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Development Model of Basic ECG Algorithm Interpretation based on Android Application to Increase Ability of Nurses

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ABSTRACT

Introduction: ECG interpretation ability by nurses is still not appropriate, thus affecting the accuracy and speed of the next action that will be given to patients to reduce mortality. This study aimed to develop the use of an Android system based ECG interpretation algorithm application to improve the ability of nurse.

Methods: Research development design to develop the Android system based ECG interpretation algorithm application. The sampling method used purposive sampling as many as 90 nurses in Universitas Airlangga Hospital, Surabaya, Indonesia. The independent variables were interpretation skills (rhythm, frequency, pacemaker, axis, extrasistole, block, enlargement of heart muscle, coronary heart disease, conclusion). The instruments that are used are ECG recording, ECG interpretation sheet, and focus group disscusion. The analysis used an independent t-test with a significance level of $\alpha \leq 0.05$.

Results: The results of developing an ECG interpretation algorithm application based on the Android system have received recommendations from experts and feasibility tests have been carried out. There was a relationship between basic ECG interpretation capabilities with the use of an android system based ECG interpretation algorithm application. Increasing the ability of nurses had p value of 0,000.

Conclusion: The application of an ECG interpretation algorithm based on an android system can improve nurses' abilities in interpreting basic ECG. For future researchers, it is necessary to develop and refine the Android system-based ECG interpretation algorithm application and this can be applied on a case-by-case basis.

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1. INTRODUCTION

Heart disease is the leading cause of death with the third largest number of sufferers worldwide, early detection of heart disease is the right step in reducing the mortality rate (Fakhri et al., 2017). Electrocardiogram (ECG) is an important strategy in management to determine the next action in the handling of patients with cardiology diagnoses, electrocardiogram is thought to be the best marker of elevated serum levels (Zimmerman et al., 2012). Electrocardiogram is a diagnostic tool that is still relatively affordable for many people compared to other sophisticated diagnostic tools for detecting abnormalities in the heart (Fent et al., 2016). The ability of nurses in ECG examination is still minimal, the ability is only limited to measuring and very minimal in interpretation (Zhang & Hsu, 2013).

Every year, one in six deaths in the world is a result of cardiovascular disease. The American Heart Association reports that 405,309 Americans died from Cardio Vascular Diseasse in 2008, and that

every year it is estimated that 785,000 Americans will experience a coronary event for the first time, 470,000 will suffer a recurring event, and 195,000 will have the first myocardial infarction without symptoms (Muhlestein et al., 2015). Most STEMI deaths occur within the first 1-2 hours. Many obstacles that have been identified prevent the initial recognition of STEMI including the lack of patients' ability to identify that they have ischemia or the ability of health workers to detect infarctions on electrocardiogram results (Muhlestein et al., 2015; Zhang & Hsu, 2013). Nurses have 99% ability to detect electrocardiogram waves when the patient is in lethal arrhythmia or a very life-threatening disorder, only the nurse's ability to detect ischemia or infarction on electrocardiogram results is still below 50% (Fakhri et al., 2017; Zimmerman et al., 2012).

Various efforts have been made to improve nurses 'ability to interpret ECGs, it's just that not all health services are aware of the importance of increasing nurses' ability to reduce mortality due to handling less quickly (Zhang and Hsu, 2013). Several methods have been developed to facilitate the interpretation of ECGs, including automatic reading machines, mobile ECGs, or computerized ECGs, only the method does not improve the ability of health workers to replace the role of health workers in interpretation. ECG (Rolskov Bojsen et al., 2015). The benefits of ECG are very diverse including identifying arrhythmias or dysrhythmias, identifying coronary disorders, identifying enlargement of the heart muscle, identifying the presence of metabolic disorders, and identifying side effects of drugs, making a diagnosis (Nickasch et al., 2016). Seeing the many benefits of ECG, the nurse as a health care provider who is always beside the patient, the ability to see changes in ECG morphology is considered important for a fast response time and good quality of service (Nazmah, 2014). The purpose of this study was to develop an ECG basic interpretation algorithm model based on Android applications for nurses.

2. METHODS

Study Design

This study used research and development research (RnD) design that conducted from March to June 2018 at the Airlangga University Hospital, Surabaya Indonesia. Phase I research design is descriptive research and phase II research was a true experiment with a Randomized pretest – posttest control group design plan. RnD research focuses on developing an Android-based ECG application through focus group discussions and expert consultations, after that research focused on testing the application on nurses' abilities, so that it can be seen whether there is an improvement or not.

