Review Article

Digital slides and ACGME resident competencies in anatomic pathology: An altered paradigm for acquisition and assessment

Lewis A. Hassell, Kar-Ming Fung, Brad Chaser

Department of Pathology, University of Oklahoma Health Sciences Center, Oklahoma City, USA

E-mail: *Lewis A. Hassell - lewis-hassell@ouhsc.edu
*Corresponding author

Abstract

Whole slide digital imaging technology has matured considerably over the past decade. Applications in pathology education are widespread and are rapidly transforming the manner in which medical students learn pathology and histology, and they have a novel and significant impact on postgraduate continuing medical education. Whole slide digital images for use in pathology graduate education have been slower in adoption and remain much less widespread. Emphasis on professional competency by the Accreditation Council on Graduate Medical Education (ACGME) and credentialing organizations, however, appear poised to significantly increase. The convergence of these two forces is propitious for pathology training. This article examines the opportunities for the use of whole slide images (WSI) in pathology residency training along with the developing potential uses in each of the areas of competency, as categorized by the ACGME. Barriers to WSI adoption in the pathology community are identified along with potentially significant promoters for adoption in training and practice. Current literature and recent presentations are reviewed. Digital pathology coupled with emphasis on competency is a shift of tremendous magnitude that can dramatically improve our abilities to help trainees acquire, demonstrate, and maintain the skills to practice pathology in the generation ahead.

Key words: Anatomic pathology, competency, digital pathology, quality assurance, resident education, virtual slides

INTRODUCTION

The past two decades have seen rapid growth in the use of electronic media, particularly the internet, and digital whole slide images (WSI) in pathology education. These have been most pronounced in the way histology and pathology are taught to medical students, dental students, and other healthcare professionals.[1-3] Postgraduate continuing medical educators have also been willing adopters of these new capabilities.[4] However, unlike the introduction of sliced bread in Missouri in 1928, which rapidly led to the nationwide sale and consumption of pre-sliced bread, or even the introduction of digital still image cameras, which have been readily adopted in pathology laboratories for both gross and microscopic images, WSI have not yet become part of the daily fare for pathology trainees. One of the only consistent ways in which pathology residents currently interact with digital slides is during board examinations, where over two-thirds of the slide-based questions use digital slides.[5]

In the past decade, the Accreditation Council on

Graduate Medical Education (ACGME) has introduced a major emphasis on graduate medical education, including pathology, which focuses on specific areas of competency essential to practice medicine. This initiative demands more than just completion of a prescribed schedule of months or weeks within a particular area of training. Beginning in 2001, the outcomes project of the ACGME mandated that training programs assess trainees in six specific areas of competency: patient care, medical knowledge, communication skills, professionalism, practice-based learning, and systems-based practice.[6] This transition has been generally embraced, but poses several challenges in a field as broad as pathology. Implementing reproducible means to assess resident progress and competency has always been challenging for program directors in pathology. We assert that WSI, and many of the attendant changes in the workflow, as also the interface of interaction with such images, can serve as an objective, reproducible medium for resident assessment, and documentation of the residents' abilities in these core competencies. We also believe that WSI holds a powerful potential to disrupt or shift the paradigm under which residents acquire these competencies.

The term 'digital pathology' has been used to refer to a wide array of interactions with diseases and patients in a digital environment, but may generally be defined as, "an image-based information environment enabled by computer technology that allows for the management of information generated from a digital slide. Digital pathology is enabled in part by virtual microscopy, which is the practice of converting glass slides into digital slides that can be viewed, managed, and analyzed."[7] These imply an array of tools that may shift the workflows and analysis used to interact with the pathological strata.

The purpose of this article is to examine some of the ways digital pathology is beginning to impact anatomic pathology training at the interface of the six areas of competency and competency assessment, and to suggest ways in which it may be able to further assist in the acquisition and assessment of these competencies in the future. We will suggest some sample statements of competency in each of the six areas and illustrate ways in which digital pathology has or could potentially impact the attainment and assessment of that capability by pathology residents. Our purpose in taking this approach is to further catalyze the shift in the paradigm for residency education toward competency achievement, and the integration of digital pathology tools into this level of graduate medical education.

SAMPLE COMPETENCY STATEMENTS FOR ANATOMIC PATHOLOGY TRAINEES

Although the range of competency statements or goals for anatomic pathology trainees is almost unlimited, we have selected some sample statements [Table 1] as teachers and residents in anatomic pathology. Some of these have a relatively obvious connection to the currently available digital pathology tools, while others may initially seem to have little or no such link. Although this list is not exhaustive, we believe it provides sufficient breadth to illustrate our points presented below.

