

Original Article

Use of concept maps to promote electrocardiogram diagnosis learning in undergraduate medical students

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Received January 22, 2015; Accepted April 23, 2015; Epub May 15, 2015; Published May 30, 2015

Abstract: Concept mapping is an effective method in teaching and learning, however this strategy has not been evaluated among electrocardiogram (ECG) diagnosis learning. This study explored the use of concept maps to assist ECG study, and sought to analyze whether this method could improve undergraduate students' ECG interpretation skills. There were 126 undergraduate medical students who were randomly selected and assigned to two groups, group A (n = 63) and group B (n = 63). Group A was taught to use concept maps to learn ECG diagnosis, while group B was taught by traditional methods. After the course, all of the students were assessed by having an ECG diagnostic test. Quantitative data which comprised test score and ECG features completion index was compared by using the unpaired Student's t-test between the two groups. Further, a feedback questionnaire on concept maps used was also completed by group A, comments were evaluated by a five-point Likert scale. The test scores of ECGs interpretation was 7.36 ± 1.23 in Group A and 6.12 ± 1.39 in Group B. A significant advantage ($P = 0.018$) of concept maps was observed in ECG interpretation accuracy. No difference in the average ECG features completion index was observed between Group A ($66.75 \pm 15.35\%$) and Group B ($62.93 \pm 13.17\%$). According qualitative analysis, majority of students accepted concept maps as a helpful tool. Difficult to learn at the beginning and time consuming are the two problems in using this method, nevertheless most of the students indicated to continue using it. Concept maps could be a useful pedagogical tool in enhancing undergraduate medical students' ECG interpretation skills. Furthermore, students indicated a positive attitude to it, and perceived it as a resource for learning.

Keywords: Concept maps, electrocardiogram (ECG), diagnosis

Introduction

In clinical medicine, the electrocardiogram (ECG) is a very common primary diagnosis method in cardiovascular disease. Although ECG interpretation is a core skill, obvious deficiencies among medical students and residents have been reported [1-5]. Several studies have analyzed on some teaching techniques adopted for ECG teaching [6-8], however more studies are needed to identify effective ECG teaching methods for undergraduate [9].

The first contact undergraduate medical students in China have with ECG interpretation is diagnostics, the subject that students receive initial clinical knowledge in the fourth term of

the Chinese medical curriculum. There are total 10 hours assigned for ECG interpretation study, which is challenge for both educators and students. Proper interpreting of an ECG requires mainly knowledge in cardiac electrophysiology, physiologic mechanisms, electrocardiography basic components and lead system, and cardiac anatomy. These complex physiological systems and monitoring system with 12 leads make it a big challenge for teaching and learning ECG interpretation.

Concept mapping is an effective method to help this out [10]. It was first developed in the 1960s by Professor Joseph D. Novak et al. in the United States [11]. The basis of concept maps is the theory of "meaningful learning" and "concept