Population, Samples, and Sampling

The sample in the study was inpatient room nurses of Universitas Airlangga Hospital, with inclusion criteria 1) Having work experience of more than 1 year; 2) Have clinical competence in ECG interpretation; 3) Minimum D3 Nursing education; 4) Have never attended ECG training. The exclusion criteria are 1) Unable to attend the research (leave, study permit, etc.); 2) Work in the pediatric inpatient ward. There were 16 participants for the FGD activity, namely the service coordinator, head of the room, Nursing Committee, Quality Control and Patient Safety Committee, and Nurse Representative in the Inpatient Room. Participants in the expert discussion were experts in the field of ECG (Cardiologists and Specialist Nurses and Information Technology (IT). The sampling technique used was purposive sampling technique. Purposive sampling is a sample determination technique by selecting a sample from the population according to the researcher's wishes, so that the sample can represent previously known characteristics of the population. This study included 90 nurses that work inpatient room. Phase II of the research took samples in this research using simple random sampling. A total of 25 respondents in each group were recruited for this study.

Instruments

The instrument used in this phase I research was an evaluation sheet of nurses' knowledge in basic ECG interpretation which has been carried out for validity and reliability, ECG interpretation sheet and FGD guide. This FGD guide was prepared by researchers with the aim of exploring the opinions of service coordinators, heads of rooms, nursing committees, quality control and patient safety committees, and in-patient nurse representatives regarding the current basic ECG interpretation capabilities of nurses and their expectations for the Android system-based ECG algorithm application. so that from the FGD there was a mutual agreement regarding the form of developing an ECG Algorithm Application based on the Android system.

Phase II evaluates the results of implementing the development application on nurses' abilities. The independent variable of this research is the ECG algorithm application. The ECG algorithm application that has been designed and socialized is then assessed based on the nurse's ability to operationalize the ECG algorithm application. The dependent variables of the research are ability and speed in basic ECG interpretation. The research instruments used in stage 2 are: 1) Algorithm application based on the Android system; 2) Evaluation sheet of the nurse's ability and speed in basic ECG interpretation; 3) FGD Guide

Procedure

Research Research and development in developing an ECG interpretation Android application for nurses. The research was carried out in 2 stages, namely the Android application development stage and stage 2 was the implementation of the application to be tested on clinical nurses. Phase one of the research began with literature studies and field studies to evaluate

hospital documents. The results of the search were expressed in strategic issues discussed in focus group discussions. Then an ECG interpretation Android application was developed to make it easier for nurses. The next stage is to carry out a trial application of the application on nurses in the inpatient room. The results of the application are then tested and compiled into research results. The end of the research is to socialize the development of the Android application that has been prepared.

Data Analysis

The data obtained were then analyzed using the Wilcoxon sign rank test and Mann whitney test with a significance value of 0.05. Descriptive analysis was used to determine the frequency distribution of categories for each sub-variable, namely data for questionnaires regarding the ability and speed of nurses in interpreting ECGs and FGD activities. Data analysis for FGD activities was obtained based on the results of audiovisual recordings of conversations/field notes during the FGD discussion. The results during the discussion will be transcribed and analyzed according to themes. Researchers will also increase the persistence of observations by repeating audiovisual recordings to analyze context. Data from RnD research were analyzed using descriptive analysis to evaluate input from FGDs and expert consultations. The data from the trials that have been collected is tabulated and tested to determine the distribution of the data. The data has shown normal, so the analysis used an independent t-test with a significance level of $\alpha \leq 0.05$ for test the effect of the development ECG interpretation application to nursing ability.

Ethical Clearance

Researchers must understand the principles of research ethics because most of the research subjects in nursing are humans. If this is not implemented, it will violate the rights (autonomy) of humans who happen to be clients (Nursalam, 2015). This research has received an ethical certificate from the Ethics and Legal Committee of Airlangga University Hospital with number 105/KEH/2018.

3. RESULTS

Table 1 provides information about the characteristics of nurse respondents in terms of age, gender, length of time working in the hospital, education level and employment status. The results obtained were that most respondents (63.33%) were aged 25-30 years, most respondents (86.67%) were female, most respondents (68.89%) had worked for 1-3 years, the respondent's highest education was the majority (85.56%) were Bachelor's degree nurses and the majority (77.78%) of respondents had honorary hospital employment status.