UTILITY OF DIGITAL SLIDES IN COMPETENCY-DIRECTED TRAINING OF RESIDENTS

Patient Care Competency
Although WSI are being used in a few primary diagnostic

Table 1: AP competency statements by ACGME competency area

ACGME competency area	Sample competency statements for AP trainees- "Resident can…"
Patient care	Examine a slide completely, consistently, and thoroughly.
	Find and correctly identify the important diagnostic microscopic features.
	Properly interpret the results of a broad variety of histo- and immunohistochemical stains.
	Apply advanced diagnostic tools appropriately
	Interact meaningfully and usefully with patients in explaining the diagnostic findings.
Medical knowledge	Readily diagnose a broad spectrum of pathological entities from gross and / or microscopic materials.
	Appropriately evaluate and report staging and diagnostic variables for most tumor types and similar diseases.
Professionalism	Consistently and thoroughly examine patient materials before rendering a diagnosis.
	Display appropriate patterns of preparation for patient and professional encounters (tumor boards, etc.)
	Demonstrate respect for patients, colleagues, and the profession.
Communication skills	Communicate findings clearly and succinctly to colleagues in reports and conferences.
	Explain findings directly to patients using visual, written, and verbal means of expression.
	Consistently provide all needed information for further medical care.
Practice-based learning	Use current and archived case material to guide, study, and expand knowledge.
	Identify gaps in their abilities and knowledge from QA data trends.
Systems-based practice	Consult colleagues appropriately.
	Recognize the impact of their studies on health systems and society.

ACGME - Accreditation council on graduate medical education, AP - Anatomical pathology, QA - Quality assurance

settings and in some consultative settings, these continue to be the exception with regard to day-to-day patient care. Thus, it is not surprising that there have not been many reported uses of digital slides in the routine flow of case evaluation, which forms the core of resident education in anatomic pathology. Exceptions to this current norm exist in some settings, such as, for the review of remote frozen sections in selected programs.[8] One notable exception is the proliferation of many 'technical-only' reference services for specialized immunohistochemistry (IHC), where staining results are reported back to the referring institution for interpretation in the form of a digital slide.[9] Residents training in such settings would, at least theoretically, have access to these studies.

Presently, a glass slide will not tell a resident or the attending faculty whether it has been completely examined. Assessing a resident's habits currently requires direct and inferred observation of their slide examination habits in a variety of settings, and a sufficient number of cases with subtle, commonly missed findings, to be able to determine whether a resident is consistently examining the entire slide. Tracking tools, originally targeted at quality concerns in cytology, and the use of WSI have the potential to easily change that dynamic. Electronic tracking of examination times, observed areas, and magnifications used, could provide quantitative metrics to evaluate this competency, either by providing such data on all digital slides examined by a trainee, or on slides specifically selected (and submitted blindly) for this purpose. These data can also provide feedback to residents, to help them improve their skills and attain the desired competency.

Quantitative image analysis (tissue morphometry) has a lengthy history in pathology. Various applications of these tools in the clinical and research fields are in use with digital slides today. WSI is fundamental for using these tools. New image analysis tools, drawn from applications in other industries and specialties, appear on the verge of making computer-assisted diagnosis with WSI an imminent possibility. The proper application of both the existing and future diagnostic tools of this type rest on the ability of the current trainees and our future pathologists, to acquire skill in managing digital slides and the related software.

Diagnostic skill-building with microscopic slides is dependent on learning to find and recognize specific histopathological features, so that the current diagnostic criteria can be applied to make a diagnosis. In a study of resident slide examination and diagnostic feature localization skills,[10] the authors found WSI a promising medium for diagnostic skill building and assessment. In this study, the authors presented WSI and asked each resident to find a well-defined diagnostic feature (such as perineural invasion) known to be present on the slide. The resident was asked to scan the slide until they found the specified diagnostic feature and then capture a digital image of that feature. The residents were stratified based on the postgraduate year, and the amount of time required to find the feature was recorded.

This study allowed the authors to assess several aspects of resident competency in one sitting. First, they could determine whether the resident understood and could correctly identify the characteristic feature. Also, they could track the amount of time required for the resident to identify this feature. These two parameters alone provided a valuable insight into the residents' abilities to examine a slide and identify its key features. As expected, upper level residents were faster at finding and correctly identifying the characteristic features on the digital slide.

This method could also be used to evaluate other competencies such as the completeness of resident slide examination, proper interpretation of various immunohistochemistry findings, and the ability to identify cases that may need consultation. The efficiency and sophistication of this method can be greatly improved by the development of novel software that can automate this process and provide tracking records on how the slide is examined by our trainees. This experience could afford the resident a greater sense of autonomy, while providing a means for detailed feedback on a regular basis. For example, the resident can formulate his or her own report as a part of the medical record and highlight areas of interest on the slide. The attending can review the slide, make any necessary changes to the report and comment on the resident's marked areas on the slide. This data can be stored as a de-identified digital file for the resident to review and use in subsequent formulations of similar diagnoses.

