

Whole slide images and digital media in pathology education, testing, and practice: the Oklahoma experience

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Abstract. Examination of glass slides is of paramount importance in pathology training. Until the introduction of digitized whole slide images that could be accessed through computer networks, the sharing of pathology slides was a major logistic issue in pathology education and practice. With the help of whole slide images, our department has developed several online pathology education websites. Based on a modular architecture, this program provides online access to whole slide images, still images, case studies, quizzes and didactic text at different levels. Together with traditional lectures and hands-on experiences, it forms the back bone of our histology and pathology education system for residents and medical students. The use of digitized whole slide images has also greatly improved the communication between clinicians and pathologist in our institute.

Keywords: Whole slide image, pathology education, online slides, digital imaging, residency training

1. Introduction

The University of Oklahoma Health Sciences Center includes seven health sciences related colleges and their affiliated research laboratories, two adult hospitals and the only children's hospital in the state, a comprehensive cancer center, a clinical simulation laboratory, out patient clinics, and training programs for the full range of health care professionals. Our pathology faculty and trainees are spread over this vast campus plus two off site training facilities. For this setting to be efficient, we are obliged to use modern

information technologies. A hyperlink markup language (HTML) based online and offline educational system was implemented in 2002 to give rapid access to educational materials. Whole slide imaging (WSI) is a recently added feature in education and patient care.

The central philosophy of our education is to provide materials, motivations, and enlightenments. Our online educational program is used to complement formal lectures, hands-on experiences, traditional multi-headed microscopic teachings and clinical rounds. We use a combination of computer related and traditional media to deliver educational materials. Multiple websites have been built to meet the different needs. Our residents are actively involved in the construction of this system as an educational experience. The bulk of the content is free for public access through our departmental website [1].

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2. Technical information

Our WSI system is based on a 5-slide Aperio Scanscope CS System (Aperio Technologies, Inc. California, USA). Both Spectrum Plus from Aperio and HTML based programs developed by our department are used to manage the WSI for clinical and educational applications respectively. To conserve server space, our slides are usually scanned in at 20× magnification with a smaller number scanned in at 40×. Still images at or over 40× are used as supplements; special stains and immunohistochemistry are usually provided as still images to conserve server space.

3. Pathology education

3.1. Content

Self learning is emphasized with these tools. Several websites covering multiple areas in pathology have been developed to deliver content for self study, self assessment, and interactive small group teaching. In addition, we have developed a WSI image teaching bank (restricted for internal use) for both teaching and evaluation of pathology residents.

3.2. Modular architecture

Our medical students and pathology trainees have diversified backgrounds, experience, and often very different goals. Only 1 to 3 medical students within a class of some 165 students will become pathologists. The few that would become pathologists seek more pathology experience and education while the remainder of the class may be interested in case materials geared to their specialty choices, or perhaps only core knowledge items. A similar situation exists in our residency program. In order to meet the demands of these rather heterogeneous audiences, we have developed a modular architecture to provide experiences at different coverage, depth, and sophistication.

With this architecture, the website is composed of content modules (web pages) that provide information and orientation pages that provides links directing to the content modules. This controls the amount and depth of information in the content modules. A content module at the medical student level may have further link to a content module of similar or related material at

the higher (residency) level. This avoids overwhelming and possibly discouraging students while at the same time providing additional challenges for the enthusiastic users. This modular architecture also promotes embedding URL addresses in the syllabus and lecture notes as web links.

3.3. Types of websites

Our website continues to grow with additional content and functionality. At present, four major formats are in use- the annotated WSI, case study type materials, multiple choice questions, and didactic material.

Our Department of Cell Biology uses annotated WSI in histology teaching. There are currently some 350 WSI with most of them annotated. Access to this website is restricted to OUHSC trainees and faculty only.

The case study type materials are offered at two levels of difficulty – the medical student and resident level. *OU Pathology Online Slides for Medical Students and Residents* [2] is essentially an online WSI atlas with some 75 slides. WSI are presented as unknowns with minimal clinical information. This website is easily found on the internet by using “pathology online slides” as search engine keywords. At present, most of the WSI and the corresponding discussions are set at the medical student level but some of them are set at the resident level and are more challenging. More slides will be added and we plan to add multiple choice type questions at both the student and resident levels to accompany these WSI.

OU Pathology Case of the Month contains some 100 cases with or without WSI and is directed towards residency/fellowship level trainees. These cases are prepared by residents and faculty together as a team [3]. Many of our residents find this a valuable exercise. This website is easily found by using “pathology case of the month” or “Oklahoma pathology” as search engine keywords.