Based on Table 2, data was obtained that 68 nurses (75.56%) had sufficient knowledge regarding ECG and 22 nurses (24.44%) had insufficient knowledge regarding ECG. The ability to interpret rhythms correctly has the largest percentage compared to other aspects of interpretation, namely 47.78% and the ability to interpret the entire ECG picture is still not possessed by Airlangga University Hospital nurses.

Recommendations from the FGD regarding improving nurses' abilities in ECG interpretation that will be implemented in the Inpatient unit are: a. The method for increasing nurses' ECG knowledge is expected to be more applicable and there are several examples of practice questions to increase the frequency of exposure to ECGs. b. This method of increasing nurses' ECG interpretation skills does not require special time, such as training. c. The method using the Algorithm Application is deemed appropriate in responding to the need to increase nurses' ECG Interpretation abilities.

Recommendations from expert discussions regarding the development of an Android system-based ECG interpretation application are: a. The ECG Algorithm application in the module menu needs to add some information from 5 sub menus to 7 sub menus. b. The application of the ECG algorithm in the interpretation menu is done by adding an algorithm to the rhythm sub menu with the addition of the lethal arrhythmia algorithm. c. The ECG Algorithm application in the practice menu displays practice questions based on the sub menu contained in the interpretation menu.

Table 3 shows that the age characteristics of respondents in the treatment group and control group were the majority in the 26-30 years age range, namely 17 (60.71%) in the treatment group and 15 (53.57%) in the control group. The age distribution in both groups contained no respondents (0%) who were > 35 years old. The gender characteristics of respondents in the treatment group and control group were mostly female, namely 24 (85.71%) in the treatment group and 23 (82.14%) in the control group. The majority of respondents in the treatment group and control group had a working period of 1-3 years, namely 19 (67.86%) in the treatment group and 20 (71.43%) in the control group. Characteristics of the educational level of respondents in the treatment group and the control group, the majority had a bachelor's degree in nursing, namely 26 (92.86%) in the treatment group and 24 (85.71%) in the control group. The majority of respondents' employment status in the treatment group and control group were honorary hospital employees, namely 23 (82.14%) in the treatment group and in the control group. The results of the homogeneity test using the Lavene Test showed that the overall characteristics of respondents, both the treatment group and the control group, showed homogeneous data with a significance of >0.05.

Table 4 shows that treatment group pre-test ability scores were in the "poor" category as many as 19 (67.8%) respondents, the results of the post-test ability scores showed that in the treatment group were in the "poor" category as many as 18 (64.3%)

respondents. Meanwhile, in the control group, the pre-test ability scores were in the "poor" category as many as 18 (64.3%) respondents, the post-ability test scores showed that in the control group, 17 (60.7%) respondents were "poor" category.

Table 1. Characteristics of respondents for evaluating nurses' ability and speed in basic ECG interpretation.

Respondents Characteristics	n	%
Age		
20-25 years	15	16.67
26 - 30 years old	57	63.3
31 - 35 years old	16	17.78
> 35 years	2	2.22
Gender		
Male	12	13.33
Female	78	86.67
Job experience		
0-1 year	0	0.00
2-3 years	62	68.89
4-5 years	20	22.22
> 5 years	8	8.89
Educational level		
Diploma degree	13	14.44
Bachelor degree	77	85.56
Employee Status		
Hospital honorary	70	77.78
University honorary	5	5.56
Civil servant	15	16.67

Table 2. Results of Evaluation of Nurses' Knowledge and Ability in Basic ECG Interpretation

Variable	n	%
Knowledge		
Good	0	0.00
Intermediate	68	75.56
Low	22	24.00
Rhythm interpretation ability		
Right	43	47.78
False	47	52.22
Frequency interpretation capabilities		
Right	10	11.11
False	80	88.89
Pacemaker interpretation capabilities		
Right	37	41.11
False	53	58.89
Axis interpretation capabilities		
Right	12	13.33
False	78	86.67
Ability to interpret extrasystoles		
Right	3	3.33
False	87	96.67
Block interpretation capabilities		
Right	8	8.89
False	82	91.11
Hypertrophied interpretation ability		
Right	3	3.33
False	87	96.67
The ability to interpret coronary heart disease	3	3.33
Right	87	96.67
False		
Overall interpretation ability		
Right	0	0.00
False	90	100.00

Table 3 Characteristics of respondent data in the treatment group and control group

