CME/SAM

A Synoptic Reporting System for Peripheral Blood Smear Interpretation

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Key Words: Synoptic reporting; Blood smear interpretation; Web-based system

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Upon completion of this activity you will be able to:

- list several examples of synoptic reporting systems in both surgical pathology and hematopathology.
- cite potential advantages and disadvantages of an Internet-based synoptic reporting system in peripheral blood smear reporting.
- discuss potential improvements in resident education by implementation of a synoptic reporting system for peripheral blood smear interpretation and reporting.
- list 2 examples in which morphologic findings on a peripheral blood smear can be combined with lab data and preexisting synoptic templates to generate a more comprehensive and useful final report.
- describe several drawbacks inherent in the current model of resident education in peripheral blood smear interpretation and reporting.

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Questions appear on p 476. Exam is located at www.ascp.org/ajcpcme.

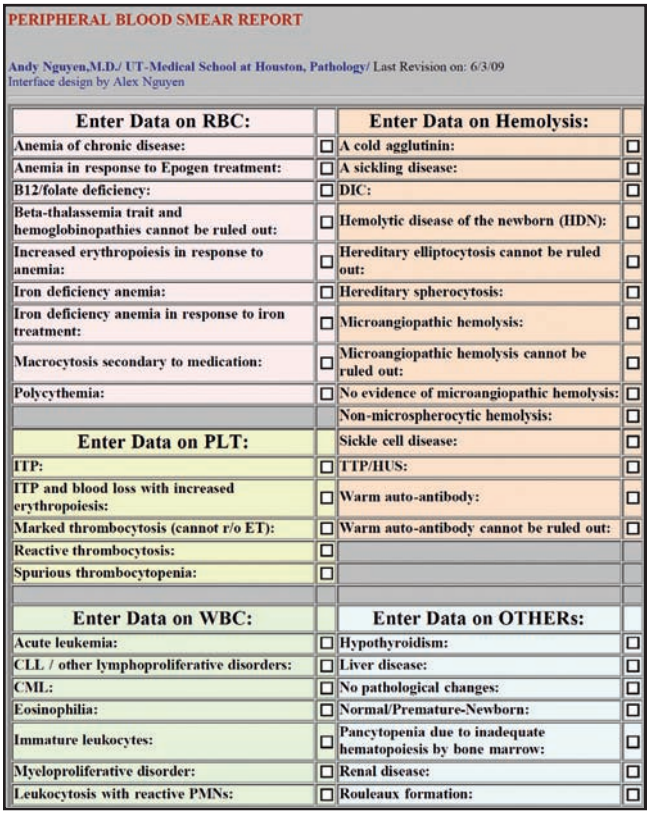
Abstract

Web-based synoptic reporting systems have been shown to improve efficiency, reduce turnaround time, and decrease reporting errors in reports of surgical pathology specimens and hematologic neoplasms and bone marrow. No such system has been previously described for the reporting of peripheral blood smears. We developed a Web-based synoptic reporting system composed of a knowledge base encompassing 150 peripheral blood smear report templates covering a wide range of findings. This system was used at our institution, The University of Texas Medical School at Houston, by pathology residents under the supervision of an attending pathologist to generate peripheral blood smear reports. This system was found to produce a significant reduction in typographic errors with decreased turnaround time and improved accuracy. This synoptic reporting system can help practicing pathologists and pathology trainees to draft a complete and concise report.

The examination and interpretation of peripheral blood smears is an important component of clinical pathology. An accurate peripheral blood smear report can elucidate a vast spectrum of hematologic disorders, guide further testing, and have a critical impact on patient care.[1] Pathology trainees usually spend a significant amount of time with attending pathologists to acquire competence in morphologic interpretation. An equal or greater amount of time is often required to gain the ability to effectively communicate these results to the treating physician. At most institutions, including The University of Texas Medical School at Houston, this is achieved by having trainees examine peripheral blood smears and draft preliminary reports. Afterwards, an attending pathologist reviews the case and the preliminary interpretation with the trainee before crafting the finalized report.

While such a system is indeed necessary for the proper education of trainees, it is not without certain drawbacks. As the complexity of the cases increases, pathology trainees and busy practicing pathologists must endeavor to craft a report that is complete and accurate while maintaining a rapid turnaround time. Inexperienced trainees may prepare drafts with typographic errors or with information already known to clinicians, such as the presence of leukocytosis. At the same time, the drafts may omit important findings, correlations, or helpful suggestions to further pursue a more definitive diagnosis. Such situations may necessitate extensive editing and redrafting of the report before submission, increasing turnaround time.

