed that self-directed learning is less effective than a workshop or lecture. However, they found no significant difference between the performance of workshop and lecture.

Computerized ECG interpretation software has been developed to automate the process of ECG interpretation. Shah et al. [18] did a statistical analysis of the accuracy of computerized ECG interpretation technology in the diagnosis of cardiac rhythms. They showed that the overall accuracy of this approach was 88%, with 95% accuracy in the identification of the sinus rhythm, but with poor interpretation (53.5% accuracy) of non-sinus rhythms. Bhalla et al. [19] investigated, in a pre-hospital setting, the ability of computerized ECG interpretation in the diagnosis of ST-segment elevation myocardial infraction (STEMI) and showed the sensitivity to be 58% and specificity to be 100%. Yet the study by Ducas et al. [20] showed a sensitivity of 99.6% and a specificity of 67.6%. Therefore, these data clearly show that the computerized ECG interpretation

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technology still has to be verified by a qualified cardiologist and should not be used as a sole interpretation technique.

The algorithm technique has been used several times for arrhythmia interpretation [21–23] but it has been mostly used for tachyarrhythmia [24–26] and has not covered all types of tachyarrhythmia.

In this paper, a new algorithm is presented to ease arrhythmia interpretation and covers both tachyarrhythmia and bradyarrhythmia. The effectiveness of the algorithm was evaluated via the teaching of medical interns, where it was used as a supplement to lecture materials.

Proposed algorithm

Medical interns and practitioners, in spite of their familiarity with different types of arrhythmia, usually encounter difficulty in recognizing arrhythmia. Therefore, in this study an algorithm was developed to aid in arrhythmia interpretation. The new algorithm was then used for arrhythmia interpretations of patients for a period of two years to validate and assess the effectiveness of the algorithm.

The proposed algorithm is illustrated in Fig. 1. First, the QRS complexes should be considered in ECG.