There are increasing calls for pathologists to take an active role as the core of a patient care team.[11] Gaining this skill will be an advantage for our future pathologists. Our sample competency in this arena foreshadows the need to address this skill in our training and assessment of resident performance. Some pilot studies are in process, which may link improved patient outcomes with greater understanding and visualization of their disease processes, often facilitated by a pathologist–patient interaction. Presentation of pathological findings on a computer screen or mobile device is more efficient and far less intimidating than asking patients and their families to look into the microscope. It is also easier for patients to point out specific features and ask questions. WSI technology combined with the internet will be the cornerstone to make this experience truly interactive. A demonstration project at CAP'10 offered pathologists the chance to test and improve their skills in this arena by interacting with a standardized patient and her breast cancer slides.[12] A summary of the potential impacts on

these sample competencies for patient care is presented in Table 2.

Competency in patient care is a product of the skill of the pathologist and the efficiency of the system. WSI can improve logistics, improve efficiency, and most likely reduce unnecessary stress on pathologists. This improved computerized workflow including simplified organization of slides and cases, ready tracking of the slides that have been seen and the ones that have not been seen, the cases that have been referred for a second opinion and those that have been seen by the consultant, and so on, relieves the pathologist of the need to keep track of these details mentally, as well as the physical slides. Pathologists will spend less time retrieving cases, particularly archive cases, for comparison. For example, pathologists will not need to manually go through stacks of slides in order to locate a particular case or slide. This technology renders missing slides potentially as historical footnotes only. The trend of using WSI for a regular sign out is now taking momentum. It is important for residents (and pathologists) to master this skill early.

Medical Knowledge

Many training programs are in the process of developing resources directed specifically toward trainees, which involve the use of digital slide archives.[13,14] These are often tailored to conform to medical school education and as an adjunct to the pathology residency training program. Generally these take the form of 'digital slide boxes' of interesting or unusual cases, perhaps organized by the organ system or another parameter, to facilitate resident exposure to a wider array of disorders than may be routinely encountered, or as a means of review for board examinations, preparation for practice, and so forth. For example, the Department of Pathology of the University of Oklahoma Health Sciences Center has developed a WSI-based pathology slide box for internal use, as well as educational materials on the public domain (http://moon.ouhsc.edu/kfung/jty1/OUMC/Default.htm, http://moon.ouhsc.edu/kfung/jty1/NeuroAnat/AA-Neuroanat-WSIOU-M.htm, http://moon.ouhsc.edu/kfung/jty1/Com/Index.htm) for pathology education at the level of medical students and residents.[15] National organizations have taken the lead in developing more extensive archives, often allowing universal access without the requirement of membership.[16,17] These resources, however, have not been directed specifically to resident-level education.

Such collections, particularly if systematically organized, do have the potential to dramatically increase resident first-hand knowledge and exposure to a wide array of diseases and diagnoses. As digital slide material can include annotations and guidance, that is, an abundance of metadata, they have the potential to be textbook- or atlas-like case files, replete with educational content, to guide trainees in the evaluation of similar cases. An example of this type of education medium would be a digital slide with annotations and an accompanying podcast or recorded video clip demonstrating the approach to the slide, identifying relevant or irrelevant findings and formulating a diagnostic communication. The resident could review specific cases organized by the organ system or possibly by a differential diagnosis, to solidify his / her current knowledge and gain additional exposure to areas seen as an individual weakness. Of course, the preparation, validation, and maintenance of such data sets is a monumental task, well beyond the means of a single department or institution to accomplish rapidly. A comprehensive software for developing these educational programs is still insufficient.

As the adoption of WSI alters the routine workflow, one can consider how this may influence resident educational activity. Just as cytotechnologist diagnoses have been tracked and trended for quality purposes, a similar functionality can be incorporated into the information systems surrounding the use of digital slides, which will allow the ready tracking of resident diagnoses for comparison with the final sign-out diagnosis. Too often, the lack of sign-out experience is cited as a shortcoming in resident education, which may lead to complacency in their approach to the slide review.[18] Knowing that their diagnosis will be recorded in the laboratory information system, as part of the medical record and used as a measurement of their progress toward diagnostic competency will encourage a greater sense of responsibility

Table 2: Summary of potential digital pathology impacts on patient care competency

