

A Web-Based Teaching Program for Laboratory Diagnosis of Coagulation Disorders

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● **Objective.**—To implement an interactive program for teaching coagulation disorders on the World Wide Web.

Design and Results.—The core materials in this program were derived from a personal computer software program previously designed by the authors. Three modules were developed in this program: (1) a coagulation profile to display typical results of coagulation screening tests for each disorder; (2) a differential diagnosis module to generate a list of diagnoses that fit the test results in a given case; and (3) a

synopsis of coagulopathy and therapy to provide essential information on disorders and therapeutic options. A total of 41 coagulation disorders were included in the knowledge base.

Conclusions.—Since the World Wide Web is increasingly more accessible to computer users, it has become an ideal medium for teaching purposes. Our experience with this program in teaching medical students and pathology residents at our institution has been very encouraging.

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Clinical cases of coagulopathy are encountered frequently in medicine and sometimes are associated with patient morbidity and fatality.^{1,2} The intricacies of hemostatic mechanisms often present a diagnostic challenge to clinicians who treat patients with coagulopathy. Since many coagulation disorders have overlapping clinical and laboratory findings,^{3,4} clinicians do not always adhere to the most efficient strategy for ordering laboratory tests and, at worst, may misdiagnose their patients.

A decision-support software program for coagulopathy, XPCOAG, was developed previously by the authors to teach medical students and pathology residents at our institution.⁵ XPCOAG was designed to run on an IBM-compatible personal computer (PC) with Microsoft Windows. To use XPCOAG, users have to install the program on their computer. The requirement for installation limits the number of users for this single-user software.

The World Wide Web (WWW) offers a simple solution to this problem by providing easy access to teaching materials.^{6–8} Existing Internet networks across multiple platforms can be used as the medium for software implementation. Users located in any part of the world with Internet connection can use browsers to get access to teaching materials that reside in centralized Web servers. In this article, we describe the design and implementation of a Web-based program for teaching laboratory diagnosis of coagulopathy at our institution and discuss the potential role of this program in medical education, as well as in clinical consultation.

DESIGN AND RESULTS

WEB COAG, a web-based teaching program for coagulopathy, was implemented in Hypertext Markup Language (HTML), a conventional language for Web documents.⁹ Interactivity with users was achieved with JavaScript, a scripting language for adding dynamic features to Web pages.⁹ Dynamic features allow users to interact with graphic interface components on the computer screen, such as buttons, lists, and check boxes, to retrieve the desired information. These dynamic features can be coded in HTML files in the form of JavaScript functions or as subroutines. JavaScript was also used to create functions and subroutines used in the search engine for differential diagnosis. WEB COAG was installed on a Microsoft Windows NT 4.0 server running Microsoft Internet Information Server 3.0 in the Department of Pathology and Laboratory Medicine, University of Texas–Houston Medical School.

The core materials in WEB COAG were derived from those developed for XPCOAG, a PC software program developed previously by the authors.⁵ The knowledge base of XPCOAG was developed by one of the authors (A.N.), who is a clinical hematopathologist with special interest in coagulation. This knowledge base was thoroughly reviewed and edited by another authors (M.U.), serving as a peer reviewer, who is also a clinical hematopathologist with the same area of interest. A total of 41 coagulation disorders were included in the knowledge base of XPCOAG. The search engine in this program was based on backward-chaining inference.^{10–12} XPCOAG has been tested with 61 clinical cases involving various coagulation disorders. It ranked the actual diagnosis as 1 of the top 5 differential diagnoses in 93% of the cases tested. Further details of the components, inference algorithm, and validation results for XPCOAG have been described previously.⁵ Since a similar inference algorithm was used in both XPCOAG and WEB COAG, the validation results for XPCOAG are also applicable to WEB COAG. Conversion of the materials from the PC-based version to the Web-based version required a complete rewriting of all the PC software codes to accommodate the Web medium. Similar to XPCOAG, 3 main modules were implemented in WEB COAG:

1. Coagulation profile, displaying typical results of 7 screening coagulation tests for each disorder. These tests include prothrombin time, activated partial thromboplastin time, fibrinogen,

