

An ECG Analysis Interactive Training System for Understanding Arrhythmias

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Abstract. The ECG remains a daily diagnostic tool for the detection of numerous cardiovascular diseases. Our goal was to use a computerized qualitative model (QM) of heart in order to build cases of simple arrhythmias dedicated to initial and more advanced medical teaching. The original QM is able to generate videograms of many cardiac disturbances. A Flash player is used to view ECG, synchronous Lewis diagram and chromatic 2D cardiac animation of a specific case. OAAT is a standardized 18 yes/no answers questionnaire which allows the learner to diagnose five main types of arrhythmias that can be compared with normal sinus rhythm (NSR) analysis. This new tool has been recently used by medical students during practical sessions. Based on medical reasoning learning on NSR video and upon trying to recognize an abnormal cardiac rhythm, all users can reach the 100% winning score since they can perform as many attempts as they like. We believe that unlimited case review with questionnaire answering, ECG and Lewis diagram replay and step-by-step visualization of the abnormal propagation of the cardiac impulse on the 2D heart videos are a highly efficient means to help students understand even complex arrhythmic mechanisms.

Keywords. e-learning, ECG arrhythmias, computer simulation, 2D heart model

1. Introduction

Cardiac electrophysiology is a combination of complex three dimensional (3D) invisible phenomenons which are known to be of special difficulty for the students. Nevertheless, ECG analysis is for every physician a daily practice which, since over a century, remains an essential tool for the detection of various cardiac diseases. Our second year medical students still have a first practical contact with live ECG recording during too short workshop sessions. Nevertheless, despite noticeable educational change in medicine, later, as residents in hospital wards, they experience many abnormal rhythms without real previous possibilities of learning a rational method of ECG analysis. Modern approaches to teaching and learning basic science include the use of computers, information and communication technologies (ICTs), the Internet and Internet-related resources, which are of special interest in physiology [1]. Many

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difficult concepts in physiology are truly learned only when the student's brain converts heard or read words, static pictures and diagrams into moving models [2]. This can explain why students are highly enthusiastic about the complementary use of multimedia resources to improve the understanding of physiopathological mechanisms [3] and the possibility to re-activate their memory before or after clinical reasoning learning sessions. Available computer technology allows the use of dynamic models, making learning more efficient. Our current approach focuses on providing computer models of the human body's multi-scale biochemical and biophysical dynamics that are occurring in response to its environment [4]. IBC has already created different heart models which are able to produce 2D and 3D dynamic simulations of the normal and pathologic cardiac electrical activity [5, 6]. The CNP (Campus Numérique de Physiologie) is a French web freely accessible virtual campus which uses the IBC dynamic models as a complement to classical teaching of cardiovascular physiology [7]. The interactive capability of computer-based instruction keeps the student involved so that learning is more interesting and not purely passive. In the present work, we present a different way to partially use an original IBC-made qualitative model (QM) [8] of the heart, aimed at practical workshop sessions for ECG learning. Our QM can model complex physical systems and processes as well as produce natural-language descriptions and summaries of simulated system behavior. But in this initial work, in order to provide medical students with a learning method of ECG disturbances analysis, our goal was to quickly produce a first generation tool able to show different synchronous aspects of dynamic simulations of the cardiac electrical activity without using the full intelligent behavior capacity of the QM. We will make the most of the reasoning/self-descriptive capacity of the QM in further developments. In what follows we will describe a simple but nevertheless powerful tool, the interactivity of which was obtained using fast classical software.

2. Material and Methods

2.1. Organization of the Sessions and Access to OAAT

The name of the tool is "O.A.A.T.", a French acronym which stands for "cardiac rhythm disturbances analysis learning tool". OAAT is freely accessible for every student after logging on the pedagogical intranet of the university. A university PC computer is dedicated to function as the server. On-line documents are transmitted over the intranet using the server Apache of the university operated on the Mandrake Linux operating system. Any connection with high data transmission rate is needed between server and learners' computers to view the different multimedia teaching resources. Among other different digital resources, the OAAT home page is accessible through the classical Moodle LCMS (Learning Content Management System) used by the university. On the home page, users can choose different cases of arrhythmia or can train on simulations of a normal sinus rhythm (NSR).