Patient care competency	Potential impact of digital pathology
Examine a slide completely, consistently and thoroughly.	Electronically track slide examination statistics of trainee.
Find and correctly identify important diagnostic microscopic features.	Structured slides with significant diagnostic features and interactive 'hot spots' for properly located features.
Properly interpret the results of a broad variety of special stains.	Digital slides from archived or live cases allow exposure and experience with stains not offered locally.
Apply advanced diagnostic tools appropriately.	Digital slides readily offer an opportunity to apply image analysis, computer-assisted diagnosis or other tools.
Interact meaningfully and usefully with patients in explaining the diagnostic findings.	Digital slides used in patient interactions in person or via chat become possible.

in case management. The resident expectation that their diagnoses and accompanying staging information will be directly transferred to the final sign-out field, would address the current challenge in providing a sign-out experience to trainees [Table 3].

Digital slides also offer a ready means of consistent measurement of the diagnostic skill progress. A pilot digital slide resident assessment tool developed at the University of Iowa has shown promise in this use of digital slides, to measure progress.[19]

Professionalism

This is inherently a difficult competency to define and measure. In anatomic pathology a few measurable behaviors, however, may serve as surrogates for the desired attitude and behavioral competency. The approach to the work of patient care, and the thoroughness displayed in that process is one general area that offers an insight into a trainee's development of the competency of professionalism. As noted earlier under Patient Care, some of the metrics can be more easily acquired with digital slides than with glass slides and may offer objective data on which to base the assessment of competency in this area. Measures such as, whether all slides in a case were viewed, the average time, range of time, magnifications used, and so on, might provide data reflecting an attitude of respect for the patient as well as care and the thoroughness in the approach to work.

Other measurements reflecting trainee attitude toward colleagues and teachers can be obtained through WSI data collection. For example, the time and effort expended to prepare for digital slide unknown sessions, tumor boards, or other settings can be tracked. Also, residents who are prone to come unprepared and 'call it from the screen' can be appropriately counseled with objective data rather than subjective impressions from the faculty.

Handling of digital slides offers some new challenges with regard to patient privacy. Tracking of access, use, copying or other use of digital slides is much easier than with tangible glass slides. Monitoring of these activities for potential breeches of protocol would also be a measure of the development of professionalism [Table 4].

Communication Skills

Competency in communication skills is currently assessed in observing resident write-up or dictation of case materials, reporting of frozen sections, intraoperative consultations or adequacy assessments, formal presentations in conferences and meetings, and written materials published online or elsewhere. Observational assessments in these settings will likely continue to form the core of this competency assessment. However, the transition to a greater use of digital slide materials, and the incorporation of digital slides into the routine workflow of pathology again offers potentially new and important means of developing and assessing this competency.

The shift to a digital slide workflow, as noted earlier, allows a more frequent and realistic case sign-out experience to a resident trainee, which can be captured and compared to the final sign-out, providing a measurable assessment of the development of diagnostic and communication skills. Development of the nuanced ability to communicate is often measured in the inclusion of pertinent negatives, clarifying comments, and important microscopic findings. With a sign-out system linked to the process of digital slide management, these can be more readily tracked. An attending pathologist's editorial changes to resident sign-out wording could potentially be qualified under one of the several types of communication areas (e.g., diagnostic content, typographic / semantic, pertinent negative or other omissions, etc.) to direct remediation or corrective effort by the resident.

Digital slides, not unlike glass slides, are often made

Table 3: Summary of potential digital pathology impacts on medical knowledge competency

Medical knowledge competency	Potential impact of digital pathology
Readily diagnose a broad spectrum of pathological entities from gross and / or microscopic materials.	Digital slide box collections allow resident study and examination of a broad spectrum of cases beyond the limitation of location.
Appropriately evaluate and report staging and diagnostic variables for most tumor types and similar diseases.	Digital slide workflow enhances resident opportunities for simulated complete sign-out and tracking of progress.

Table 4: Summary of potential digital pathology impacts on professionalism competency

Professionalism competency	Potential impact of digital pathology
Consistently and thoroughly examine patient materials before rendering a diagnosis.	Digital tools allow tracking of trainee examination habits of microscopic slides.
Display appropriate patterns of preparation for patient and professional encounters (tumor boards, etc.).	Slide examination logs for digital slides can offer objective data on resident preparation for conferences.
Demonstrate respect for patients, colleagues, and the profession.	Treatment and handling of digital slide materials outside of diagnostic use monitored.

more useful when they have accompanying annotations. This utility has been well-documented with digital slides used in undergraduate medical education.[20] Trainee use of these tools prior to sign-out can be a part of the resident record of examination that can communicate to the attending pathologist or other colleagues, the important features of interest. Additionally, digital slides offer a ready means to extract fields or regions of interest for inclusion in reports or other clinical documents. The ability to appropriately select and present these regions of interest at the appropriate magnification (free of artifacts if possible, etc.) becomes another skill residents can master more easily, and faculty can assess more readily in the expanded use of digital slides [Table 5].

