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ECG Wave-Maven: An Internet-based Electrocardiography Self-Assessment Program for Students and Clinicians

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Abstract: **Purpose**: To create a multimedia internet-based ECG teaching tool, with the ability to rapidly incorporate new clinical cases.
Method: We created ECG Wave-Maven (http://ecg.bidmc.harvard.edu), a novel teaching tool with a direct link to an institution-wide clinical repository. We analyzed usage data from the web between December, 2000 and May 2002.
Results: In 17 months, there have been 4105 distinct uses of the program. A majority of users are physicians or medical students (2605, 63%), and almost half report use as an educational tool.
Conclusions: The internet offers an opportunity to provide easily-expandable, open access resources for ECG pedagogy which may be used to complement traditional methods of instruction.

Keywords: ECG, education, teaching tools

Proficiency in the interpretation of electrocardiograms (ECGs) is an essential skill for medical professionals. Errors in reading are common, and may lead to serious consequences.[1-4] Studies have estimated a 20-50% discordance between the initial ECG interpretation and final interpretation by a senior cardiologist.[2,5] Even seasoned clinicians require continuing education in ECG analysis to maintain their proficiency. ECG interpretation is traditionally taught via lectures and textbooks in a compartmentalized, static way, rather than in a dynamic, case-based approach. Further, widely available instructional materials do not routinely integrate ECG interpretation into specific contexts where waveform findings must be correlated with other clinical data.

Computer-assisted instruction in a variety of clinical arenas has been shown to be a useful and effective learning tool.[6,7] A number of internet sites have been developed to improve ECG training.[8] However, most sites consist of "ECG of the week" type cases, which tend to stagnate. To help address limitations in the current approaches to ECG pedagogy, we have developed an interactive internet-based tutorial ("ECG Wave-Maven") with live updates from a tertiary care center repository.

Methods

Hardware and Software System Overview: The clinical information system at Beth Israel Deaconess Medical Center holds extensive online patient records and ECG waveform data from over the past decade.[9] ECGs are collected by commercial carts and the digitized waveforms, with computer measured intervals, are sent to a central station. The interpretations and measurements are edited and officially approved by staff cardiologists. The digitized ECG data are then stored in a custom written central hierarchical structure using the Caché database system (an implementation of the computer language "M" or "MUMPS", by Intersystems Corporation, Cambridge MA). Once stored, the waveforms and interpretations are available in thousands of locations through-

out the medical center enterprise to clinicians with appropriate authorization.

We have created a web-based, educational tool, termed "ECG Wave-Maven," which displays the stored electrocardiograph tracings (without patient identifiers) along with the intervals and a clinical vignette. To generate the tracings, we obtained the raw sample values by decompressing the data transmitted from the cart via the Standard Communications Protocol for ECG (SCP-ECG) format.[10] Patient identifiers were removed and the samples are converted into a GIF format image using the public domain package "gifdraw" (authored by Thomas Boutell). We then used Weblink TP (Intersystems Corporation, Cambridge, MA) to make the waveform data and clinical questions available via standard web browsers, such as Internet Explorer or Netscape. The web pages that were generated use HTML and other web standards and run equally well on all browsers, platforms and operating systems.