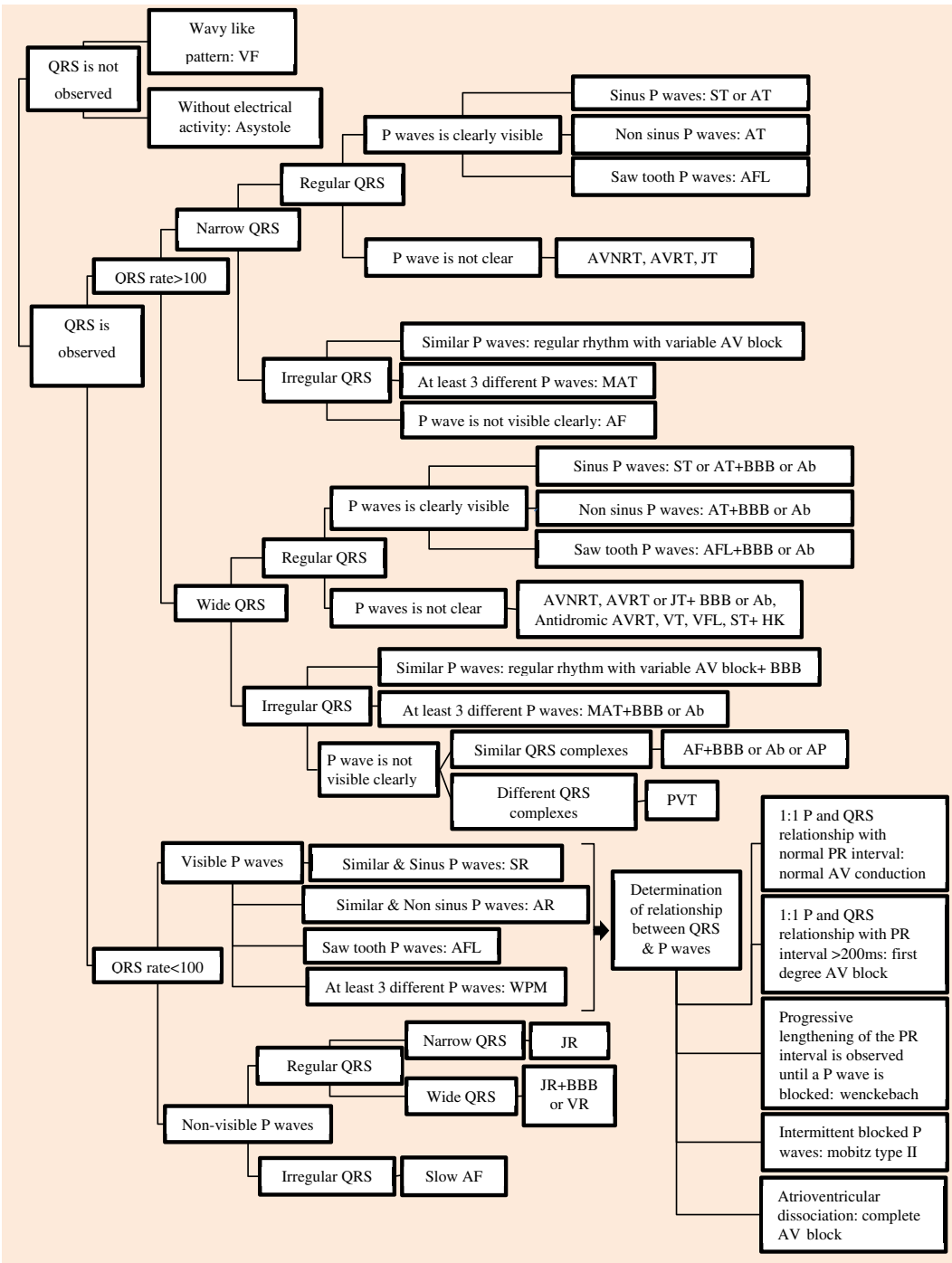

Fig. 1. New algorithm to aid in cardiac rhythm interpretation of electrocardiograms.

QRS is not present

If the QRS complexes are not present, two types of rhythms can be recognized; namely, ventricular fibrillation (VF) and asystole. VF is a wavy shape while asystole has no electrical activity.

QRS is present

If the QRS complexes are present, the QRS rate should be noticed:

QRS rate > 100 bpm

If the QRS rate is more than 100 bpm, the QRS width should be noticed:

Normal width QRS. For the case QRS width is normal (narrow width), the QRS regularity should be considered. If the QRS is regular and the P waves are clearly visible,* three rhythms can be distinguished, sinus tachycardia (ST) which has sinus P waves, atrial tachycardia (AT) which has non-sinus P waves or may have pseudo-sinus P waves and atrial flutter (AFL) which has saw tooth P waves.

For the case the QRS is narrow and regular but the P waves are not clearly visible, three differential diagnoses can be made: atrioventricular nodal reentrant tachycardia (AVNRT), orthodromic atrioventricular reentrant tachycardia (AVRT), and junctional tachycardia (JT).

If the rhythm has narrow and irregular QRS complexes, the P waves should be noticed. The rhythm with similar P waves is one of the regular rhythms, which was noted earlier with variable atrioventricular nodal block. Observation of at least three different P waves leads us to diagnose multifocal atrial tachycardia (MAT). If the P waves are not observed clearly, the rhythm is atrial fibrillation (AF).

Wide QRS complex. In wide QRS complexes, similar to narrow QRS complexes, the QRS regularity should be noticed. The regular rhythm with clear P wave has three differential diagnoses, sinus tachycardia with bundle branch block (BBB) or aberration (Ab), atrial tachycardia with bundle branch block or aberration and atrial flutter with bundle branch block or aberration.

The rhythm with wide and regular QRS complexes and without clear P waves has seven differential diagnoses, atrioventricular nodal reentrant tachycardia (AVNRT) with bundle branch block or aberration, orthodromic atrioventricular reentrant tachycardia (AVRT) with bundle branch block or aberration, junctional tachycardia (JT) with bundle branch block or aberration, antidromic AVRT, ventricular tachycardia (VT) ventricular flutter (VFL) and sinus tachycardia with additional to hyperkalemia (HK).

If the wide QRS complexes are irregular, attention should be given to the P waves. If the P waves are similar, the rhythm is one of the regular rhythms which were noted earlier with variable atrioventricular nodal block and bundle branch block. The rhythm which has different P waves is multifocal atrial tachycardia (MAT) with bundle branch block or aberration. If the P waves are not observed clearly, two differential diagnoses can be recognized; atrial fibrillation (AF) with bundle branch block or aberration or accessory pathway (AP) which has similar QRS complexes and polymorphic ventricular tachycardia (PVT) which has different QRS complexes.