Practice-based Learning

Digital pathology, particularly as it breaks down some existing barriers, has the potential to dramatically impact the acquisition of this competency, both for trainees and for active practitioners. One obvious barrier that digital slides can overcome is facilitating the comparison of the current material with previous samples. Calling up a historical slide digitally for side-by-side comparison with a current sample will be less work than physical retrieval of glass slides. This quick reference will become second nature to the digital pathologist, making routine comparison of current cases with previous specimens much simpler and routine.

Similarly, digital tools currently under development that allow search of slides or databases by image mapping will open up new means of 'learning' from the case at hand by seeing connections to other diseases or past cases that might otherwise be missed. This extensive cross referencing will usher in an entirely new concept of image analysis and teaching resident pattern recognition.

Another potential improvement added by a digital pathology workflow is the inclusion of real-time quality control diagnostic material. Digital slides are easier to standardize and distribute than traditional glass slides, which have vexed previous attempts to use anatomic pathology materials in proficiency testing programs. Interobserver variations, a well-known challenge in particular diagnostic settings, and intra-observer variation are both challenges that traditional workflow has found difficult to control. However, adoption of a digital slide workflow allows a more organized insertion of such quality control and proficiency materials into the routine workflow, either as identified quality control material or as potentially truly blinded samples. Data derived from this sort of real-time quality monitoring can form a powerful basis for individual learning, process standardization, as well as patient safety assurance. This capability would also make possible the ongoing assessment of resident capabilities, reinforcement of recent didactic presentations, and creation of customized guides for further study [Table 6].

Systems-based Practice

We have alluded to using digital slide unknown sets as a means to evaluate resident judgment regarding consultation. With the expansion of digital slide sharing services and the relative ease to move or view digital slides remotely, the barriers to both informal and formal consultation from a peer or area expert are reduced. A digital slide workflow also allows the ready capture of both the utilization of consultation as well as the quality control value of such a consultation. It could therefore be anticipated that inter-institution differences in diagnosis might also be reduced if these reduced barriers to consultation extend to include cases from known problematic situations.[21]

Table 5: Summary of potential digital pathology impacts on communication competency

Communication skills competency	Potential impacts of digital pathology
Communicate findings clearly and succinctly to colleagues in reports and conferences.	WSI use in tumor boards or other teaching conferences.
Explain pathological findings directly to patients and / or clinical colleagues using visual, written, and verbal means of expression.	Expanded ease to transfer WSI to a mobile environment encourages use in patient and other consultative settings away from the microscope.
Consistently provide all needed information for further medical care.	Extracted images or links to pertinent WSI used in reporting critical findings.

WSI - Whole slide images

Table 6: Summary of potential digital pathology impacts on practice-based learning competency

Practice-based learning competency	Potential digital pathology impacts
Uses current and archived case material to guide study and expand knowledge.	Digital slides reduce the barrier to view archived patient samples concurrently.
Identify gaps in their abilities and knowledge from QA data trends.	Systematic use of real-time QC and PT samples becomes possible, to reinforce learning, detect variation in diagnostic criteria, and guide further studies.

QC - Quality control, PT - Proficiency testing

The standardization of terminology and diagnostic criteria made possible by the application of digital pathology workflow are important to reduce 'pseudoepidemics' and similar phenomena. A dermatologist once commented to his local pathology group that there had been a noticeable increase in the incidence of certain cancer types over a period of time that seemed to correspond to the hiring of a new pathologist by the group (E. Epstein, personal communication, 1987). For the pathology group, it was the first indication that one of their number was applying a different set of criteria or terminology to their case material, and that this was having an impact on the practice of medicine in their community.

This story is repeated with many different variations as diagnostic entities are reported in the literature, new stains discovered and added to routine use or other shifts in training or practice occur. Although usually not a critical issue, at times the shift, can have both significant patient care and economic health implications. The ability to appropriately monitor day-to-day diagnostic quality in anatomic pathology and meaningfully address such issues as new criteria, the reproducibility of the diagnosis (as reflected in areas with known low interobserver kappa values), the interpretation of new stains, and so on become some of the most powerful impacts of a digital slide workflow.