Characteristis	Intervention Group		Control Group		Homogenity Test
	n	%	n	%	
Age					
20-25 years	6	21.43	8	28.57	0.678
26-30 years	17	60.71	15	53.57	
31-35 years	5	17.86	5	17.86	
>35	0	0.00	0	0.00	
Gender					
Male	4	14.29	5	17.86	0.718
Female	24	85.71	23	82.14	
Job experience					
0-1 year	0	0.00	0	0.00	0.808
2-3 years	19	67.86	20	71.43	
4-5 years	5	17.86	4	14.29	
> 5 years	4	14.29	4	14.29	
Educational level					
Diploma degree	2	7.14	4	14.29	0.392
Bachelor degree	26	92.86	24	85.71	
Employee Status					
Hospital honorary	23	82.14	23	82.14	1
University honorary	1	3.57	1	3.57	
Civil servant	4	14.29	4	14.29	

Table 4 Distribution of basic ECG interpretation abilities in the treatment group

Ability to ECG interpretation	Intervention group			
	Pre	%	Post	%
Good	9	32.1	10	35.7
Low	19	67.8	18	64.3
Ability to ECG interpretation	Control Group			
	Pre	%	Post	%
Good	10	35.7	11	39.3
Low	18	64.3	17	60.7

Table 5 ECG interpretation ability in the treatment group and control group

Variable	Group	Pre test (Mean ±SD)	P value
Ability to ECG interpretation	Intervention	1.25±1.295	0.000
	Control	1.29±1.301	0.000
Variable	Group	Post test (Mean ±SD)	Delta
Ability to ECG interpretation	Intervention	4.39±1.729	3.14
	Control	2.54±1.427	1.25

Table 5 shows that after carrying out data analysis tests using the Paired T Test in the treatment group, a p value of 0.000 ($p \leq 0.05$) was obtained, which means that there is an influence of the Android system-based algorithm application on nurses' ability to interpret ECGs. In the control group, it showed that after conducting a data analysis test using the Paired T Test, a value of 0.000 ($p \leq 0.05$) was obtained, which means that there was an influence of standard hospital treatment on nurses' ability to interpret ECGs.

4. DISCUSSION

The majority of nurses' knowledge level in this study was sufficient. The knowledge of Inpatient nurses at Airlangga University Hospital can be said to be quite good, but it turns out that there are still quite a lot of nurses who are unable to interpret ECGs. The results of the study showed that not a single nurse was able to conclude the overall ECG results correctly, this was because the nurses only mastered one or some of the steps for reading the ECG so that the final conclusion did not obtain the correct overall interpretation. Nurses relatively rely on the ECG interpretation results from the machine rather than directly reading the ECG image results. Several previous studies stated that the error rate in machine readings is relatively large because the machine cannot verify the patient's physical condition or complaints.

Various efforts have been made to improve nurses 'ability to interpret ECGs, it's just that not all health services are aware of the importance of increasing nurses' ability to reduce mortality due to handling less quickly (Zhang & Hsu, 2013). Several methods have been developed to facilitate the interpretation of ECGs, including automatic reading machines, mobile EKGs, or computerized ECGs, only these methods do not improve the ability of health workers to replace the role of health workers in ECG interpretation (Palmer et al., 2014; van den Berge et al., 2013). This statement is also in accordance with research conducted Hartman, Barros and Brady (2012) found that the ST elevation algorithm used can help improve nurses' ability to interpret ECGs and shorten respontime (Breen et al., 2019; Fent et al., 2016). Similar research conducted Mirtajaddini (2017) suggests that the arrhythmia algorithm can improve the quality and confidence of nurses in ECG interpretation (Avegno et al., 2012; May et al., 2019).

Researchers developed the application of ECG algorithms at Airlangga University Hospital based on FGD results, expert discussions, and based on existing theories. The instrument designed by the researcher was presented and offered to participants. This application is an android system based application that can be installed on a smartphone, although it is not yet available in the Play Store and the spread of this application is still through manual sharing. This application contains 3 (three) main menus namely modules, interpretations and exercises. Menu modul. The module menu contains summary material that is considered important in carrying out ECG interpretations, consisting of 7 (seven) sub menus including general provisions, P waveforms, waveforms and QRS

complexes, T waveforms, U waveforms, PR segment shapes and segment shapes ST. The second menu of this application is interpretation, containing steps or algorithms in the form of commands that appear by applications to guide users to get an interpretation of ECG results. This menu has 10 (ten) sub menus including rhythm interpretation, frequency interpretation, pacemaker interpretation, axis interpretation, extracystole interpretation, AV Block interpretation, interpretation of cardiac muscle enlargement, coronary heart disease interpretation, RBBB / LBBB interpretation, and overall interpretation interpretation.