Checklists, such as those provided by the College of American Pathologists, are frequently used to generate surgical pathology reports.[2] Web-based synoptic reporting systems



PERIPHERAL BLOOD SMEAR REPORT

Andy Nguyen,M.D./ UT-Medical School at Houston, Pathology/ Last Revision on: 6/3/09
Interface design by Alex Nguyen

Enter Data on RBC:		Enter Data on Hemolysis:	
Anemia of chronic disease:	☐	A cold agglutinin:	☐
Anemia in response to Epogen treatment:	☐	A sickling disease:	☐
B12/folate deficiency:	☐	DIC:	☐
Beta-thalassemia trait and hemoglobinopathies cannot be ruled out:	☐	Hemolytic disease of the newborn (HDN):	☐
Increased erythropoiesis in response to anemia:	☐	Hereditary elliptocytosis cannot be ruled out:	☐
Iron deficiency anemia:	☐	Hereditary spherocytosis:	☐
Iron deficiency anemia in response to iron treatment:	☐	Microangiopathic hemolysis:	☐
Macrocytosis secondary to medication:	☐	Microangiopathic hemolysis cannot be ruled out:	☐
Polycythemia:	☐	No evidence of microangiopathic hemolysis:	☐
		Non-microspherocytic hemolysis:	☐
Enter Data on PLT:		Sickle cell disease:	☐
ITP:	☐	TTP/HUS:	☐
ITP and blood loss with increased erythropoiesis:	☐	Warm auto-antibody:	☐
Marked thrombocytosis (cannot r/o ET):	☐	Warm auto-antibody cannot be ruled out:	☐
Reactive thrombocytosis:	☐		
Spurious thrombocytopenia:	☐		
Enter Data on WBC:		**Enter Data on OTHERs:**	
Acute leukemia:	☐	Hypothyroidism:	☐
CLL / other lymphoproliferative disorders:	☐	Liver disease:	☐
CML:	☐	No pathological changes:	☐
Eosinophilia:	☐	Normal/Premature-Newborn:	☐
Immature leukocytes:	☐	Pancytopenia due to inadequate hematopoiesis by bone marrow:	☐
Myeloproliferative disorder:	☐	Renal disease:	☐
Leukocytosis with reactive PMNs:	☐	Rouleaux formation:	☐

Image 1 Data input panel, allowing user to select relevant findings from the peripheral blood smear. CLL, chronic lymphocytic leukemia; CML, chronic myelogenous leukemia; DIC, disseminated intravascular coagulation; ET, essential thrombocythemia; ITP, immune thrombocytopenic purpura; PLT, platelets; PMNs, polymorphonuclear leukocytes; TTP/HUS, thrombotic thrombocytopenic purpura/hemolytic uremic syndrome.

that incorporate such checklists have been shown to improve efficiency, reduce turnaround time, and decrease reporting errors.[3] Synoptic systems for hematologic neoplasms and bone marrow reporting have also been described with similar results.[4,5] To date, such a system has not been described for the reporting of peripheral blood smear findings.

We developed a Web-based synoptic reporting program to assist in peripheral blood smear reporting. This program has a knowledge base containing 150 peripheral blood smear report templates covering a wide spectrum of pathologic findings. Users can access this system on the Internet and select relevant attributes from drop-down lists to obtain a short list of report templates with findings that match those of the case under consideration. These templates are used to create a preliminary draft that can then be edited online to create a final report. We believe that practicing and training pathologists could benefit from such a system that aids in peripheral blood smear reporting while allowing the instruction of trainees.