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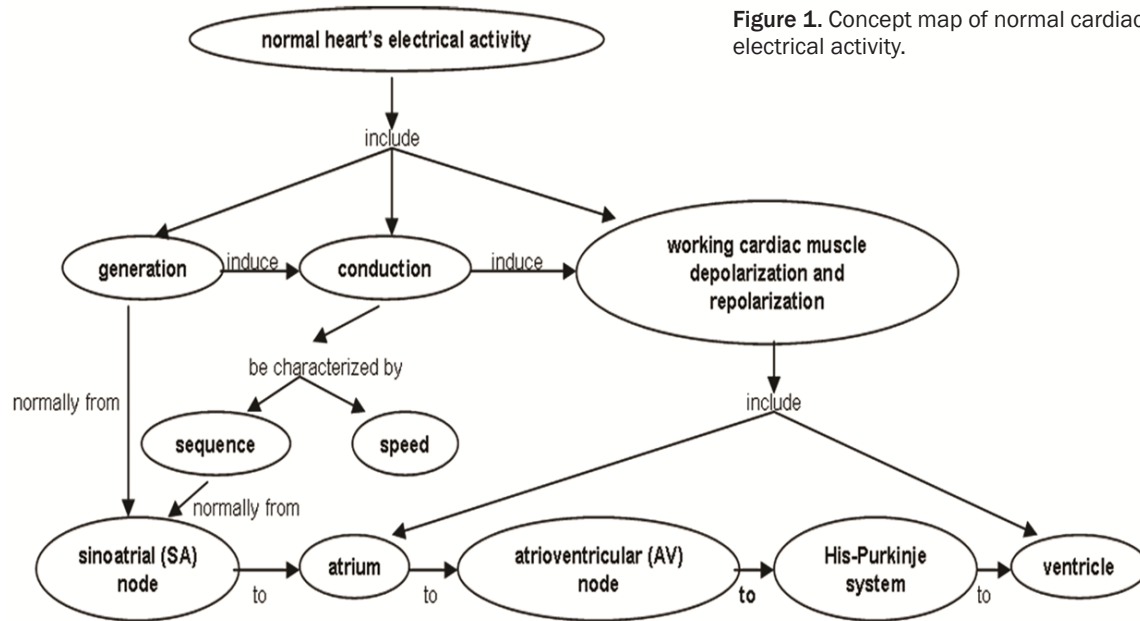


Figure 1. Concept map of normal cardiac electrical activity.

assimilation”, which was proposed by Professor David P Ausubel [12, 13]. Prior knowledge of learner is an important factor for learning. New knowledge should be linked to existing knowledge in order to produce “meaningful learning” [14, 15]. The psychological mechanism underlying the meaningful learning is “concept assimilation” [16]. Concept maps will hierarchically arrange different concepts and their relationships. This helps students organize multiple concepts in a single subject while learning the initial concepts. Concept maps describe top-down relationships, bottom-up relationships and composition of a hierarchical system. This helps students visualize abstract concepts and form their own cognitive structure. Concept mapping is an excellent approach if a complex problem needs to be explicitly expressed or solved.

In recent years, concept mapping is also suggested to be an instructional method to foster the learning and thinking process in undergraduate medical education [17]. It has been assessed as a learning tool in many medical education areas, such as clinical learning, pathology, surgical training [18-20]. However, there is limited analysis on the effectiveness and applicability of medical students using concept maps during ECG training. In this report, we explored the use of concept maps to assist ECG study for undergraduate medical students in the diagnostics course, and sought to objec-

tively assess whether this method could improve students’ ECG interpretation ability. We will also collect the students’ perceptions of this method.

Materials and methods

Study population and setting

In the winter of 2012/09, there were total 126 (56.3% female) grade 2 undergraduate medical students enrolled at Sun Yat-Sen University in Guangzhou, China. The students were randomly assigned to two groups. Group A (n = 63) was taught to use concept maps to learn ECG diagnostics, while Group B (n = 63) was taught by traditional teaching methods. Training and practice phases were adopted in both groups, meanwhile the learning objectives, teaching contents and the practice ECG stripe samples were all the same.

Training and practice by concept maps

Constructing concept maps

It is important to explain to students how to construct a concept map [21]. The structure of conceptual maps includes three parts: nodes (or junctions), connections and linking words [22]. Node refers to the concept of a subject, labeled on a circle or box. Connection is used to join two concepts associated with each other, and may be unidirectional or bidirectional.