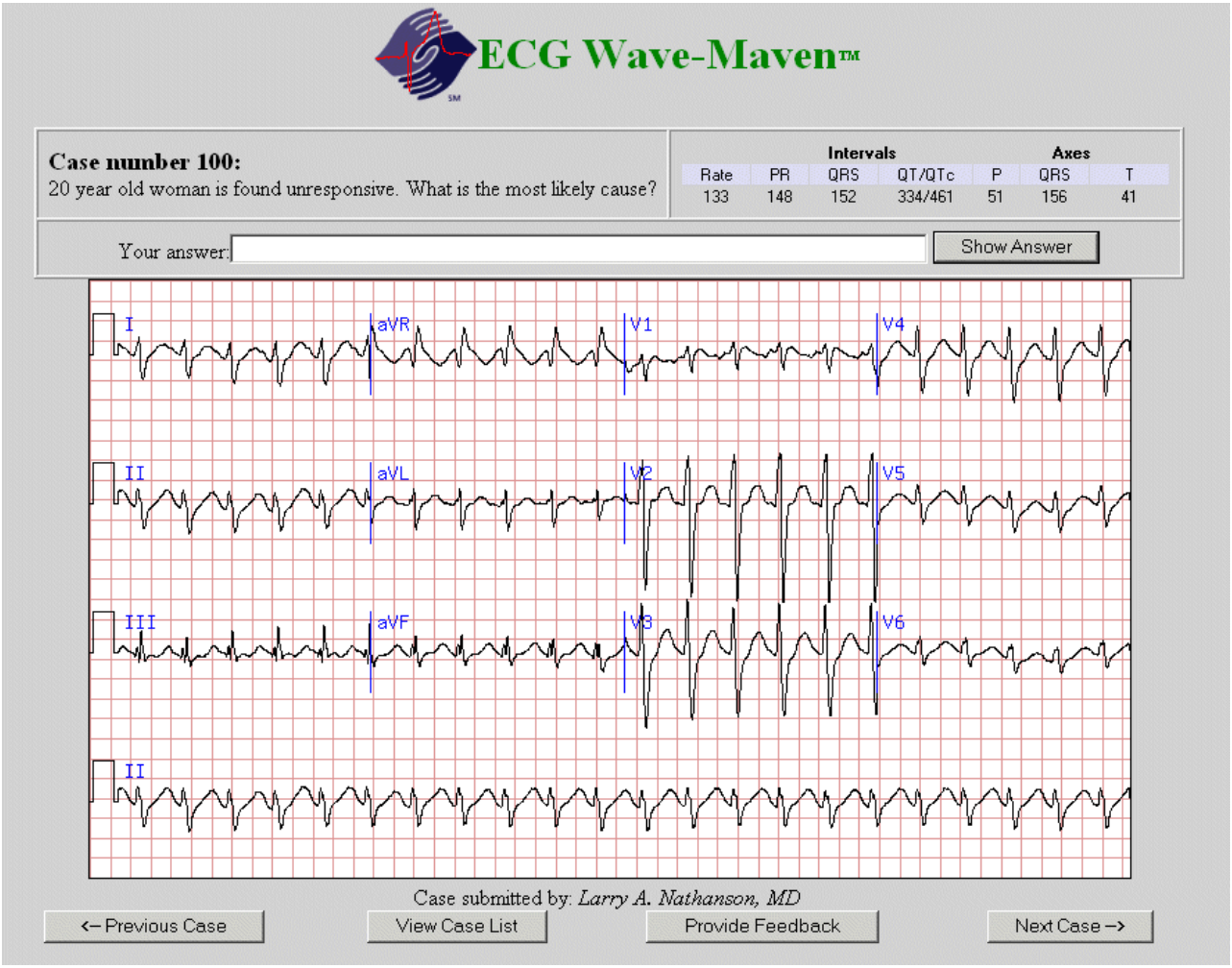


Figure 1. **Example of ECG Wave-Maven question (quiz mode)**

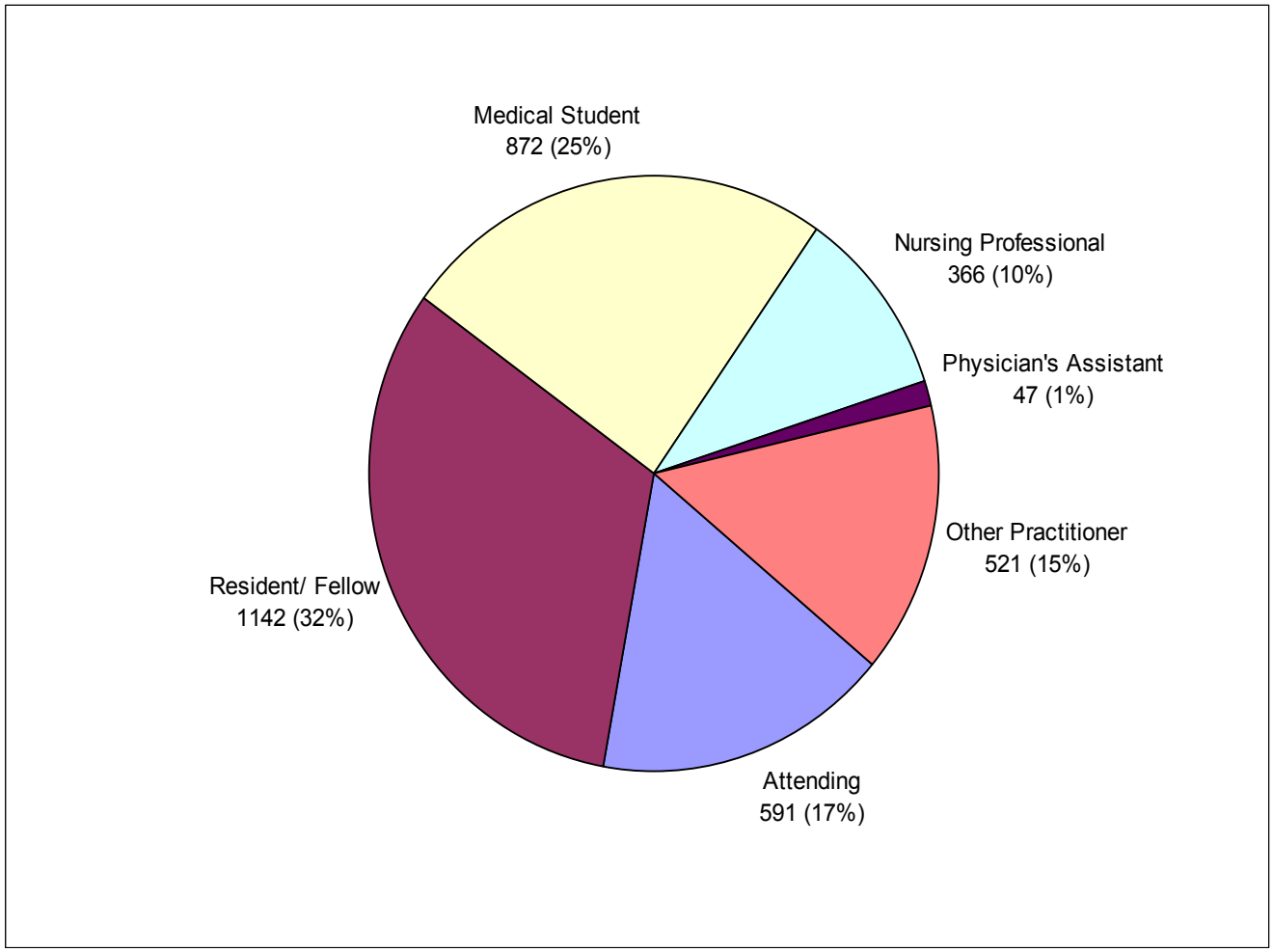
Case Vignette: 20 year old woman is found unresponsive. What is the most likely cause?
Answer: In addition to prominent sinus tachycardia, there is an intraventricular conduction delay (IVCD) with a rightward or indeterminate QRS axis. The QT is somewhat prolonged for the rate. The triad of sinus tachycardia, a wide QRS and a long Q-T in an obtunded patient should immediately suggest tricyclic antidepressant (TCA) overdose. Of note, the IVCD in these cases is often associated with a terminal S wave (rS) in lead I, and a terminal R wave (qR) in aVR, as present here (see: Crit.Care Med.1997;25:1721). *Difficulty rating:* ***

User Interface Overview: Users access the Wave-Maven web site via either its own address (http://ecg.bidmc.harvard.edu) or from multiple outside institutional-based homepage links.[11-13] Upon first accessing the site, the user is prompted with a brief questionnaire, asking for level of training, reason for viewing the site, and (optionally) their email address. If the latter is supplied, direct feedback to any questions is available from one of the authors. "Cookies" or other longitudinal tracking devices are not utilized, and users cannot be identified unless they voluntarily provide contact information.