This ability also has important implications for resident training by helping define both diagnostic recognition skills and retention of learning. Such questions as, "how many examples of *entity A* must be seen before a resident can reliably make that diagnosis?" or "how long following a prior single exposure will knowledge of *diagnosis Y* persist?" can help us gauge the proper means to improve both training and long-term maintenance of competency in meaningful ways. Both of these become pertinent questions when we have the capability to design our systems in a way that can provide ongoing diagnostic quality challenges, in addition to the day-to-day challenges of live patient care, in anatomic pathology [Table 7].

ADOPTION OF WSI IN THE PATHOLOGY COMMUNITY

The adoption of WSI in the pathology community is unquestionably much slower than the spread of sliced bread in 1928. A recent informal survey of directors of surgical or anatomic pathology with residency programs revealed that only approximately 65% used WSI in any way. The majority of these uses are limited and center around conferences, tumor boards, and to a lesser extent include teaching conferences or digital slide study sets.[22] What are the reasons for this lag in adoption?

The most commonly identified barrier to greater use of digital slides is the cost. Digital pathology slides, unlike the transition to digital radiology, have no immediate and readily identifiable payback that resonates with the holders of the purse-strings. Implementation of a reasonable volume digital slide scanning system requires significant capital to acquire the scanner, software, servers, data storage systems, network upgrades, and workstations. In addition, the ongoing expenses of maintenance and personnel to perform the work of scanning slides add operating costs. Savings in distribution, improved productivity, filing and so forth have not fully balanced these costs. While low volume scanning scenarios might be considered at a lower cost, currently, there are few reasonably priced 'desktop' whole slide digital scanners in the market. Existing costs of slide processing are not reduced in transitioning to digital slides. Histopathology slides must still be prepared in the normal fashion prior to digital scanning and stored afterward. In high volume settings, additional dedicated personnel responsible for scanning slides into the database will be required. As vendors struggle to make the case for adoption by examining the savings to be gained in efficiencies[23] and the potential quality improvements in patient care,[24] others point to the lack of added clinical value as the principal barrier.[25]

Related to the cost barrier are the current technological limitations, which, although rapidly diminishing, still pose important challenges. The speed with which large files can be transmitted through the internet and the explosive consumption of storage and server space are still problems. While Moore's Law continues to hold true, technological advances in memory and data transmission have not yet caught up to the demands of histopathology. Digitized pathology images are approximately ten times the size of a radiology image and even a low-to-mid size volume of pathology cases can quickly swamp the current infrastructure of most hospitals. User interfaces that seem inherently slower than the speed of glass on a stage have also biased early users toward the retention of physical slides.[26]

Table 7: Summary of potential digital pathology impacts on systems-based practice competency

Systems-based practice competency	Potential digital pathology impacts
Consult colleagues appropriately.	Cost and time barriers to formal and informal consultation are reduced through widespread use of digital slides.
Recognize the impact of their work on health systems and society.	Digital slide workflow allows use of real-time QA data to adjust the diagnostic criteria and impact the health system utilization and costs positively.

Also, storage and retrieval of images becomes increasingly complex and will require sophisticated database management to ensure all patient samples are added to appropriate files, from where they can be accessed by a simple search. Managing workflow on a day-to-day basis will present a similar problem. Crucial to efficient workflow is the widespread adoption of the visual code recognition technology, a step which is far from complete in the histology laboratories.[27]

Technophobia on the part of some pathologists has been observed as a barrier to adoption, along with the fear of losing control of the slide itself. Cumbersome user interfaces dependent on a mouse and keyboard, rather than the facile and speedy scanning capabilities of a slide stage without a slide-holder have also been observed to bias existing pathologists and trainees toward continued use of a glass rather than a digital slide.[26]

Although the absence of regulatory approval, (aside from approval in a select number of image analysis settings) may be seen by some as a barrier as well, we believe that the routine use of digital slides will not wait for a regulatory body action, if the imperatives in other use cases are strong enough. It is our belief that education of trainees and the potential quality control improvements of an all digital workflow will be one of those scenarios.

ADOPTION OF WSI IN THE PATHOLOGY RESIDENCY EDUCATION COMMUNITY

The above-mentioned potential improvements in our ability to guide residents in the acquisition of important competencies are a strong incentive to move toward greater use of digital pathology in residency training. The realization of many of these benefits, however, will depend on the work yet to be done by many. Anticipating what can and will be the world of our trainees today, we call for a concerted effort to the following ends:

Development of and open sharing of training-oriented digital slide databases.

Development of similar digital slide-based, validated, quality-control anatomic pathology materials and protocols for the use thereof, to enable real-time quality control of diagnostic processes.

Enhancement of digital slide educational software capability to facilitate annotation, linkage with video and audio tours, as well as simplified testing / assessment tools.