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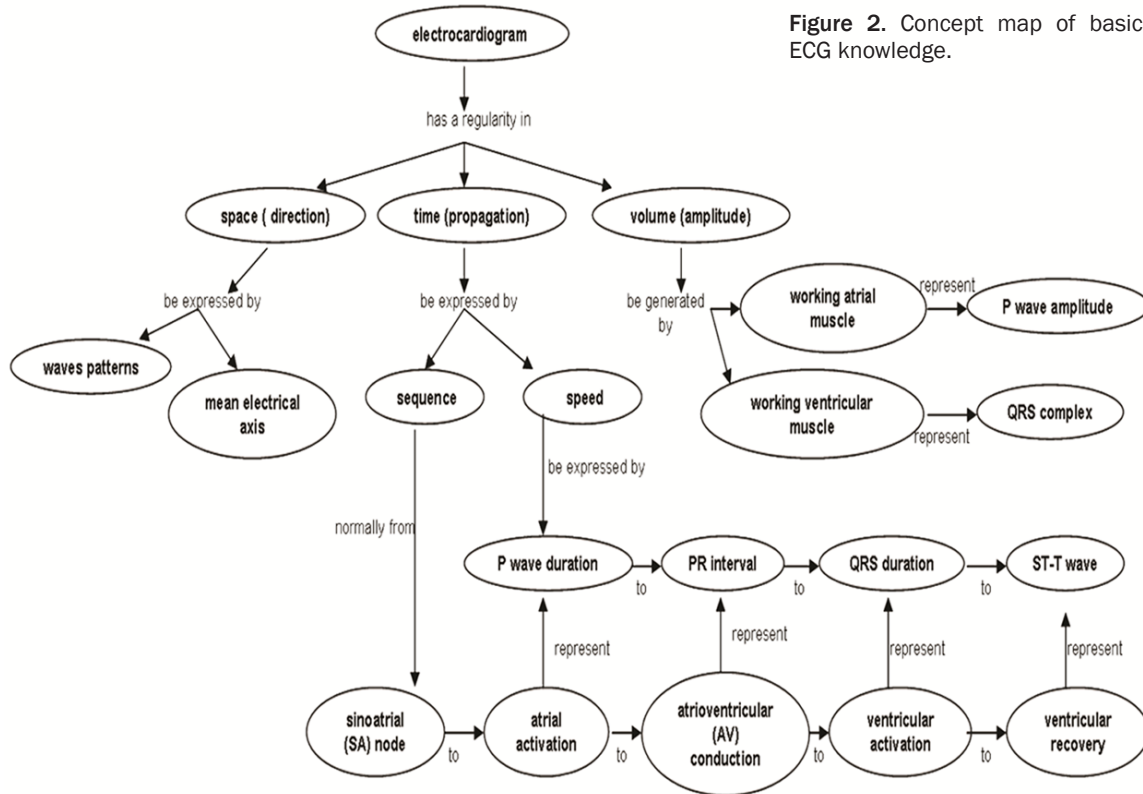


Figure 2. Concept map of basic ECG knowledge.

Linking words are placed next to the connections, and indicate the nature of the association between the two concepts, such as “is”, “includes”, or “means”. Under normal circumstances, important general concepts are located on the top level of a concept map, and subordinate concepts are placed below. Hyperlinks can be used to provide literature and background knowledge related to the concept. Each concept map can express one subject, which is a diagram of spatial network structures showing the relationship between concepts.

Teaching basic ECG concepts by concept mapping

Concept maps were applied in teaching sufficient knowledge to interpretation of ECG. First, a concept map including the basic mechanism of cardiac electric activity was established by the teachers. This concept map showed the process of cardiac electrical activity in a relationship diagram (Figure 1). The complex mechanism underlying the generation of cardiac electrical activity was explained by illustrating the origin and conduction of normal electrical activity, and the depolarization and repolarization of myocardium. This helped the students

understand the relationship between cardiac electrical activities in different parts of the heart.

Next, another concept map including the basic knowledge of electrocardiograms (Figure 2) was made. In this concept map, we illustrated different ECG indicators related to the direction, time and volume of cardiac electric activity. The direction of the cardiac electrical activity was typically shown as a change in the electrical axis in electrocardiograms. Timing was the time of measurement for each segment. Volume, the intensity of electric potential, was reflected by the amplitude of ECG wave group. Electrocardiograms were explained starting from the principle of electrocardiogram generation. This allowed explanation of the different parts of the electrocardiogram, and guided the students from basic knowledge of cardiac electrical activity to the basic concepts of ECG. It helped to turn abstract and difficult theories into concrete terms.

Applying concept maps to read ECGs

When the students entered practice phase that involve reading ECGs, students in group A were

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required to use concept maps (**Figure 2**). Previously established diagrams were used for comparison during each reading and relevant new knowledge was added to the existing concept maps. The specific method was as follows.