After submitting the optional information described above, the users are presented with two viewing options: "quiz mode" or "reference mode". In the quiz mode, the ECG tracing is shown with a brief clinical history, a question, and a text space for typewritten responses by the online reader (Figure 1). The user is provided the computer-derived ECG intervals. After entering a response, the answer by the authors is viewable next to the answer entered by the reader, as well as a level of difficulty, ranging from easiest (1 star) to most difficult (5 stars). In the reference mode each case description and diagnosis is listed, and the ECG, with full explanation, is viewable by the user. In both modes, feedback is encouraged, and sent via an automated e-mail to the authors. The main menu also has separate options for feedback to the authors, and suggestions for submitting new cases.

Currently, the interface with the clinical information system limits ECGs qualified for submission only to those performed at the Beth Israel Deaconess Medical Center. In selected cases where additional

***Figure 2*. Training level of Wave-Maven users (3539 respondents)**



multimedia information is appropriate and available (such as cardiac catheterization images, nuclear perfusion images, and echocardiographic loops), these are viewable via a direct link from the ECG.

Results

The ECG Wave-Maven program was released to the academic community via the internet in December, 2000. It has expanded since its inception and now includes over 200 cases, with ongoing submissions. The case content includes ECGs related to acute coronary syndromes, toxicological emergencies, metabolic derangements, and incidental findings.

As of May 2002, there were 4105 distinct uses of the program. Three hundred twenty-eight individuals (8%) chose to identify themselves with an email address. Three thousand five hundred thirty-nine users gave a training level; 2605 (74%) were physicians or medical students (see Figure 2). Users spent a mean duration of 10 minutes viewing the site (range: 6 seconds – 90 minutes), and viewed 12 cases on average (range: 1 - 128). The most common reason cited for visiting the site was for educational purposes.

Discussion

ECG Wave-Maven is a recently introduced internet tutorial designed to help develop and maintain electrocardiography reading proficiency. This program has a number of features which distinguish it from traditional teaching methods. The addition of clinical data and multimedia images along with the ECG is intended to stimulate the development of integrative diagnostic skills. A direct link to the hospital electronic ECG repository makes it very easy to add cases. The option to commit to a typed answer before seeing the expert interpretation in each case encourages judicious evaluations by the user. In addition, direct feedback to the authors is unique among web-based ECG training tools. Users who provide an e-mail address and submit questions or disagreements are promptly answered by one of the authors. Based on this feedback, answers can be modified to clarify the case explanations.

Future enhancements are under development, including more links to cardiology multimedia images. In addition, we are developing pan and zoom technology, which allows for the identification of subtle low-amplitude or difficult-to-discern ECG waveforms. Finally, we plan to catalogue and identify cases based on specific diagnosis and level of difficulty to facilitate varying individual learning needs of users.

Freely-available internet programs show promise as a way to enhance pedagogy in integrated clinical assessment of ECG waveforms. ECG Wave-Maven is one step in this direction. We hope this program will aid in the development and maintenance of the ECG reading skills of clinicians and trainees, and welcome critical input and suggestions from the internet-user community. We anticipate and encourage the use of properly-cited downloads from our site among medical educators. This type of pedagogic technology may also be applicable to instruction in other waveform-based diagnostic skills, such as clinical electroencephalography or interpretation of intracardiac electrograms obtained in the electrophysiology laboratory.

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