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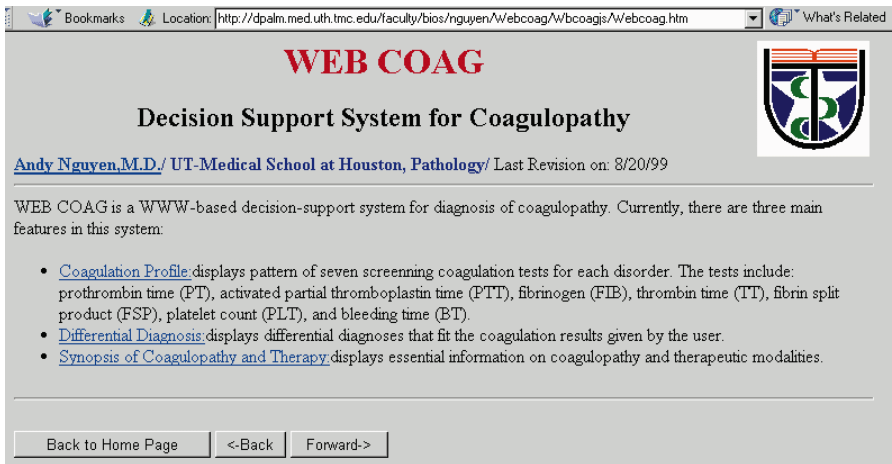


Figure 1. The main Web page of WEB COAG.

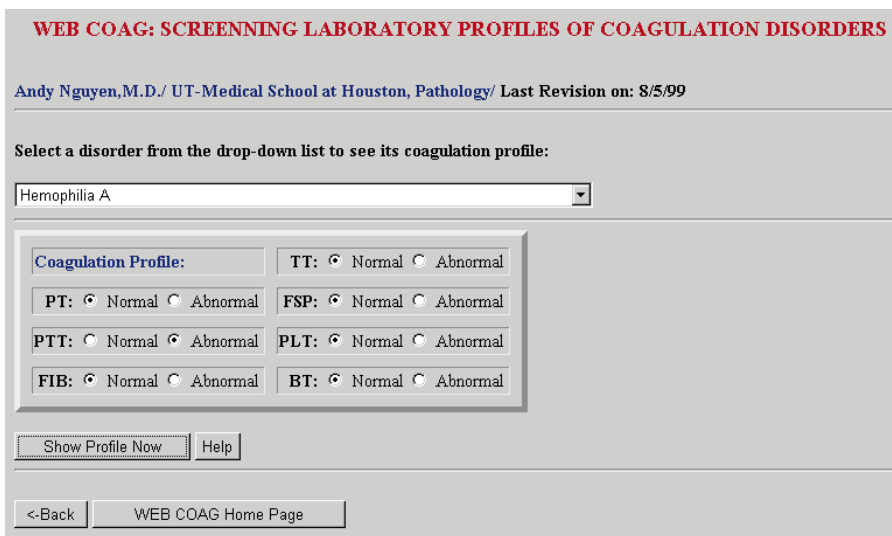


Figure 2. Display of coagulation profile for a disorder.

thrombin time, fibrin(ogen) split product, platelet count, and bleeding time.

2. Differential diagnosis, generating a list of disorders for which the diagnostic test pattern fits that of the case entered by the user.

3. Synopsis of coagulopathy and therapy, displaying essential information on various coagulation disorders and the current therapeutic options. Information on disorders typically includes biochemical aspects, pathological basis, treatment, and diagnostic criteria. The synopsis of therapeutic components includes composition, supply format, indication, and dosage.

Figure 1 shows the main Web page of WEB COAG with the 3 modules listed. Clicking on any of these options will take the user to the selected module. An example of a coagulation profile for hemophilia A is illustrated in Figure 2. Typical results of all the screening tests were displayed in tabular format for the selected disorder.

An example of consultation using the differential diagnosis module is shown in Figure 3. In this session, the user entered the test results (abnormal result for prothrombin time and normal results for all other tests). The inference process was started by clicking the "Diagnose Now" button. A short list of differential diagnoses was displayed in the lower panel in Figure 3. The list included factor VII deficiency, vitamin K deficiency, and warfarin (Coumadin) treatment. All of these disorders were found by WEB COAG to fit the given data.

Laboratory data input may be subject to errors due to technical problems in laboratory testing and also due to subjective inter-

pretation of results (a "normal" value versus a "borderline abnormal" value). For this reason, it is critical to take into account certain elements of uncertainty in data input while evaluating a clinical case. WEB COAG offers the user the option of "What If" reruns to enhance the flexibility in handling data that are not clear-cut. The reruns can be performed after the user edits 1 or more of the input data. This editing may be in the form of changing the value of the data (normal to abnormal or vice versa) or adding additional data. Without requiring different sets of data entry, the "What If" reruns offer the user a convenient way to consider all the potential diagnoses based on laboratory data that may be subject to errors due to various reasons.