2.2. Construction of the Tool

The pedagogical contents are implemented through XML files which are visualized by a Flash player which was specially developed inside the limits of our project. After entering OAAT, the learner can find on each page of the session different frames which

include animations and texts. Among the teaching materials, only the animations were directly obtained from the QM. Three synchronous types of animation were built from images extracted in the .GIF format from the videograms generated by the QM: a 2D colored representation of the heart, and the two consecutively generated Lewis diagram and ECG trace, disposed in the 3 upper frames (Figure 1). Interactivity is obtained by “clicking” on classical buttons. The user can start, interrupt, continue a 6 s one lead ECG. One relevant lead (mostly D2 or V1) was imposed by the authors, chosen among the classical 12 leads generated for each case by the QM in the frontal and transverse plans. At any time, the user can move backward or forward in time and unfold in a stepwise manner the ECG animation. The lower part of the screen is set apart for the interactive quiz. The authors have devised a means to assist the learner’s reasoning by presenting a standardized succession of 18 identical questions for each case. Contrary to the automated construction of the animations, in this OAAT prototype, the authors wrote the textual explanations without directly using the self-descriptive capability of the QM. Also, each arrhythmia case presented to the student is treated in 20 pages, the first 18 of which only provide the QM-produced ECG along with a question related to it. At this level of the analyzing process, the Lewis diagram and the 2D cardiac animation frames are masked. The Lewis diagram and the 2D cardiac animation frames are respectively unmasked on the 19th and 20th pages of the program. The Lewis diagram is a classical and simple linear animated representation of the cardiac impulse propagation from the sino-atrial node to the end of the ventricular myocardium. Our 2D heart produces a different and more precise spatial and dynamic representation of the cardiac impulse. The three animations ECG, Lewis diagram and 2D heart are synchronous. A color-coded system allows a simplified view of the activation, deactivation (refractory periods) and resting of the different tissues and compartments of the heart. The 19th and 20th pages do not include questions but synthetic textual explanations of the arrhythmic mechanism in addition to the didactic Lewis and 2D heart animations.

3. Results

During a first practical session, the students in their third year may be advised by a skilled instructor to begin to familiarize himself with the color-coded heart animation by training on the NSR simulation. They will easily associate the normal progression of the impulse on both the Lewis diagram and on the 2D heart model with the apparition of the different waves on the ECG. The learner must answer each question and validate his answer before going to the next reasoning step. OAAT approves or disapproves and justify the answer in a textual mode before asking to view the following question. Each case of arrhythmia is characterized by one or more negative answers to the 18 questions which are strictly identical from one case to another. For the moment, five blind cases of simple rhythmic disturbances are proposed to the students: isolated atrial or ventricular premature beat, 2^d (MOBITZ type II) or 3^d degree atrio-ventricular block, and ventricular tachycardia. Thanks to the cursors, the learner can check the possible absence or extra-presence and duration of each wave and interval. After answering the 17 questions about the characteristics of the ECG, the student expresses his diagnostic by choosing between different types of arrhythmias proposed on the 18th page. Whether the answer is right or wrong, if requested, the Lewis diagram will appear on the 19th page with a textual description of the cardiac impulse pathway. Upon request, the 2D

heart simulation is available on the 20th page with a synthetic explanation of the abnormal events and mechanisms of the current case. The step by step analysis of the chromatic heart animation synchronous with the unfolding of the ECG and of the Lewis diagram, make it easy to understand either the disponibility for a reentrant or extra-impulse, or the unexcitability of a cardiac compartment blocking a normal or abnormal impulse. The last page gives the learner his personal score as the number of right answers out of 18 and as a percentage of success. At this stage, the user can either decide to investigate a different case or try again to improve his score and come back to a specific page to check a specific point.