The QRS rate <100

First, the P waves should be considered. If P waves are observed, the following two steps should be checked:

Step 1: The morphology of P waves should be noted. The rhythm with sinus P waves is called sinus rhythm (SR), the rhythm with non-sinus P waves is called atrial rhythm (AR), the rhythm with saw tooth P waves is called atrial flutter (AFL) and the rhythm with at least three different P waves is called wandering pacemaker (WPM).

Step 2: The relationship between P waves and QRS complexes should be noted. For example, in first degree atrioventricular (AV) block, each P wave is followed by a QRS complex but the PR interval is longer than 200 milliseconds. In type I second degree AV block or wenckebach AV block, the progressive lengthening of the PR interval is observed until a P wave is blocked. In type II AV block or mobitz type II, the intermittent blocked P waves are observed with no change in the PR interval. Third-degree AV block or complete AV block is characterized by the presence of atrioventricular dissociation.

In the absence of P waves, the QRS regularity should be noted. For the irregular rhythm, slow atrial fibrillation is diagnosed. But for the regular rhythm, the QRS width should be considered. If the QRS width is normal, the rhythm is junctional rhythm (JR) while for wide QRS complexes, the rhythm is ventricular rhythm (VR) or junctional rhythm with bundle branch block.

Some examples of how to use the proposed algorithm and diagnosis of rhythm are provided in Figs. 2–5.

Example 1. In the ECG presented in Fig. 2, the QRS complexes are not present and the rhythm is wavy shape so the rhythm is ventricular fibrillation (VF).

Example 2. In the ECG shown in Fig. 3, the QRS complexes are present with rate of more than 100 bpm, wide, irregular and similar so the rhythm is atrial fibrillation with bundle branch block or aberration (AF + BBB or Ab).

Example 3. In the ECG illustrated in Fig. 4, the QRS complexes are present with rate of less than 100 bpm. Sinus P waves are visible. The progressive lengthening of the PR interval is observed until the P wave is blocked, so the rhythm is sinus rhythm with type I second degree AV block or wenckebach AV block.

Example 4. In the ECG presented in Fig. 5, the QRS complexes are present with rate of less than 100 bpm. P wave is not present. QRS complexes are regular and narrow so the rhythm is junctional rhythm (JR).

* The clear P wave is the wave that does not fall on the QRS complex, ST segment and T wave and also does not include the fibrillation wave which has a rate more than 450–650 bpm.

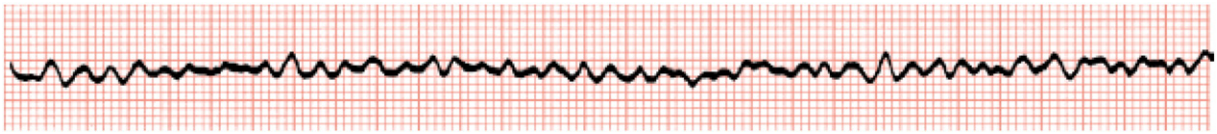

Fig. 2. Diagnosis of ventricular fibrillation using the proposed algorithm (ECG is taken from [25] for illustrative purposes only).

Method

In order to investigate the effectiveness of the proposed algorithm, a study was undertaken on interns at the Medical University of Kerman, Iran from September 2014 to June 2016.

In the Medical University of Kerman, Iran, each month 6–13 medical interns are sent to the cardiology center. These medical interns are randomly and unequally divided into two groups (group A and group B) and they are sent to two different hospitals. These groups are trained to interpret ECGs by two different instructors (both instructors are from the cardiovascular research center of the Medical University of Kerman). At the end of one month of training, interns of both groups are blindly evaluated by a written test which included twenty tracings of rhythms which are different from teaching materials. A preliminary study, before undertaking this research in 2012, showed that both groups performed poorly in ECG interpretation with no significant difference between the final scores of two groups. This investigation clearly showed a need for a supplemental technique to aid in ECG interpretation.

The algorithm was developed in 2012 and reviewed for a period of two years by several expert cardiologists via a large number of ECG tracings. Then, the effectiveness of this algorithm was evaluated on medical interns of the Medical university of Kerman. During the period of 21 months of this study, a total of 163 medical interns were recruited: 91 interns were trained in group A and 72 of them were trained in group B. Medical interns in group A were trained using the algorithm while the interns in group B were trained using the normal teaching rounds. The curriculum for arrhythmia interpretation in both groups was otherwise the same. The teaching basics of both groups were the same: using the same teaching reference books, and teaching was for two sessions per week and each session included 1 hour training. The teaching of group B was based on the explanation of each arrhythmia. It started with the explanation of supraventricular and ventricular tachycardia. Then, AV node blocks were explained. However, in group A, the order of teaching arrhythmia was based on the algorithm and the step-by-step approach of the algorithm was used for the diagnosis of arrhythmia and then each arrhythmia was explained.