The Web page for synopsis of coagulation disorders and therapy is shown in Figure 4. A total of 41 disorders were grouped into 5 categories: (1) hereditary disorders of coagulation proteins and inhibitors, (2) acquired disorders of coagulation proteins and inhibitors, (3) hereditary disorders of platelets, (4) acquired disorders of platelets, and (5) complications associated with anticoagulant therapy.

A typical synopsis for a disease (von Willebrand disease, type I) and a therapeutic component (platelets) are shown in Figure 5 and Figure 6, respectively. Additionally, 3 decision-support tools were included in this synopsis module:

1. Calculating dosage of cryoprecipitate for treatment of hypofibrinogenemia using the baseline fibrinogen level, the desired fibrinogen level, and the patient's body weight. The example in Figure 7 shows the calculation for a patient weighing 65 kg. A

Figure 3. Differential diagnosis for a coagulopathy case.

WEB COAG: DIFFERENTIAL DIAGNOSIS

Andy Nguyen, M.D./ UT-Medical School at Houston, Pathology/ Last Revision on: 8/10/99

Enter Coagulation Data:

TT: Normal Abnormal

PT: Normal Abnormal

FSP: Normal Abnormal

PTT: Normal Abnormal

PLT: Normal Abnormal

FIB: Normal Abnormal

BT: Normal Abnormal

Diagnose now Start Over Help

LIST OF DIFFERENTIAL DIAGNOSES:

Factor VII deficiency
 Vitamin K deficiency
 Coumadin treatment

<-Back WEB COAG Home Page

Figure 4. Partial list of coagulation disorders.

WEB COAG: Synopsis of Coagulopathy and Therapeutic Modalities

Andy Nguyen, M.D./ UT-Medical School at Houston, Pathology/ Last Revision on: 8/15/99

Hereditary Disorders of Coagulation Proteins:

- [Factor XII Deficiency, Hereditary](#)
- [Prekallikrein Deficiency](#)
- [Factor XI Deficiency](#)
- [Factor IX Deficiency \(Hemophilia B\)](#)
- [Factor VIII Deficiency \(Hemophilia A\)](#)
- [Acquired Factor VIII Inhibitor in Hemophilia A](#)
- [vonWillebrand's Disease, type I](#)
- [vonWillebrand's Disease, type IIA](#)
- [vonWillebrand's Disease, type IIB](#)
- [vonWillebrand's Disease, type III](#)
- [Factor VII Deficiency](#)
- [Factor X Deficiency](#)
- [Factor V Deficiency](#)
- [A-fibrinogenemia](#)
- [Hypofibrinogenemia](#)
- [Dysfibrinogenemia](#)
- [Factor XIII Deficiency](#)
- [Antithrombin III Deficiency](#)
- [Alpha-2 Antiplasmin Deficiency](#)
- [Protein C Deficiency](#)

Acquired Disorders of Coagulation Proteins:

- [Coagulopathy in Vitamin K Deficiency](#)

total of 10 units of cryoprecipitate were needed to raise the fibrinogen level from 50 to 150 mg/dL (0.50 to 1.50 g/L).

2. Viewing coagulation cascade diagram with image map for hyperlinks. Clicking on any coagulation factor in the cascade will take the user to the synopsis of the disorder associated with the selected factor (Figure 8).

3. Viewing platelet aggregation pattern for platelet disorders with typical aggregation agents (adenosine diphosphate, epinephrine, collagen, and ristocetin). An example in Figure 9 for platelet storage pool disease shows normal aggregation with ristocetin and abnormal aggregation with the other reagents.

As shown in the preceding examples, WEB COAG was designed with a user-friendly interface. This graphic user interface

was arranged such that the sequence of data entry, display of results, and review of information should be intuitive to the user.