Application users can choose one sub menu only if the interpretation needs are only limited to one part of the ECG interpretation, or can be done in a series and select the entire sub menu until the whole interpretation appears at the conclusion. When the user has obtained the results of interpretation in each sub menu there is a repeat and save option, the user can select "repeat" if they feel the steps are still not appropriate, and the user can choose "save" if they are sure they have chosen the steps correctly will be saved as a summary of the results in the conclusion sub menu. The third menu in this application is exercise, in this menu there are ECG images that users can use to do ECG interpretation exercises anywhere and anytime when opening this application. The question exercise consists of reading only part or whole reading, this exercise is connected directly with the researcher to be corrected and given feedback to the user. In accordance with the expectations of nurses at Airlangga University Hospital who want a method of improving the ability of ECG interpretation that is applicable and does not require special time so that the formation of ECG interpretation algorithm application is expected to improve the ability of nurses in interpretation and can improve the quality of service.

This study uses an Android system-based algorithm application, the results of this study indicate an increase in basic ECG interpretation capabilities. The ability to interpret ECG is important for a nurse to be aware of cardiology abnormalities experienced by the patient, as it is known that cardiology abnormalities have a fast process leading to worse conditions. Through interesting media will provide students with cognitive, affective and psychomotor changes can be accelerated (Adib-Hajbaghery & Sharifi, 2017; Mirtajaddini, 2017).

The use of simulators in ECG learning is the development of an efficient, effective and attractive learning media for nurses in performing basic ECG interpretations (Bond et al., 2014; Gregg et al., 2013). The increase in the value of the ability indicates that the use of the Android system-based algorithm application can affect the increase in ability (van den Berge et al., 2013). Advances in technology affect many sectors, one of which is access to teaching. ECG interpretation using the Android system-based algorithm application creates a new, interesting, efficient and easy to access experience anywhere (Breen et al., 2019; Cesari et al., 2017).

5. CONCLUSION

Nurses' knowledge in ECG interpretation is in the sufficient category and nurses' ability in ECG interpretation is still not good. The ECG interpretation algorithm in the Android system-based application is prepared based on the results of FGDs and expert discussions, consisting of a module menu, interpretation (rhythm, frequency, source of pacemaker, axis, extrasystole, AV block, heart muscle enlargement and coronary heart disease), and practice questions. The implementation of the ECG interpretation algorithm application at Airlangga University Hospital shows the results of increasing the ability and speed of nurses in carrying out ECG interpretations. For future researchers, it is necessary to develop and refine the Android system-based ECG interpretation algorithm application and this can be applied on a case-by-case basis.

REFERENCE

Adib-Hajbaghery, M., & Sharifi, N. (2017). Effect of simulation training on the development of nurses and nursing students' critical thinking: A systematic literature review. In *Nurse Education Today*. https://doi.org/10.1016/j.nedt.2016.12.011

Avegno, J. L., Murphy-Lavoie, H., Lofaso, D. P., & Moreno-Walton, L. (2012). Medical students' perceptions of an emergency medicine clerkship: An analysis of self-assessment surveys. *International Journal of Emergency Medicine*, *5*(1). https://doi.org/10.1186/1865-1380-5-25

Bond, R. R., Zhu, T., Finlay, D. D., Drew, B., Kligfield, P. D., Guldenring, D., Breen, C., Gallagher, A. G., Daly, M. J., & Clifford, G. D. (2014). Assessing computerized eye tracking technology for gaining insight into expert interpretation of the 12-lead electrocardiogram: An objective quantitative approach. *Journal of Electrocardiology*, *47*(6), 895–906. https://doi.org/10.1016/j.jelectrocard.2014.07.011

Breen, C. J., Kelly, G. P., & Kernohan, W. G. (2019). ECG interpretation skill acquisition: A review of learning, teaching and assessment. In *Journal of Electrocardiology*. https://doi.org/10.1016/j.jelectrocard.2019.03.010

Cesari, M., Mehlsen, J., Mehlsen, A. B., & Sorensen, H. B. D. (2017). A New Wavelet-Based ECG Delineator for the Evaluation of the Ventricular Innervation. *IEEE Journal of Translational Engineering in Health and Medicine*, *5*. https://doi.org/10.1109/JTEHM.2017.2722998