Table 1
Pathologic Findings in Peripheral Blood Smears

Findings on erythrocytes
Iron deficiency anemia
Anemia of chronic disease
Increased erythropoiesis in response to anemia
Iron deficiency anemia in response to iron treatment
Anemia in response to epoetin alfa treatment:
β-Thalassemia trait cannot be ruled out
B_{12}/folate deficiency
Macrocytosis secondary to medication
Polycythemia
"Sickling" disease
Sickle cell disease in crisis
Warm autoantibody
Warm autoantibody cannot be ruled out
Cold agglutinin
Microangiopathic hemolysis
Thrombotic thrombocytopenic purpura/hemolytic uremic syndrome
Disseminated intravascular coagulation
Microangiopathic hemolysis cannot be ruled out
Hereditary spherocytosis
Nonmicrospherocytic hemolysis
Hereditary elliptocytosis cannot be ruled out
Findings on leukocytes
Leukocytosis with a few reactive lymphocytes
Leukocytosis with reactive polymorphonuclear leukocytes
Leukemoid reaction
Reactive neutrophilia
Reactive eosinophilia
Leukopenia
Histoplasma capsulatum
Chronic lymphocytic leukemia/other lymphoproliferative disorders
Chronic myelogenous leukemia
Acute leukemia
Myeloproliferative disorder
Immature leukocytes
Findings on platelets
Reactive thrombocytosis
Marked thrombocytosis (cannot rule out essential thrombocythemia)
ITP
ITP and blood loss with increased erythropoiesis
Spurious thrombocytopenia
Other findings
Pancytopenia due to inadequate hematopoiesis by bone marrow
Liver disease
Renal disease
Rouleaux formation
Rouleaux formation due to monoclonal gammopathy
No pathologic changes
Normal/premature newborn
Hypothyroidism

ITP, immune thrombocytopenic purpura.

Design and Methods

A closer look at the system and an example session follow.

Design

The user interface consists of 2 components: *data input panel* and *report template display*. The data input panel **Image 1** contains 45 typical findings categorized into 5 groups for ease of input: (1) erythrocytes, (2) hemolysis, (3) leukocytes, (4) platelets, and (5) other miscellaneous findings. The list of these findings is tabulated in **Table 1**. The report template display **Image 2** represents an editable window in which the

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report templates (anywhere from 1 to 5) are displayed. These templates are extracted from reports in the knowledge base of the system. The extracted templates are actual reports of previous cases with findings and interpretations most resembling the case under consideration.

The Knowledge Base

The knowledge base is a repertoire of 150 selected reports previously issued for patient care in the laboratory of The University of Texas Medical School at Houston. They represent typical reports, which cover a wide spectrum of clinical findings. As new cases with particular findings are encountered during sign-out, they are selectively added to the knowledge base for future use.

This system is designed to help users create an optimum report in a short time using preexisting templates conveniently available on the Internet. The templates encompass specific peripheral blood smear findings and describe the findings in a manner that is designed to be comprehensive yet concise. When appropriate, the templates also include additional information regarding potential differential diagnoses and suggestions for further workup. For example, a template reporting the presence of thrombocytopenia, increased schistocytes, and polychromasia would include the presence of microangiopathic hemolytic anemia in the differential diagnosis and advise the clinician to check the coagulation status of the patient and rule out evidence of hemolysis **Image 3**. In this manner, clinicians receive a comprehensive report and guidance for further workup and management. The templates also allow pathologists or trainees to incorporate preexisting laboratory data in the report. For example, a template for a case with hypochromic normocytic anemia may include a differential diagnosis of iron deficiency anemia vs anemia of chronic disease. However, if an iron panel has been performed in clinical chemistry, a different template can be chosen incorporating the results **Image 4**. These templates are designed to aid in crafting the report and are not intended to replace careful examination of the blood smear. A final report is given only after the user, alone or under the guidance of an attending pathologist, has found all pertinent pathologic findings in the peripheral blood smear.

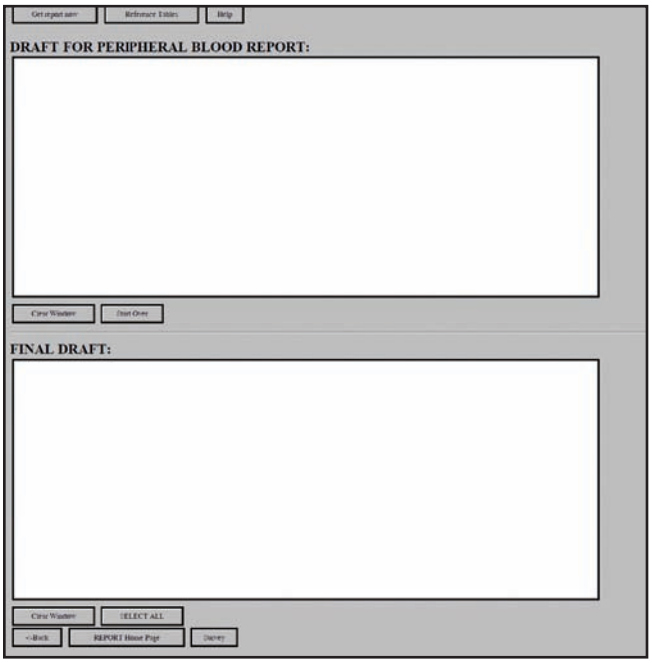

Image 2 Report template display window. Preexisting templates appear after the user has selected findings and clicks "Get Report Now."