Reading an example of a normal electrocardiogram: In order to identify abnormal electrocardiograms, one must be able to describe the waveforms that constitute a normal electrocardiogram and normal values of ECG parameters. Reading should be carried out in the following order: 1. heart rate and regularity; 2. rhythm; 3. P wave morphology; 4. PR interval; 5. QRS wave morphology; 6. ST segment morphology; 7. T wave morphology; 8. U wave morphology; 9. corrected QT interval. Students were instructed to use the concept map of cardiac electrical activity when reading a normal electrocardiogram and to find ECG indicators corresponding to each node in the concept map. They were required to use the method to measure each variable and to add normal values of parameters to the original concept map.

Evaluation of abnormal electrocardiogram: After learning a normal electrocardiogram, students were guided to create concept maps of ECGs representing cardiac disorders. According to the Textbook of Diagnostics being used in the Sun Yat-Sen University Medical School, we selected 14 typical abnormal electrocardiograms: right atrial enlargement, left atrial enlargement, left ventricular hypertrophy, right ventricular hypertrophy, acute myocardial infarction, myocardial ischemia, sinus arrest, premature ventricular contraction, premature atrial contraction, paroxysmal supraventricular tachycardia, ventricular tachycardia, atrial fibrillation, ventricular fibrillation, atrioventricular block. The students were required to measure different parameters in accordance with the order of electrocardiogram reading. During this learning process, students were also encouraged to expand the concept map of reading normal electrocardiograms into a concept map of arrhythmias on their own, and even more to establish concept maps of differential diagnoses using parameters found in abnormal electrocardiogram.

Test setting

After the training and practice phases, students from both group A and group B were

asked to diagnose 8 ECGs in forty minutes. Presentations of the ECG features were also demanded. These ECGs had not been used during practice phase, but were selected from the same training categories.

Students in Group A were also required to conduct a feedback questionnaire survey at the end of the course. The survey was consisted of 9 items which was developed by the teachers. All of the items were close ended questions to record students' perceptions about concept maps as a learning tool in ECG diagnosis. The answers were recorded on a typical five-level Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree) [23].

Data analysis and statistics

Quantitative data comprised test score and ECG features completion index. Test score was calculated as absolute ECG diagnostic accuracy, and the highest test score was 10. ECG features completion index was defined as the percentage of identification of correctly ECG features that were present in the ECG and were related with the right diagnosis. Results between the two groups were compared by using the unpaired Student's t-test. Data were presented as mean \pm standard deviation, and $P < 0.05$ was considered significant.

Qualitative data analysis was also carried out by an independent researcher. Students' comments in response to items were evaluated by a five-point Likert scale, which were expressed as percentages.

Results

The test scores of ECGs interpretation was 7.36 ± 1.23 in Group A ($n = 63$) and 6.12 ± 1.39 in Group B ($n = 63$). A significant difference ($P = 0.018$) of diagnostic accuracy was observed between the two groups. The average ECG features completion index in Group A was $66.75 \pm 15.35\%$ whereas in Group B the index was $62.93 \pm 13.17\%$. Students learning by concept maps seemed to identify more relevant ECG features than students taught by traditional method, but there was no statistically significant ($P = 0.072$).

All of the students in Group A have completed the questionnaire, and the results were out-

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Table 1. Students' responses about concept maps used in ECG learning