Interns of both groups were evaluated by a written exam which included 20 tracings with the following diagnoses: atrial fibrillation (*QRS* rate ≈ 160), sinus tachycardia, atrial tachycardia, junctional rhythm, sinus rhythm with wenkebach atrioventricular nodal block, ventricular rhythm, atrioventricular nodal reentrant tachycardia, sinus bradycardia, multifocal atrial tachycardia, polymorphic ventricular tachycardia, atrial flutter (4:1), sinus rhythm with mobitz type II atrioventricular nodal block, ventricular tachycardia, atrial rhythm, atrial fibrillation with left bundle branch block, asystole, sinus rhythm with third degree atrioventricular nodal block, wandering pacemaker, slow atrial fibrillation (*QRS* rate ≈ 70), ventricular fibrillation.

The ECG tracings, which were used for the evaluation exam, were different from the teaching materials. In the evaluation exam, each of the 20 rhythm diagnoses was valued as one point. The exam time was 30 minutes and exam sheets were scored out of 20. Then, statistical analysis was undertaken on the final scores to investigate if any significant difference could be found between the final scores of these groups or not. This analysis was carried out using SPSS software and the results are presented in Results.

The validity analysis of the test was based on 'consequences' in which the final scores of the interns in the two groups were compared where the only difference in these two groups is the use of the algorithm in group A [27,28]. This approach is a common and widely used method for evaluating the consequence of a change in an education system [1,13,17,29].

Results

The average scores for each group were 18.6/20 (93%) for group A (medical interns trained using the algorithm) and 12.3/20 (62%) for group B (medical interns trained without the algorithm). The Kolmogorov–Smirnov test was carried out to determine the statistical distribution of each group. This analysis showed that the statistical distributions of both

Fig. 3. Diagnosis of atrial fibrillation with bundle branch block or aberration using the proposed algorithm (ECG is taken from [25] for illustrative purposes only).

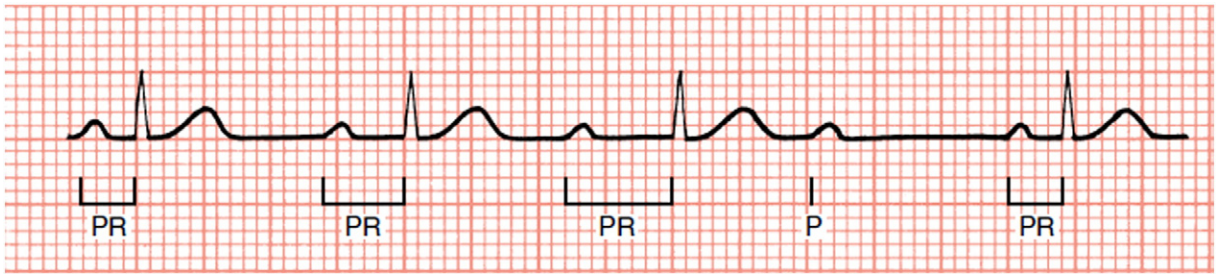

Fig. 4. Diagnosis of sinus rhythm with type I second degree AV block or wenckebach AV block using the proposed algorithm (ECG is taken from [25] for illustrative purposes only).

groups were not normal. The *t*-test can be used for evaluating the significance of difference between two normal distribution groups, while the Mann–Whitney *U* test can be used for non-normal distributions. The Mann–Whitney U test showed that there was a statistically significant difference in the performance of the groups ($P < 0.01$). Therefore, the analysis showed a 31% absolute improvement in the performance of group A compared to group B.

Discussion and conclusion

The ECG is used as an important diagnostic tool in cardiac medicine and mistakes in ECG interpretation can lead to serious effects on patient health. However, previous investigations show that the interpretation competence is often poor in medical students [3,4], internal medicine residents [6,7], pediatric residents [8], family practice residents [9–11] emergency medicine residents [6] and physicians [5] in general.