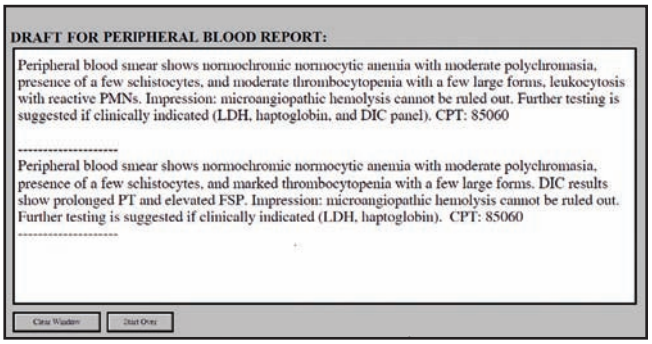

Image 3 Example of a template displaying information regarding further workup in a patient with possible microangiopathic hemolytic anemia. CPT, *Current Procedural Terminology* code; DIC, disseminated intravascular coagulation; FSP, fibrin split products; LDH, lactate dehydrogenase; PMNs, polymorphonuclear leukocytes; PT, prothrombin time.

Example Session

A typical session with the system is shown in **Image 5**, **Image 6**, and **Image 7**. In this session, the user entered the following findings: presence of a warm autoantibody,

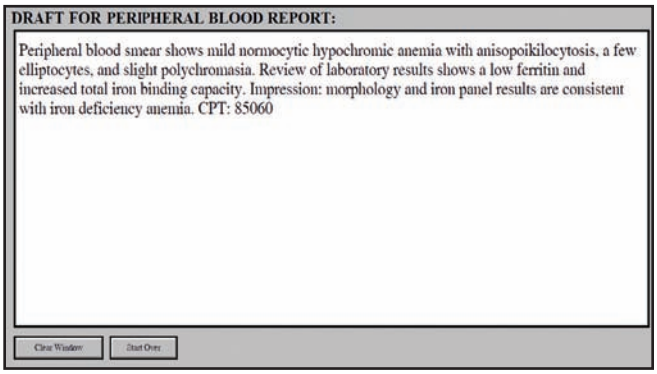

Image 4 Example of a template combining peripheral blood smear findings and iron panel results. CPT, *Current Procedural Terminology* code.

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reactive leukocytosis, and thrombocytosis (Image 5). The report templates are extracted by clicking the "Get Report Now" button. The appropriate report templates are extracted from the knowledge base and are displayed in the report template display window (Image 6). These templates contain relevant information associated with the input data and pertinent correlation and interpretation. Note that some templates may contain only 1 or 2 of the selected findings or sometimes more than 3 selected findings. This allows for more available information to be used in compiling the draft. Since archived templates rarely correspond exactly to all details of the case under consideration, the user needs to edit one or more templates in the display window to compile the draft for the report. All editing events can be done directly in the display window without affecting the archived templates for subsequent use. Large amounts of free text can also be added for cases needing information not available in the templates. Image 7 shows the appearance of a final draft after the addition of free text and extensive editing of the templates. The user can then copy the final draft from the display window and paste it into the editing buffer in the laboratory information system (LIS) for reporting purposes.

As shown in the preceding examples, the synoptic reporting system is designed with a user-friendly interface. This graphic user interface is arranged such that the sequence of data entry, display of report templates, and editing of templates should be intuitive to users.