4. Discussion and Conclusions

Computer-assisted learning is generally assumed to be worth and to have a positive influence on student learning [6, 9]. Although useful at distance learning, OAAT is not intended to become a surrogate for classical forms of teaching. Different surveys have confirmed the will of a physical classroom in preference to a virtual one, expressed by many students when a direct interactive aid by dedicated teachers is possible [10]. Thus, we uniquely use ICTs and multimedia as tools for learning, providing learners with complementary knowledge in fundamental sciences necessary to scientific and medical education. OAAT needs being appraised as precisely as possible in order to improve its technical effectiveness and to come up to the users' expectation [11, 12]. Methods of assessing the effectiveness of our e-learning/e-training system will be explored by inquiries about both customer satisfaction and service quality taking in account the evolution of the students' scores. Nevertheless, a first examination of the scores of an 18 student group already showed that, after a rate of two attempts, all the students reached the 100% winning score and the right diagnosis of the five cases of arrhythmia. E-learner satisfaction is linked to learner's performance. Figure 2 shows the results of a preliminary students' evaluation of the contribution of OAAT to their understanding of the arrhythmia cases. It consisted of a five item questionnaire with each item scored from 0 to 4 with 0 = "worthless", 1 = "weak", 2 = "moderately helpful", 3 = "helpful", 4 = "very helpful". The user's satisfaction level was globally good and the post-diagnosis explanations were specially appreciated. In the coming months, according to students' wishes, OAAT will allow the analysis of different cases covering the main classes of rhythmic disorders and will be freely accessible to all (students and practitioners alike) via the Université Médicale Virtuelle Francophone (UMVF) portal. The case-independent methodology provides a means to extract the right features from the ECG while step-by-step dynamic process visualization provides insight to the electrophysiological correlates of the ECG. This is similar to recent training methods [13, 14] to develop understanding of the cardiac electrical performance through less sophisticated series of 2 or 3-dimensional pictures of both the normal and the pathological myocardium. Our students are in favour of the development of a tool using the 3D dynamic heart model already developed by IBC. OAAT is a first step towards more accomplished training tools dedicated to Problem-Based Learning and Clinical Reasoning Learning where students will be faced with cases derived from a virtual human patient. Novel cases call for hypothesis-and-test inference patterns which differ from rule-based inference that operate in "already-seen" ones. Loosely speaking, in physiopathology-based diagnosis, solutions and explanations are provided by going "backwards" through the causal paths, from the

observation to the cause(s) of a mental physiopathological model. Outside the simplest cases, ECG interpretation is typically a hypothetico-deductive inference pattern which makes it a difficult topic. Self-descriptive models of cardiac physiopathology such as the QM, associated with case-independent question/answer processes can play a central role in helping students acquire this cognitive ability.

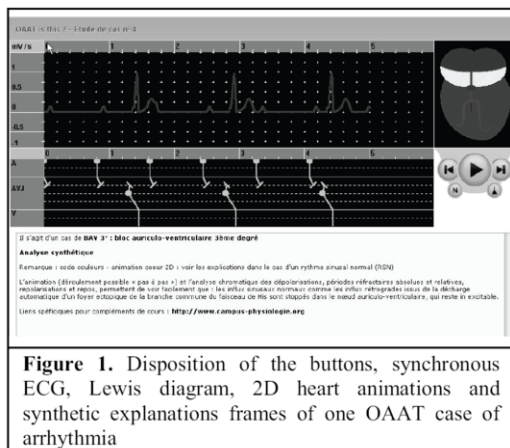


Figure 1. Disposition of the buttons, synchronous ECG, Lewis diagram, 2D heart animations and synthetic explanations frames of one OAAT case of arrhythmia

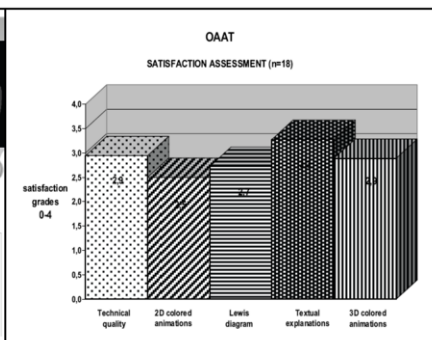


Figure 2. Evaluation of students' satisfaction

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