Several collections of quizzes [4] that cover neuropathology, surgical pathology, cytopathology, and hematopathology are available and are set to challenge residents. This website provides links to over 300 quizzes and is easily found using “pathology quiz” as search engine keywords.

The last type of online educational content is didactic material. This is, perhaps, the smallest component in our online programs. Current content is limited to some areas of neuropathology and is used for internal training of our residents and fellows but the general

public can also gain access through NeuroHelp in our NeuroLearn website [5].

3.4. Integrated websites and complementary lectures

Neuropathology training is particularly challenging at our institution as the rotating trainees include senior medical students, pathology residents, neurology residents, and neurosurgery residents. The needs and emphases of their rotations are quite different. The benefits of using the internet for neuropathology education has been previously discussed [6]. Digital media are fully integrated into our neuropathology training.

Our modular architecture allows a high level of combination and permutation. Integrated websites containing different types of material are generated for neuropathology teaching. These websites serve as the prototype of our integrated websites and we plan to extend this approach to other areas of anatomic pathology.

The NeuroLearn website [5] is the prototype of our integrated websites for pathology residents. This website contains several smaller sites which provide didactic materials, study cases, and quizzes on neuropathology. An additional WSI based neuroanatomy website [7] is embedded in NeuroLearn to facilitate neuroanatomic correlation.

The emphases for neurology and neurosurgery residents are different. We rearranged our modules and generated *Pathology for Neurology and Neurosurgery Trainees* for this special group [8]. It is easily found using “neurosurgery pathology” as search engine keywords. This website is particularly useful at the beginning of their neuropathology rotations and also for small group interactive teaching.

To supplement neuropathology rotations, a monthly neuropathology lecture was implemented since 2004 [9] with didactic lectures and WSI review supplemented by invited guest lectures over a two year cycle. NeuroLearn is the key website to complement this lecture series. In addition, there is an offline HTML based neuropathology test at the end of the rotation. We plan to extend this model of integrated lecture-rotation-online materials to other areas of anatomic pathology.

3.5. Evaluation of competency

The evaluation of diagnostic skills and competency of residents is a time consuming process that is easily

biased and difficult to complete in a comprehensive fashion. Based on the requirements of Accreditation Council on Graduate Medical Education (ACGME), we have suggested the integration of more information technology and WSI in order to mitigate these issues [10].

We have created a WSI bank for teaching and evaluation of our residents. Recently, we have started a study which involves giving the first year residents a WSI based test at the beginning followed by a test after they have completed a certain number of rotations. This approach provides a method of comparing trainees and also allows multiple residents to view the same slides simultaneously.

4. Pathology practice

4.1. Daily operation

In our department, WSI is used primarily to archive slides that are sent in from other laboratories and in clinical-pathology correlation conferences (tumor boards). WSI are welcomed by the clinicians. Clinicians can easily ask questions on particular areas of the slides and particularly on the status of resection margins. It also allows a last minute addition of new cases as it eliminates photomicrography. For example, a set of 10 slides can readily be scanned and available for presentation across campus in a tumor board in 30 minutes or less. In addition, we use WSI for monitoring of our estrogen receptor/progesterone receptor controls. WSI allows rapid and on-going comparison of multiple stained slides from several days or weeks on the same screen and helps to identify staining issues early.

4.2. Evaluation of WSI technology

For several reasons, we have not fully adopted WSI in our everyday diagnostic activities. We have, however, conducted multiple studies in the evaluation of this technology particularly its use in telepathology. We have completed a retrospective study in the use of mobile high resolution devices for remote diagnosis of frozen sections which showed promise for this approach [11]. Additional studies on telepathology for second opinion consultation in frozen section will be performed.

4.3. Discussion

Information technologies have made tremendous progress in the past 10 years. The improvements in hardware, software, bandwidth, and storage capacity have made the efficient use of WSI a reality in education, testing and evaluation, as well as telepathology. Our department has successfully evolved with technology and uses WSI in a routine fashion. Although there are still many challenges in terms of histologic techniques, hardware, software, bandwidth, and human factor, before we can widely use WSI for routine diagnostic sign out, we have no doubt that a combination of information technologies and WSI will continue to dramatically change the landscape of pathology education and practice in the near future. We firmly believe WSI and other information technologies will be key in improving education and patient care in pathology.

5. Search engine keywords

Websites being discussed in this article can be found by using the following search engine keywords-“pathology online slides”, “pathology case of the month”, “pathology quiz”, “neurosurgery pathology”, “Oklahoma pathology”, and “NeuroLearn”.

6. Disclosure

The Department of Pathology of the University of Oklahoma Health Sciences Center and the authors

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