Revision of the medical curriculum is most likely to help improvement in the ECG interpretation. It is widely accepted that the ECG interpretation accuracy improves with years of training [30] and with further classes and lessons [6]. No standard method has been proposed for teaching and training ECG interpretation, but guidance of trainees is known as a minimum requirement. Various methods are now available to assist teachers to improve ECG interpretation skills. Algorithms are the most effective technique in interpretation of ECGs compared to other approaches due to their step-by-step approach to analyzing ECGs and highlighting the key notes for interpretation of ECGs. Some efforts have been taken to develop algorithms for arrhythmia interpretation, but all important rhythms have not been included in these algorithms [21–23]. A new algorithm has been presented in this paper to cover both tachyarrhythmia and bradyarrhythmia.

In order to investigate the effectiveness of the proposed algorithm, two groups of medical interns were trained to interpret ECGs with and without the use of the proposed algorithm. The statistical analysis on the exam results of these groups showed that the group that was trained using this algorithm performed better in the exam. This analysis showed that the education of arrhythmia interpretation via this method can improve physician competence in ECG interpretation.

It is interesting to note that there was a significant improvement in the performance of the group that was trained using the algorithm in diagnosis of atrial fibrillation with left bundle branch block (87.04%), wandering pacemaker (70.38%), polymorphic ventricular tachycardia (62.33%), junctional rhythm (61.75%), ventricular rhythm (60.36%), atrial rhythm (56.5%) and slow atrial fibrillation (52.32%) compared to the other group. However, the group that was trained without using the algorithm could also perform acceptably in diagnosis of sinus tachycardia, sinus rhythm with wenkebach atrioventricular nodal block, atrioventricular nodal reentrant tachycardia, sinus bradycardia, asystole, ventricular fibrillation and atrial flutter (4:1).

After the period of training for both groups, students of group B were invited to take part in ECG interpretation workshops, which were held for internal medicine residents, to learn the algorithm and improve their interpretation skills thus becoming better physicians.

The new algorithm covers a wide range of arrhythmia. The sample size for statistical analysis was acceptable and 20 ECG tracings were used in the written exam which covered all important types of arrhythmia. Both groups were evaluated using the same exam.

The sample size in this study was limited to the available medical interns from one university. It is possible that the results of this study are not representative of all medical interns in other environments. Pre-evaluation was not carried out on these medical interns before education and the level of

Fig. 5. Diagnosis of Junctional rhythm using the proposed algorithm (ECG is taken from [25] for illustrative purposes only).

their prior ability was unknown. The results of this study demonstrated a significant effect on medium-term retention of ECG interpretation skills by using the proposed algorithm, but the long-term efficacy was not evaluated.

Results of this study may mean that the instruction using algorithmic methods would lead to better performance in ECG interpretation. Future scope of this research is to evaluate teaching methods of ECG interpretation which result in a sustained benefit and demonstrate measureable real world benefits in the form of reduced clinical events.