Expansion of the use of digital pathology workflow in routine case work to both model use and to identify enhanced means of use of this workflow, to better pathology education

We have asserted that the creation of digital slide sets of sufficient volume and variety for the breadth of residency education is beyond the ability of a single department, within a reasonable time frame, although efforts to date have been admirable and positive. However the challenge of creating this resource in a manner that can provide the same utility to residency education that the 'Virtual SlideBox' is for teaching basic histology and pathology to undergraduate medical education[28] is of an entirely different magnitude. Key characteristics of such a database would be (a) searchability by diagnosis and microscopic features; (b) linkage or capability to be linked to peer-reviewed commentary, written or audio; (c) sufficient numbers of examples of common and uncommon entities to illustrate the breadth of disease manifestations and variations and to allow use as assessments; and (d) open access. In this manner, each slide might function to an extent as its own wiki in creating and maintaining educational value.

Such a vetted database of digital slide material could also form an element of open source QA digital diagnostic material that could be incorporated into the digital workflow models described earlier. Organizations with existing validated materials that could contribute to such a library, as well as digital technology companies, have it in their interests to collaborate in the creation of such a database rather than trying to accomplish this in relative isolation. This quality improvement alone, we believe has the capability to alter the paradigm of diagnostic pathology sufficiently to catalyze the adoption of digital pathology more widely, and that would be to their ultimate interests on many fronts; and clearly it has tremendous educational impact as well.

It is our experience that digital pathology capabilities currently represent only a small factor in recruiting medical students into the field of pathology. However as more medical students begin to enjoy the study of pathology in medical school, as a consequence of their time with digital slides,[29] these tools may further influence specialty choice. It seems likely, at some point, that residency programs may be seen by residency applicants as either 'haves' or 'have nots' in terms of digital pathology capacity. Candidates with foresight to the digital pathology transformation may become preferential in their rankings on this parameter, along with the traditional factors.

Finally, in order to maintain leadership in the search for new knowledge, training programs will need digital pathology capability. New morphometric and quantitative algorithms are being developed to help in diagnosis (such as computer-assisted identification of small metastases in lymph nodes) and resident trainees will need experience in these methods. Without in-depth experience with processes like digital slide morphometry technology, we cannot improve patient care with these programs. Digital

pathology coupled with emphasis on competency is a shift of tremendous magnitude that can dramatically improve our abilities to help trainees acquire, demonstrate, and maintain the skills to practice pathology in the generation ahead.