Methods (Software Platform)

This Web-based synoptic reporting system is implemented in hypertext markup language (HTML), a conventional

Enter Data on RBC:		Enter Data on Hemolysis:	
Anemia of chronic disease:	☐	A cold agglutinin:	☐
Anemia in response to Epogen treatment:	☐	A sickling disease:	☐
B12/folate deficiency:	☐	DIC:	☐
Beta-thalassemia trait and hemoglobinopathies cannot be ruled out:	☐	Hemolytic disease of the newborn (HDN):	☐
Increased erythropoiesis in response to anemia:	☐	Hereditary elliptocytosis cannot be ruled out:	☐
Iron deficiency anemia:	☐	Hereditary spherocytosis:	☐
Iron deficiency anemia in response to iron treatment:	☐	Microangiopathic hemolysis:	☐
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Spurious thrombocytopenia:	☐		
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CLL / other lymphoproliferative disorders:	☐	Liver disease:	☐
CML:	☐	No pathological changes:	☐
Eosinophilia:	☐	Normal/Premature-Newborn:	☐
Immature leukocytes:	☐	Pancytopenia due to inadequate hematopoiesis by bone marrow:	☐
Myeloproliferative disorder:	☐	Renal disease:	☐
Leukocytosis with reactive PMNs:	☑	Rouleaux formation:	☐

Image 5 User has selected several peripheral blood smear findings, including the presence of a warm autoantibody, reactive leukocytosis, and reactive thrombocytosis. CLL, chronic lymphocytic leukemia; CML, chronic myelogenous leukemia; DIC, disseminated intravascular coagulation; ET, essential thrombocythemia; ITP, immune thrombocytopenic purpura; PLT, platelets; PMNs, polymorphonuclear leukocytes; TTP/HUS, thrombotic thrombocytopenic purpura/hemolytic uremic syndrome.

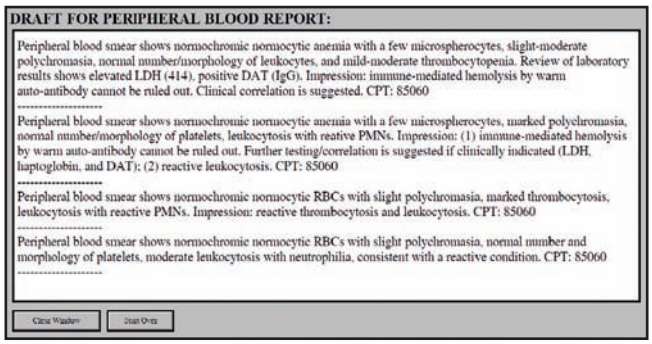

Image 6 The report template display window imports several templates incorporating the findings in Image 5. CPT, *Current Procedural Terminology* code; DAT, direct antiglobulin test; LDH, lactate dehydrogenase; PMNs, polymorphonuclear leukocytes.

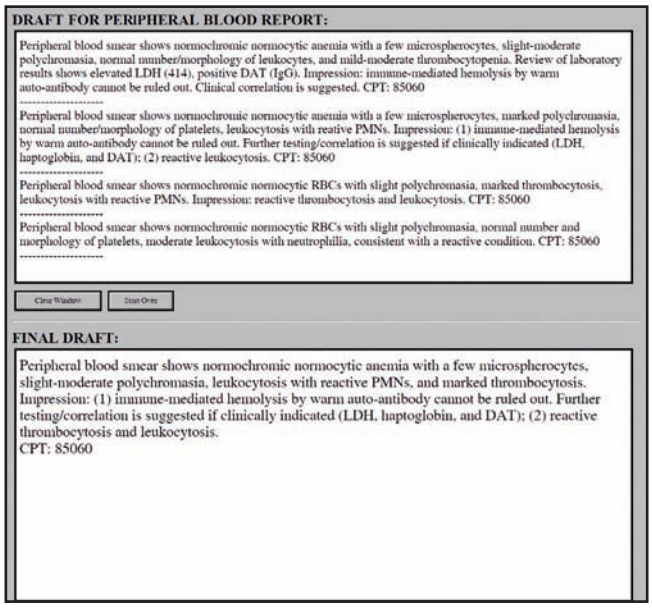

Image 7 The user has crafted a final report after extensive editing of the templates from Image 6. CPT, *Current Procedural Terminology* code; DAT, direct antiglobulin test; LDH, lactate dehydrogenase; PMNs, polymorphonuclear leukocytes.