| NO | Statements | SD | D | N | A | SA |
|----|---|----------|----------|------------|------------|------------|
| 1 | Concept map was a pleasurable tool | 0 (0.00) | 0 (0.00) | 3 (4.76) | 11 (17.46) | 49 (77.78) |
| 2 | Helped to integrate basic knowledge | 0 (0.00) | 3 (4.76) | 3 (4.76) | 13 (20.63) | 44 (69.84) |
| 3 | Helped to link ECG theoretical information to interpretation | 0 (0.00) | 2 (3.17) | 1 (1.59) | 7 (11.11) | 53 (84.13) |
| 4 | Helped to solve problem in ECG diagnosis | 1 (1.59) | 3 (4.76) | 4 (6.35) | 5 (7.94) | 50 (79.37) |
| 5 | Promotes active learning | 0 (0.00) | 1 (1.59) | 0 (0.00) | 21 (33.33) | 41 (65.08) |
| 6 | Helped to remember | 0 (0.00) | 0 (0.00) | 4 (6.35) | 11 (17.46) | 48 (76.19) |
| 7 | Difficult to learn using concept map at the beginning | 1 (1.59) | 4 (6.35) | 33 (52.38) | 19 (30.33) | 6 (9.52) |
| 8 | Using concept map was time consuming | 0 (0.00) | 3 (4.76) | 18 (28.57) | 38 (60.32) | 4 (6.35) |
| 9 | Would you continue to use concept map to solve problem in ECG diagnosis | 0 (0.00) | 1 (1.59) | 10 (15.87) | 45 (71.43) | 7 (11.11) |

A five-point Likert scale was used to evaluate qualitative data. Values in parentheses indicate percentages. Recording from students' responses: SD strongly disagree, D disagree, N neutral, A agree, SA strongly agree.

lined in **Table 1**. Internal consistency was measured using the Cronbach's alpha, and it was 0.847 for all 9 items.

Overall, 77.78% of the students strongly agreed that concept maps were pleasurable tool of ECG interpretation, and 17.46% agreed on it. Most of the students indicated that concept maps were helpful in ECG learning. Among all 63 students, 69.84% strongly felt that concept maps were helpful in integrating basic ECG knowledge, 84.13% pointed out that concept maps could link ECG theoretical information to interpretation, and 79.37% students strongly agreed that concept maps were helpful to solve problem in ECG diagnosis. In be viewed as a system thinking tool, concept maps were obviously perceived by 65.08% of the students for promoting active learning, and 76.19% strongly remarked that concept maps were helpful to remember and recall ECG knowledge and each parameters of variable as well.

As for concerns of using concept maps, 63.33% of the students agreed that it was difficult to learn concept maps at the beginning, and 60.32% of the students also mentioned that using concept maps were time consuming. Nevertheless, a significant majority of students expressed that they would continue using concept maps to solve problem in ECG diagnosis (**Table 1**).

Discussion

Undergraduate ECG training is a challenge to medical educator. There have been several studies on methods for teaching and learning ECG interpretation [24-27], but training still seems to be deficient [5]. In present study, we intended to find a new way for undergraduate

medical students to take ECG study effectively. Concept maps were the pedagogical tool that we used to assist students to construct their electrocardiography knowledge system and read ECG strips. To our knowledge, this is the first study to examine the impact of concept maps on ECG diagnosis learning. We found that this approach might be more effective to improve diagnostic accuracy in ECG interpretation. Majority of the students in the study perceived it as an effective learning tool.

Quantitative Data from ECGs diagnosis test was statistically significant improved in the intervention group comparing with the control group, which showed that concept maps had a positive influence on enhancing undergraduate medical students' ECG interpretation skills. Higher ECG diagnostic accuracy was observed in the students using concept maps. Although we could not make sure whether students using concept maps when they were doing ECGs diagnosis test, they should be influenced by prior knowledge and analysis strategy. ECG diagnosis is an analytical course to gather some relatively algorithmic data that would be translated to the associated cardiac disorder. Thus, some special knowledge and technical terms should be understood in advance [28], and the accuracy of diagnosis partly depend on sufficient knowledge to define, recognize and understand the basic electrocardiographic pathophysiology. Concept maps can not only help learner to facilitate their conceptual understanding and integration of concepts of a new course [22, 29], but also stimulates critical thinking and promotes meaningful learning [11, 16]. In our study, during training phase, teachers have selected a topic and showed general basic ECG concepts by using concept mapping

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to provide organized knowledge frameworks. Most of the students in the study felt that concept mapping can improve their basic ECG concepts understanding. Further more, in practice phase, the students used the same concept map again and developed their own concept maps. They could identify more special concepts and tie general and special concepts together, which would be expected that students could promote meaningful learning of ECG concepts.