REFERENCES

1. Dee FR. Virtual microscopy in pathology education. Hum Pathol 2009;40:1112-21.
2. Farah CS, Maybury T. Implementing digital technology to enhance student learning of pathology. Eur J Dent Educ 2009;13:172-8.
3. Yazmin AC. Integration of virtual microscopy for the learning and teaching in veterinary parasitology. Available from: http://www.aperio.com/pathology-events/webinar_events.asp [Last accessed on 2010 Dec 27].
4. Hassell LA, Frishberg D. The exciting and expanding role of digital pathology in pathology education. Available from: http://education.cap.org/SumTotal/lang-en/management/LMS_ActDetails.asp?UserMode=0&ActivityId=191871&CallerURL=/SumTotal/lang-en/taxonomy/TAX_NodeDetails.asp?UserMode=0&RootNodeID=135&NodeID=175&SelectedNodeID=0&VSC=ItemName&VSO=A&SourceRef=-1&DispMode=normal. [Last accessed on 2010 Dec 27].
5. Johnson, Betsey B. American Board of Pathology, personal communication. 24 Feb 2010. in possession of author (LH).
6. ACGME. Available from: http://www.acgme.org/outcome/comp/compfull.asp [Last accessed on 2010 Dec 27].
7. Digital pathology, Wikipedia. Available from: http://en.wikipedia.org/wiki/Digital_pathology [Last accessed on 2011 Feb 7].
8. Evans AJ, Chetty R, Clarke BA, Croul S, Ghazarian DM, Kiehl TR, *et al.* Primary frozen section diagnosis by robotic microscopy and virtual slide telepathology: The University Health Network experience. Semin Diagn Pathol 2009;26:165-76.
9. See for example, Genzyme Genetics, iScope virtual Microscopy, available from: http://www.genzymegenetics.com/Our-Services/Oncology-Testing/iscope-virtual-microscopy.aspx [Last accessed on 2011 Feb 1.
10. Chaser B, Fung KM, Hassell LA. Use of Whole Slide Digital Images in Residency Education: Utility in Documenting Microscopic Feature Finding Skills. Modern Pathol 2010;23(Suppl 1):123A.
11. CAP TPO, "The Case for Change" Available from: http://www.cap.org/apps/docs/membership/transformation/new/transform_index.html [Last accessed on 2011 Feb 1].
12. Titus K. Face value—pathologists one on one with patients. CAP Today, Nov 2010 Available from: http://www.cap.org/apps/cap.portal?_nfpb=true&cntvwrPtlt_actionOverride=%2Fportlets%2FcontentViewer%2Fshow&_windowLabel=cntvwrPtlt&cntvwrPtlt%7BactionForm.contentReference%7D=cap_today%2F110%2F1110e_face_value.html&_state=maximized&_pageLabel=cntvwr [Last accessed on 2011 Feb 1].
13. Li L, Dangott BJ, Parwani AV. Development and use of a genitourinary pathology digital teaching set for trainee education. J Pathol Inform 2010;1:2.
14. Lundin M, Lundin J, Helin H, Isola J. A digital atlas of breast histopathology: an application of web based virtual microscopy. J Clin Pathol 2004;57:1288-91.
15. Fung KM, Hassell LA, Holliman JH . (http://moon.ouhsc.edu/kfung/jty1/OUMC/Default.htm, Fung KM, http://moon.ouhsc.edu/kfung/jty1/NeuroAnat/AA-Neuroanat-WSIOU-M.htm, 2011, Fung KM http://moon.ouhsc.edu/kfung/jty1/Com/Index.htm) [Last accessed on 2011 Feb 8].
16. USCAP. Available from: http://www.uscap.org/index.htm?vsbindex.htm [Last accessed on 2011 Jan 27].
17. CAP Foundation Case of the Month. Available from: http://www.cap.org/apps/cap.portal?_nfpb=true&cntvwrPtlt_actionOverride=%2Fportlets%2FcontentViewer%2Fshow&_windowLabel=cntvwrPtlt&cntvwrPtlt%7BactionForm.contentReference%7D=cap_foundation%2FcaseOfMonth%2Fjanuary11%2Fjanuary_2011_cotm_late.html&_state=maximized&_pageLabel=cntvwr. [Last accessed on 2011 Feb 22].
18. Talbert ML, Ashwood ER, Brownlee NA, Clark JR, Horowitz RE, Lepoff RB, *et al.* Resident Preparation for Practice: A White Paper From the College of American Pathologists and Association of Pathology Chairs. Arch Pathol Lab Med 2009;133:1139-47.
19. Bruch LA, De Young BR, Kreiter CD, Haugen TH, Leaven TC, Dee FR. Competency assessment of residents in surgical pathology using virtual microscopy. Hum Pathol 2009;40:1122-8.
20. Dee F. Virtual microscopy in pathology education. Hum Pathol 2009;40:1112-21.
21. Khalifa MA, Dodge J, Covens A, Osborne R, Ackerman I. Slide review in gynecologic oncology ensures completeness of reporting and diagnostic accuracy. Gynecol Oncol 2003;90:425-30.
22. Hassell LA. Whole Slide Digital Images in Residency Education: Sliced Bread or Iced Dread? Available from: http://www.pathologyvisions.com/2010/Presentations_ByName.asp [Last accessed on 2011 Feb 2].
23. Stratman C. Digital pathology in the clinical histology lab: A time and motion study. Available from: http://www.pathologyvisions.com/2010/Presentations_ByName.asp [Last accessed on 2011 Feb 2].
24. Eichorn O. Digital pathology for improved patient care. Available from: http://www.pathologyvisions.com/2010/Presentations_ByName.asp [Last accessed on 2011 Feb 2].
25. Lennerz J. Lack of added clinical value outranks IT challenges as the limiting factor in the implementation of virtual microscopy in to pathology practice. Available from: http://www.pathologyvisions.com/2010/Presentations_ByName.asp [Last accessed on 2011 Feb 2].
26. Sharma G, Dangott BJ, Piccoli A, Wiehagen LT, Kelly SM, Stewart WR, *et al.* Reduction in slide label mis-identifications due to implementation of 2 dimensional bar coding in the anatomic pathology laboratory at a tertiary care hospital. APIII 2010. Available from: http://www.pathinformatics.pitt.edu/node/598 [Last accessed on 2011 Feb 22].
27. Chaser B, Fung KM, Hassell LA. Implementing Whole Slide Digital Images into Resident Unknown Conferences. Arch Path Lab Med 2009;133:1714.
28. Dee FR, Heidger P. Virtual slides for teaching histology and pathology. Virtual Microscopy and Virtual Slides in Teaching, Diagnosis, and Research. In: Jiang Gu, Robert W, Ogilvie, editors. United state: CRC Press; 2010. p. 141-50.
29. Kumar RK, Velan GM, Korell SO, Kandara M, Dee FR, Wakefield D. Virtual microscopy for learning and assessment in Pathology. J Pathol 2004;204:613-8.