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language for Web documents.[6] Interactivity with users is achieved with JavaScript, a scripting language for adding dynamic features to Web pages.[6] 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 subroutines. JavaScript is also used to create functions and subroutines used in the search engine for displaying the report templates. In the preceding example session, the selected input data correspond to 3 findings in the knowledge base coded as D12, D24, and D33. When the user clicks the "Get Report Now" button, the JavaScript code in the Web page looks for any archived report templates that contain all 3 findings. Templates that meet these search criteria are then displayed in the window labeled "Draft for Peripheral Blood Report." The synoptic system is installed on a Microsoft Window XP server running on a Microsoft Internet Information Server (Microsoft, Redmond, WA) in the Department of Pathology and Laboratory Medicine, The University of Texas Medical School at Houston. The hospital LIS at our institution (Memorial Hermann Texas Medical Center, Houston) is Cerner Millennium (Cerner, Kansas City, MO), which is well integrated with other Cerner clinical systems, including electronic medical records, radiology, and pharmacy.

Image 8 User survey for the synoptic system.

Validation

This synoptic reporting system was implemented for resident training from May 2009 through May 2010. A total of 20 pathology residents were recruited to use the system for drafting preliminary peripheral blood smear reports during their month-long rotation in hematopathology. None of the residents had prior experience with the system. Each resident used the system to generate a report, which was then evaluated by the attending pathologist for accuracy and comprehensiveness and for the presence of typographic errors. At the end of the rotation, each resident was asked to complete an online survey **Image 8** regarding the effectiveness of this synoptic system.

The resident input and feedback was unanimously positive. All 20 residents reported that the use of this synoptic reporting system greatly improved turnaround time and accuracy. In addition, all 20 residents reported that they would use similar systems for other types of reports. On average, 6 minutes (range, 5-7 minutes) were required to complete 1 report with the use of the synoptic system, whereas 10 minutes (range, 8-12 minutes) were required to complete 1 report without the use of the synoptic system. The time used for compiling the draft was therefore decreased by about 40% (10 minutes vs 6 minutes). Typographic, spelling, and grammatical errors were decreased, as observed by the residents compiling the drafts and the attending hematopathologist who signed out the final reports. Exclusion of important information in the drafts was also decreased, as observed by the attending hematopathologists signing out the final reports.

Discussion

We developed a Web-based synoptic reporting program to assist pathology residents in reporting peripheral blood smear findings. This synoptic reporting system aids pathology trainees to draft a complete and concise report using a system freely available on the Internet. Unlike traditional models of stand-alone software on a personal computer, the Internet provides users from all over the world and on any computer platform with the same materials located in centralized servers.[7-9] Updating materials in teaching modules is greatly simplified with this centralization. Interactive tools based on a situated learning framework have been shown to stimulate higher-order thinking,[10] suggesting that trainees are learning concepts rather than just simple rules. Many researchers have investigated the effectiveness of online teaching and have found interactive software to be a valuable teaching method.[11-14] At The University of Texas Medical School at

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Houston, several Web-based programs have also been developed for teaching pathology residents on coagulation and hematopathology rotations.[15-18]

The use of synoptic reporting systems in pathology is not a novel concept. Many excellent systems have been described in the literature. These include systems for solid tumor reporting[3] and systems for reporting hematologic neoplasms and bone marrow findings.[4,5] We believe that our system incorporates many of the positive aspects of these systems by providing useful report templates that are easy to edit with the ability to add free text. Like many of these systems, there is potential to incorporate laboratory data, provide a differential diagnosis, and suggest testing for further workup.

However, our system provides this information for the generation of peripheral blood smear reports, which has not been previously described. In addition, the system is unique in its ease of use and availability. Unlike other systems, there is only 1 main window and the user is not required to scroll through multiple menus, windows, and drop-down lists. Also, the interface is very user friendly and intuitive enough that users can become adept at its use with only a few sessions. Because it is freely accessible on the Internet, the system is available to users at any location during anytime of the day or night and does not require the installation of a separate program.

In addition, our system is an effective teaching tool for residents. Simply entering findings such as cell count or even morphologic features is not sufficient to generate a report. It requires users to critically evaluate the findings of each component of the peripheral blood smear and choose a clinical diagnosis that best suits those findings. For example, instead of simply reporting "microcytic, hypochromic red cells with anisopoikilocytosis and numerous elliptocytes," a user must realize and report that these findings most likely indicate a diagnosis of iron-deficiency anemia. He or she must further recognize that additional testing may be required to establish this diagnosis and suggest such testing to the treating clinician. In this way, residents learn to see the peripheral blood smear report not only as a list of findings but also as an important tool for patient evaluation and treatment. Furthermore, they learn to incorporate information from other disciplines such as clinical chemistry, microbiology, immunology, and blood banking. Finally, they can begin to learn the important skill of communicating their findings in a manner that is useful to clinicians.