COMMENT

We developed a Web-based teaching program for laboratory diagnosis of coagulopathy. This program has been used since 1996 as supplemental teaching material for our pathology residents on coagulation rotation and for sophomore medical students in the problem-based learning course. This Web-based program has been received with enthusiasm by our residents and medical students. We have also received numerous e-mail messages from resi-

VON WILLEBRAND'S DISEASE (TYPE I)

Andy Nguyen, M.D./ UT-Medical School at Houston, Pathology/ Last Revision on: 8/5/99

- **Biochemical aspects:**
von Willebrand factor consists of a series of multimers that range in molecular weight from 800,000 to more than 12,000,000.
- **Pathological Basis:**
 - Mode of inheritance: autosomal dominant.
 - The biochemical abnormality in type I of von Willebrand's disease is strictly quantitative. In such patients, analysis of the multimeric structure of von Willebrand factor with crossed immunoelectrophoresis or sodium dodecyl sulfate- agarose gel electrophoresis is normal. There are concordant decreases in the levels of factors VIII R:RCo, VIII R:Ag, and VIII:C.
- **Treatment:**
 - DDAVP (1-desamino-8-D-arginine vasopressin).
 - Cryoprecipitate: 1 bag per 10 kg of body weight, twice a day.
 - Epsilon-aminocaproic acid (EACA): is a useful adjuvant in dental surgery. The usual loading dose is 5 gm, followed by 1 gm per hour for 5 - 7 days.

Diagnostic Criteria:

1. Family_history_of_coagulation_disorders:positive
2. Factor_VIII:C_activity:abnormal
3. Factor_VIII_R:Ag:abnormal
4. Factor_VIII_R:RCo:abnormal
5. Factor_VIII,cross_immunoelectrophoresis:normal
6. Bleeding_time:abnormal

Figure 5. A typical synopsis of a disorder.

PLATELET CONCENTRATE

Andy Nguyen, M.D./ UT-Medical School at Houston, Pathology/ Last Revision on: 8/15/99

Random-donor platelet:

- **Composition:**
platelets ($>5.5 \times 10^{10}$ /unit), WBC's, plasma, RBC's.
- **Supply format:**
one unit (bag) contains 50 ml. One dose consists of 6 units. Shelf life is 3-5 days.
- **Indication:**
thrombocytopenia or thrombocytopathy.
- **Dosage:**
For a 70 kg adult, one unit of random-donor platelets will increase the platelet count by 3,000-10,000/ul. For children, one unit of random-donor platelet will increase the platelet count by 3,000/ul per 1 kg of body weight.

Single-donor platelet:

- **Composition:**
platelets ($>3 \times 10^{11}$ /units), WBC's, plasma, RBC's.
- **Supply format:**
one bag contains 300 ml. Shelf life is 24 hours.

Figure 6. A typical synopsis of a blood component.

Calculating Units of Cryoprecipitate Needed for Fibrinogen

Andy Nguyen, M.D./ UT-Medical School at Houston, Pathology/ Last Revision on: 8/9/99

Baseline Fibrinogen Level (mg/dl):

Desired Fibrinogen Level (mg/dl):

Patient's Body Weight (Kg):

Calculate Units of Cryo Needed->

Start Over

Help

Figure 7. Calculating dosage of cryoprecipitate for hypofibrinogenemia.

Figure 8. Coagulation cascade diagram with hyperlinks to synopsis of disorders.