However, on the other hand, using uniform concept maps might possibly weaken students' understand that concept maps is assisting them in learning how to learn. Concept mapping is not only graphic expression of teaching content, but also the process to integrating of knowledge and active individual cognition [21]. It is a new way and challenge to teachers, which requires them to understand that concept maps are designed to implement the concepts of meaningful learning and to help the students to create their own knowledge structures [10]. In our study, during teaching phase we did not encourage the students to create their own concept maps, instead of using uniform concept maps to assist the teachers in clarifying ECG basic knowledge. It would be effective to explain to students how to construct a concept map, but this may undermine students awareness that concept mapping is further more an initiative learning skill. In addition, as concept mapping is also a thinking process, it will be varied from different people. Thus, the concept maps using for teaching should be adapt to learning strategy of the students. Further research and analysis is needed to explore how to teach ECG basic knowledge by using proper concept maps.

The statistically significant differences did not found between the intervention and control groups on the average ECG features completion index, which was not consistent with diagnostic accuracy test. One explanation is that, according to Norman et al.'s study, additional features identification was not to tend to be relevant to the correct diagnosis in ECG interpretation, especially for novice trainees [30]. In addition, as diagnostic accuracy test demands a greater level of problem-solving abilities than ECG features completion, concept maps could possibly enhance students the skills to transfer the knowledge into solving problems [31].

It is also important to mention that concept map might be suitable to ECG interpretation, because the task of ECG diagnosis appears to be amenable to an analytical decomposition [30]. During reading ECG strip, relevant features are extracted, ordered, filtered step by step, and the rules are applied. This is analogous to the process that taking place in concept mapping. In this way, it appears that there is the same straightforward matter of logic in processes of concept maps construction and ECG strip analysis. Thus, the students may use the concept maps as an analysis tool rather than as a tool for memorizing the knowledge. However, additional research is needed to confirm this assumption.

Although most of the students felt that concept map was an effective tool of ECG interpretation, there are still some limitations. Creation of a concept map was a new learning strategy to the students, and it might be difficult at the beginning. Thus, it is important to explain to students how to construct a concept map [21]. The method used during introductory period is important, which would affect learner's perceptions of apply concept maps [32]. Time consuming was another concern. It seemed there was more time spent in reading ECG strips if using concept maps, and it would cause resistance to use for some students. Actually, time consuming might be the major common drawback for concept map user [17, 33]. Furthermore, more effort into the course of constructing maps than into the analytical performance would weaken the role of problem-solving [34, 35]. The computer-based concept map program may be a choice to easy editing the map content [36], even the internet-delivered education may be a more useful instrument. However, once the students have an intimate knowledge of concept mapping and continue to use it, the problem will be alleviated [37, 38].

Teaching time is limited in medical school curricula, preparing students for their own learning remains a challenge for medical teachers. Besides, because of the widespread clinical use, it is necessary to highlight ECG interpretation training for persistent learning among medical students [39]. Concept maps could encourage individuals to take the responsibility and initiative for their own learning, as well as foster lifelong learning [12]. In our study, qualitative analysis suggests that the first contact of this

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pedagogical tool could improve students' motivation to develop ECG knowledge by using this method. This can be explained that concept maps could facilitate in learners the skill to construct their own individual cognitive processes [40]. Due to the lack of follow-up in our study, we think a more thorough evaluation, especially a retention test should be undertaken to find the possible advantages with concept maps and to assess long-term effect.

Conclusion

Concept maps could be a useful pedagogical tool to enhance undergraduate medical students' ECG interpretation skills. Furthermore, students indicated a positive attitude to it, and perceived it as a resource for learning.

Acknowledgements

This study was approved by the Research Ethics Committee at the Third Affiliated Hospital of Sun Yat-Sen University and the Institutional Review Board at the Chinese CDC for the protection of human subjects. The study was carried out in accordance with the Declaration of Helsinki. There was no potential harm to participants and anonymity was maintained.

Disclosure of conflict of interest

None.

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