The response to the system by our residents was very positive. In our limited validation study, the system was shown to reduce typing errors and prevent exclusion of important information in the drafts. The system was also shown to improve turnaround time. Although these findings come from a single online survey, they are encouraging enough to justify further testing and validation of the system. We will continue to have residents voluntarily use the system while rotating on our hematopathology service. In this way, we hope to collect a larger series of reports generated with the system and determine the number of typographic and grammatical errors present. These findings can be compared with reports generated without the system by residents using free text entry or transcription. We also plan to determine the rate of major errors present in reports generated with and without the system.

However, it seems reasonable to assume, as have other authors,[4] that turnaround time will be reduced with synoptic reporting because synoptic reporting allows users to bypass the use of a transcription service. Users input the report into the system themselves, and it can be quickly reviewed and verified at the microscope. This removes the extra step of proofreading and editing a transcriptionist's report, which may itself contain added errors. Consequently, a report can be generated at any time of the day or night and on weekends. Similarly, it can be assumed that the number of grammatical and typographic errors will be decreased in a report that is partially generated using templates rather than one generated entirely by free text entry and without the potential for grammatical or typographic errors introduced by a transcriptionist.

Despite this, we acknowledge that many factors cannot be easily analyzed and that certain aspects of our validation studies will be limited. Factors such as ease of use of the system, completeness of the report, and even turnaround time are difficult to contrast when the experience of users, the amount of free text used in a report, and overall case complexity can vary so greatly.

Of course, the ultimate validation of any software is how often it is used. It is for this reason that we have reported this study. We hope that users, both inside and outside of The University of Texas Medical School at Houston, will be encouraged to use the system and provide us with feedback. In this way, we can gather the perspectives and advice of a wide array of users, which will allow us to improve the system accordingly.

Despite our enthusiasm for the usefulness of this synoptic reporting system, we acknowledge that there are certain constraints inherent in its use: (1) Users must have a functional knowledge of pathologic changes in peripheral blood to be able to use the program effectively. It cannot be overemphasized that clinical judgment is the most important element in finalizing the report. The number and complexity of hematologic disorders require that the templates displayed by the synoptic reporting program be reviewed and edited thoroughly to suit the case under consideration. Complicated clinical cases often contain multiple pathologic changes in the peripheral blood smear. Such cases would require thorough correlation with clinical information and other relevant laboratory results before a diagnosis and useful recommendation

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can be made. The reports for these cases typically would use details from multiple draft templates and require careful correlation with clinical and laboratory data. (2) Each user, whether a trainee or practicing pathologist, may have a different reporting style. A synoptic reporting system such as this one would be especially useful during the training period when reporting style is largely influenced by emulating the teaching faculty's reporting style. Practicing pathologists, however, might prefer their own reporting style, which has been developed over years of experience. The current version of this synoptic reporting system is not amenable to editing of the knowledge base to better reflect the personal reporting style of an individual user. To do so, one has to edit the JavaScript code directly to make appropriate modifications. Even though JavaScript coding is relatively simple compared with most other programming codes, it is still a challenge to the uninitiated. (3) This reporting system is accessed on the Internet. This availability represents the strength of the system in term of universal access. However, it is also a drawback in user interface design. To use the reporting system, its Web page has to be opened together with the interface of the LIS. The compiled draft from the synoptic reporting system needs to be copied and pasted into the LIS before finalizing the report. Optimally, the synoptic reporting system should be embedded into the LIS to allow for a single user interface with seamless integration of texts in the synoptic module to those in the LIS report module. It is predicted that LIS vendors may incorporate synoptic modules into their LIS in the future.[3]

Conclusion

This synoptic reporting system for peripheral blood smears helps users to draft a complete, accurate, and concise report. It is found to reduce typing errors, enhance completeness, and improve reporting turnaround time. Trainees and practicing pathologists may benefit from this system, which is freely available on the Internet. This synoptic reporting system can be accessed at the following Web sites: http://HemePathReview.com/ and http://www.uth.tmc.edu/pathology/faculty/pages/nguyen-nghia/decision.html.

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