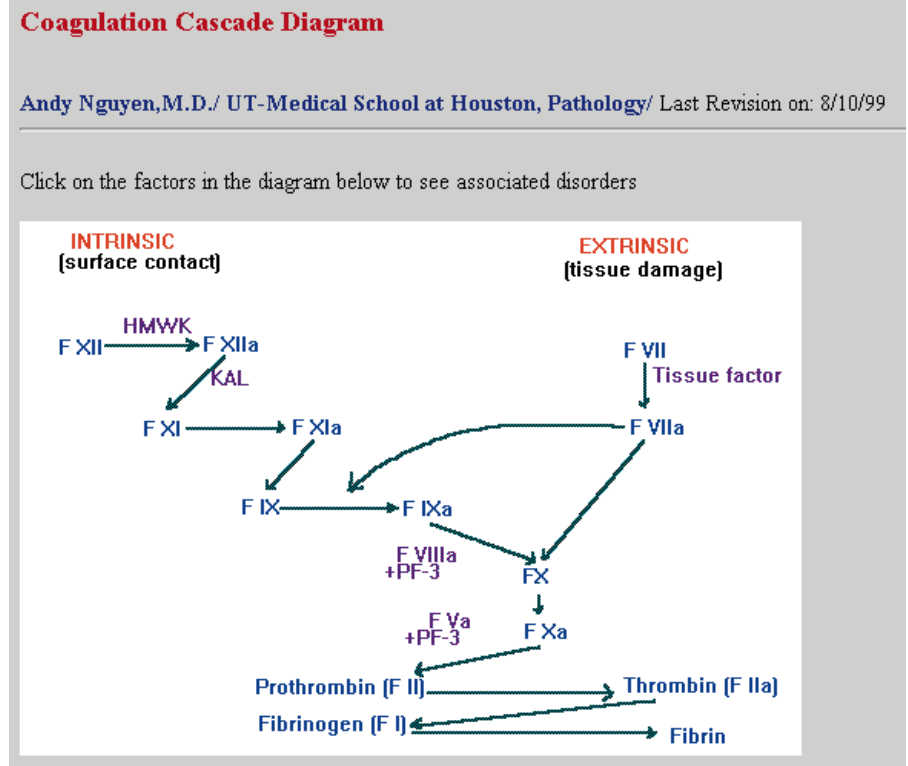


Figure 9. Platelet aggregation pattern for a platelet disorder.

WEB COAG: Platelet Aggregation Patterns

Andy Nguyen, M.D./ UT-Medical School at Houston, Pathology/ Last Revision on: 8/12/99

Select a disorder from the drop-down list to see its aggregation pattern:

Storage Pool Disease

Aggregation with Reagents:

ADP: Normal Abnormal

EPI: Normal Abnormal

COL: Normal Abnormal

RIS: Normal Abnormal

dents and medical students all over the country with positive comments on how they actually used the materials in WEB COAG in their clinical cases. A few hematologists and hematopathologists have responded to our request for critique (on WEB COAG home page) with valuable information and suggestions. We have incorporated most of these suggestions into our program. A number of Web sites have been dedicated to different topics in coagulation.¹³⁻¹⁷ Such sites are usually developed by academic institutions for teaching¹³⁻¹⁵ and by commercial vendors^{16,17} for advertisement purposes. While a great deal of valuable

information can be retrieved from these sites on many topics, we believe that our WEB COAG program is the most comprehensive program for teaching coagulopathy.

Unlike traditional models of stand-alone software on a PC, the WWW provides users from all over the world and on any computer platform with the same materials located in centralized servers. Updating materials in teaching modules is greatly simplified with this centralization. With the widespread access to WWW resources, it is predicted that many medical educational materials will find their way to the Web in the near future.⁷ Interactive mul-

timedia instruction based on a situated learning framework has been shown to stimulate higher-order thinking,¹⁸ suggesting that students are learning concepts rather than just simple rules. Many researchers have investigated the effectiveness of online teaching and have found this to be a valuable teaching method.^{19–23}

Bandwidth limitation has not been a problem for WEB COAG in our experience. The current design of WEB COAG allows for a minimum requirement of hardware and software. A low-end system (486 CPU, 16 megabytes RAM, 14.4 kilobyte-modem) has been found to be adequate for using WEB COAG.

Despite the utility of WEB COAG, there are certain constraints inherent in its use. Some of these limitations have been described previously for its predecessor, XPCOAG.

1. The user must have a functional knowledge of coagulation disorders to be able to use WEB COAG effectively, since this program only serves as a search tool to aid the user in making a diagnosis. It cannot be overemphasized that human judgment is the most important element in finalizing the diagnosis. The number and complexity of coagulation disorders require that the differential diagnoses suggested by WEB COAG be reviewed before making a final diagnosis. We believe that the experienced pathologist's clinical judgment and the information he or she gathers from WEB COAG should yield an accurate diagnosis.

2. Multiple coagulation disorders in the same patient may at times present difficulty to WEB COAG, because the interactions between disorders are complicated and are often poorly understood. These cases are also a challenge to clinical experts.

3. The current version of WEB COAG focuses on laboratory diagnosis of coagulopathy. Information on clinical history and physical examination is only covered to a limited extent since it is beyond the scope of the current version. However, we plan to include this important data component of coagulopathy in the next version of WEB COAG. This enhancement will make the program more informative not only for clinical personnel, but also for laboratorians who want to learn more about clinical information associated with coagulopathy.

As the WWW provides medical students and residents with convenient tools for self-study and clinical decision support, Web-based education programs may eventually form the core materials for life-long learning by physicians, especially at the point of service. Further studies are

needed to determine the most effective ways to utilize this emerging technology in medical education.

WEB SITE URL

WEB COAG can be accessed at the following URL: <http://dpalm.med.uth.tmc.edu/faculty/bios/nguyen/nguyen.html>. In the event that this URL is changed, please contact the authors by e-mail to obtain the new URL (e-mail addresses: Dr Nguyen, nguyen@casper.med.uth.tmc.edu; Dr Uthman, uthman@casper.med.uth.tmc.edu; and Dr Johnson, Kathy.A.Johnson@uth.tmc.edu).

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