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References

[1] Jablonover RS, Lundberg E, Zhang Y, Stagnaro-Green A. Competency in electrocardiogram interpretation among graduating medical students. Teach Learn Med 2014;26(3):279–84.
[2] De Jager J, Wallis L, Maritz D. ECG interpretation of South African emergency medicine residents. Emerg Med 2010;28(4):309–14.
[3] Salerno SM, Alguire PC, Waxman HS. Competency in interpretation of 12-lead electrocardiograms: a summary and appraisal of published evidence. Ann Intern Med 2003;138(9):751–60.
[4] Little B, Mainie I, Ho KJ, Scott L. Electrocardiogram and rhythm strip interpretation by final year medical students. Ulster Med J 2001;70(2):108–10.
[5] LaPointe NM, Al-Khatib SM, Kramer JM, Califf RM. Knowledge deficits related to the QT interval could affect patient safety. Ann Noninvasive Electrocardiol 2003;8(2):157–60.
[6] Berger JS, Eisen L, Nozad V, D'Angelo J, Calderon Y, Brown DL, et al. Competency in electrocardiogram interpretation among internal medicine and emergency medicine residents. Med 2005;118(8):873–80.
[7] Eslava D, Dhillon S, Berger J, Homel P, Bergmann S. Interpretation of electrocardiograms by first-year residents: the need for change. J Electrocardiol 2009;42(6):693–7.
[8] Snyder CS, Bricker JT, Fenrich AL, Friedman RA, Rosenthal GL, Johnsrude CL, et al. Can pediatric residents interpret electrocardiograms? Pediatr Cardiol 2005;26(4):396–9.
[9] Margolis S, Reed R. EKG. Analysis skills of family practice residents the United Arab Emirates: a comparison with US data. Fam Med 2001;33(6):447–52.
[10] Sur DK, Kaye L, Mikus M, Goad J, Morena A. Accuracy of electrocardiogram reading by family practice residents. Fam Med 2000;32(5):315–9.
[11] Boltri JM, Hash RB, Vogel RL. Are family practice residents able to interpret electrocardiograms? Adv Health Sci Educ Theory Pract 2003;8(2):149–53.
[12] Mahler SA, Wolcott CJ, Swoboda TK, Wang H, Arnold TC. Techniques for teaching electrocardiogram interpretation: self-directed learning is less effective than a workshop or lecture. Med Educ 2011;45(4):347–53.
[13] Raupach T, Harendza S, Anders S, Schuelper N, Brown J. How can we improve teaching of ECG interpretation skills? Findings from a prospective randomised trial. J Electrocardiol 2016;49(1):7–12.
[14] Fincher RE, Abdulla AM, Sridharan MR, Houghton JL, Henke JS. Computer-assisted learning compared with weekly seminars for teaching fundamental electrocardiography to junior medical students. South Med J 1988;81(10):1291–4.
[15] Nilsson M, Bolinder G, Held C, Johansson BL, Fors U, Ostergren J. Evaluation of a web-based ECG-interpretation programme for undergraduate medical students. BMC Med Educ 2008;8(1):1–7.
[16] Lessard Y, Sinteff JP, Siregar P, Julen N, Hannouche F, Rio S, et al. An ECG analysis interactive training system for understanding Arrhythmias. Stud Health Technol Inform 2009;150:931–5.
[17] Rubinstein J, Dhoble A, Ferenchick G. Puzzle based teaching versus traditional instruction in electrocardiogram interpretation for medical students - a pilot study. BMC Med Educ 2009;9(1):1–7.
[18] Shah AP, Rubin SA. Errors in the computerized electrocardiogram interpretation of cardiac rhythm. J Electrocardiol 2007;40(5):385–90.
[19] Bhalla MC, Mencl F, Gist MA, Wilber S, Zalewski J. Prehospital electrocardiographic computer identification of ST-segment elevation myocardial infarction. Prehosp Emerg Care 2013;17(2):211–6.
[20] Ducas RA, Wassef AW, Jassal DS, Weldon E, Schmidt C, Grierson R, et al. To transmit or not transmit: how good are emergency medical personnel in detecting STEMI in patients with chest pain? Cardiol 2012;28(4):432–7.
[21] Atwood D, Wadlund DL. ECG interpretation using the CRISP method: a guide for nurses. AORN J 2015;102(4):396–405.
[22] Khan S, Hua RJ. Master visual diagnosis of ECG: A short atlas (learn ECG through ECG) 1st ed. New Delhi: Jaypee Brothers Medical Pub; 2013.
[23] Podrid P, Malhotra R, Kakkar R, Noseworthy PA. Podrid's real-world ECGS: A Master's approach to the art and practice of clinical ECG interpretation. Arrhythmias, vol. 4A. Minneapolis: Cardiotext; 2014.
[24] Mann DL, Zipes DP, Libby P, Bonow RO. Braunwald's heart disease: A textbook of cardiovascular medicine. 10th ed. Philadelphia: Saunders; 2015.
[25] Goldberger AL, Goldberger ZD, Shvilkin A. Goldberger's clinical electrocardiography. A simplified approach. 8th ed. Philadelphia: Saunders; 2013.
[26] Wren C. Concise guide to pediatric Arrhythmias. 1st ed. Wiley-Blackwell; 2011.
[27] Gall M, Sullivan MD. A primer on the validity of assessment instruments. J Grad Med Educ 2011;3(2):119–20.
[28] Varvaroussis DP, Kalafati M, Pliatsika P, Castrén M, Lott C, Xanthos T. Comparison of two teaching methods for cardiac arrhythmia interpretation among nursing students. Resuscitation 2014;85(2):260–5.
[29] Lucas J, McKay S, Baxley E. Arrhythmia recognition: a third-year clerkship teaching experience. Fam Med 2003;35(3):163–4.
[30] Hoyle RJ, Walker KI, Thomson G, Bailey M. Accuracy of electrocardiogram interpretation improves with emergency medicine training. Emerg Med Australas 2007;19(2):143–50.