Fakhri, Y., Sejersten, M., Schoos, M. M., Melgaard, J.,

Graff, C., Wagner, G. S., Clemmensen, P., & Kastrup, J. (2017). Algorithm for the automatic computation of the modified Anderson–Wilkins acuteness score of ischemia from the pre-hospital ECG in ST-segment elevation myocardial infarction. *Journal of Electrocardiology*, *50*(1), 97–101. https://doi.org/10.1016/j.jelectrocard.2016.11.005

Fent, G., Gosai, J., & Purva, M. (2016). A randomized control trial comparing use of a novel electrocardiogram simulator with traditional teaching in the acquisition of electrocardiogram interpretation skill. *Journal of Electrocardiology*, *49*(2), 112–116. https://doi.org/10.1016/j.jelectrocard.2015.11.005

Gregg, R. E., Helfenbein, E. D., & Babaeizadeh, S. (2013). New ST-segment elevation myocardial infarction criteria for left bundle branch block based on QRS area. *Journal of Electrocardiology*, *46*(6), 528–534. https://doi.org/10.1016/j.jelectrocard.2013.07.001

May, A. M., DeSimone, C. V., Kashou, A. H., Hodge, D. O., Lin, G., Kapa, S., Asirvatham, S. J., Deshmukh, A. J., Noseworthy, P. A., & Brady, P. A. (2019). The WCT Formula: A novel algorithm designed to automatically differentiate wide-complex tachycardias. *Journal of Electrocardiology*, *54*, 61–68. https://doi.org/10.1016/j.jelectrocard.2019.02.008

Mirtajaddini, M. (2017). A new algorithm for arrhythmia interpretation. *Journal of Electrocardiology*, *50*(5), 634–639. https://doi.org/10.1016/j.jelectrocard.2017.05.007

Muhlestein, J. B., Le, V., Albert, D., Moreno, F. L., Anderson, J. L., Yanowitz, F., Vranian, R. B., Barsness, G. W., Bethea, C. F., Severance, H. W., Ramo, B., Pierce, J., Barbagelata, A., & Muhlestein, J. B. (2015). Smartphone ECG for evaluation of STEMI: Results of the ST LEUIS Pilot Study. *Journal of Electrocardiology*, *48*(2), 249–259. https://doi.org/10.1016/j.jelectrocard.2014.11.005

Nickasch, B., Marnocha, S., Grebe, L., Scheelk, H., & Kuehl, C. (2016). "What do i do next?" Nurses' confusion and uncertainty with ECG monitoring. *MEDSURG Nursing*, *25*(6), 418–422.

Palmer, L., O'Donnell, J. M., Ren, D., & Henker, R. (2014). Comparison of Nurse Anesthesia Student 12 Lead EKG Knowledge, Interpretation Skill, Satisfaction and Attitude: Traditional Instruction vs. Asynchronous Online Video Lecture. *MERLOT Journal of Online Learning and Teaching*, *10*(3), 420–436.

Rolskov Bojsen, S., Räder, S. B. E. W., Holst, A. G., Kayser, L., Ringsted, C., Hastrup Svendsen, J., & Konge, L. (2015). The acquisition and retention of ECG interpretation skills after a standardized web-based ECG tutorial-a randomised study Approaches to teaching and learning. *BMC Medical Education*, *15*(1). https://doi.org/10.1186/s12909-015-0319-0

van den Berge, K., van Gog, T., Mamede, S., Schmidt, H. G., van Saase, J. L. C. M., & Rikers, R. M. J. P. (2013). Acquisition of visual perceptual skills from worked examples: Learning to interpret electrocardiograms (ECGs). *Interactive Learning Environments*, *21*(3), 263–272. https://doi.org/10.1080/10494820.2011.554422

Zhang, H., & Hsu, L. L. (2013). The effectiveness of an education program on nurses' knowledge of electrocardiogram interpretation. *International Emergency Nursing*, *21*(4), 247–251. https://doi.org/10.1016/j.ienj.2012.11.001

Zimmerman, T., Beuhler, M. C., & Kerns, W. (2012). Is Nurse Interpretation of the ECG QRS Width Reliable? *Journal of Medical Toxicology*, *8*(2), 140–144. https://doi.org/10.1007/s13181-011-0205-z