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Poster Session

Presented in the
Exhibitor Ballroom
Wyndham Grand Pittsburgh Hotel

Wednesday, May 24, 2017

10:20-11:20 am
And
3:30-4:30 pm

Listed in alphabetical order by
First Author

Pathologists in Clinical Informatics: The Data Never Lies

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Content
Pathologists are earliest practitioners of Clinical Informatics (CI) with publications from the 1940s, and the American Board of Pathology, having first sought sub-specialty certification in Pathology Informatics 25 years ago, co-sponsored the final implementation of CI board certification in 2013. This study was performed to determine if pathologists comprise a larger proportion of CI-related groups than of the general physician population.

Technology
Data was collected from peer-reviewed published articles from the Federation of State Medical Boards, the College of American Pathologists' workforce analyses, from the American Medical Informatics Association and from Clinical Informatics Fellowship program data.

Design
Multiple studies of pathologists and all physicians were analyzed to compare the proportion of pathologists among all physicians and in various CI-related professional societies and awards. The expected percentage of Pathologists in any given category was set to the proportion of pathologists in the general physician population. The Chi-Squared test was used to determine the p-value between observed and expected values.

Results

Table 1. Statistics of pathologists compared to physicians in all specialties.

	All Physicians (including Pathologists)	Pathologists	% Pathologists
Actively Licensed Physicians in USA (2014)	916,264	17,981	2.0%
Total CI Diplomates (2013-2015)	1106	65	5.9%
CI Program Directors*	24	3	12.5%
ACMI Fellows*	243	6	2.5%
Morris F. Collen Awards*	15	2	13.3%
CI Current Fellows*	56	5	8.9%

* as of March 2017

Pathologists are significantly more likely to be a CI diplomate compared to non-pathologists (odds ratio 3.12; $p < 0.0001$). The odds ratios for a pathologist becoming a CI Fellowship Program Director or a recipient of the Morris F. Collen Award, the highest award given by the American Medical Informatics Association, were 7.14 and 7.68, respectively. The proportion of CI fellows who were pathologists was also higher than expected.

Conclusions
The consistent strong presence of Pathologists in CI is concordant with the increasingly data intensive nature of the Pathology specialty. However, there are fewer women pathologists in CI than would be expected, so pathologists have an opportunity to further strengthen our presence and improve patient care by addressing these gaps.

An Opportunity for Pathology to Trailblaze: Bridging the Gender Gap in Clinical Informatics

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Content
Clinical informatics (CI) has been long practiced in pathology but has only recently become a board-certified subspecialty. The percentage of women with CI board certification across all medical specialties and for pathology appears lower than the average proportion of women in medicine. Pathology is in a unique position to bridge the CI gender gap.

Technology
Reported percentages of female physicians overall were compared with percentages of women in pathology and CI.

Design
Multiple gender prevalence studies in medicine, CI and pathology were analyzed to determine if gender gaps exist. Various online resources were also assessed for participation of women in CI-related professional societies.

Results
Table 1. Gender statistics in CI.

	All Physicians (Pathologists and non-Pathologists)		Pathologists Only	
	Total	**Female**	**Total**	**Female**
Actively Licensed Physicians in USA (2014)	916,264	293,565 (32%)	17,981	6183 (34%)
Total CI Diplomates (2013-2015)	1106	209 (19%)	65	7 (11%)
ACMI Fellows*	243	15 (6%)	6	1 (17%)
Morris F. Collen Awards (AMIA)*	15	0 (0%)	2	0 (0%)
CI Current Fellows*	56	6 (11%)	5	1 (20%)
CI Fellowship Program Directors*	24	0 (0%)	3	0 (0%)
API Lifetime Achievement Awards*	N/A	N/A	15	0 (0%)
API Presidents*	N/A	N/A	15	2 (13%)

* as of March 2017

Pathology has the fifth highest percentage of female residents (54%) and eighth highest female full-time faculty. Statistics of all CI fellows is concerning, despite Pathology's strong showing. The reasons for the gender gap between CI pathology diplomates and all Pathologists and all CI diplomates are unknown. The proportion of female pathologists who are CI diplomates is lower than that of female Academic Medicine Department Chairs (15%), Pathology Chairs (15%) and Medical School Deans (15%).

Conclusions
While one-third of pathologists and over half of pathology residents are women, the percentage of female pathologists and physicians in general who are board-certified in CI is alarmingly low. The causes of these gaps are unknown. The ever-increasing demand for qualified pathology informaticists and the growing proportion of female pathologists present unique opportunities for Pathology to lead by example in piloting programs to close these gaps. Future work includes assessing gaps in ethnic and racial minorities.

Procedural Optimization and Signal Normalization of Kinomic Peptide Microarrays

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Content

Kinases play a role in every cellular process involved in tumorigenesis ranging from proliferation, migration, and protein synthesis to DNA repair. While genetic sequencing has identified most kinases in the human genome, it does not describe the 'kinome' at the level of activity of the kinases against kinase targets. The PamGene PamChip system records and compares the phosphorylation of 144 tyrosine or serine/threonine peptides as they respond to cellular kinases utilizing a peptide microarray. This microarray platform records phosphorylation at multiple time points resulting in both end level and kinetic measurements. Similar to other microarray technologies this technology needs a thorough investigation of background and signal determination.

Technology

Web Server: Node v5.6.0; Programming Language: JavaScript; Database: Mongo v3.2.6.

Design

We utilized four Glioblastoma cell lines with various changes to the MARKS kinase ran in triplicate as technical replicates. Based on these results we created a level based Mongo Database that is accessed utilizing a standard web environment (JavaScript, HTML5, CSS) to perform analyses and visualize results of various reproducibility measures.

Results

Current analytical techniques shift all signal – background values recorded above the 5th quantile, and log transformation all possible values. This normalization technique is applied across all samples in a given experiment and complicates any future analytical processes. Additionally this results in 5% of the data being lost. We proposed a new technique of log transforming signal / background this makes all values comparable and results in no data loss. Additionally, we observed local background and signal were highly correlated ($\rho = 0.96$), we corrected this utilizing linear regression to eliminate the effect of the signal on its own background without removing the effect it may have neighboring signal backgrounds ($\rho = 0.23$). These techniques in combination resulted in a moderate increase in signal reproducibility of $\rho = 0.9918$ to 0.9925.

Conclusions

The changes proposed here allow global comparison of results, correct the issue of missing data, correct an error that dampens the signal from high signal spots and leads to a increase in reproducibility. These analyses utilize web techniques that allow any dataset to be corrected without any downloads or data sharing.

Sharing CellaVision Blood Smear Images with Clinicians Via the Electronic Medical Record

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Content
The CellaVision automated system digitizes peripheral blood smears and performs blood cell differentials. These images are available for local review in hematology laboratories on computer monitors or they can be transmitted for remote review via telehematology. Clinicians such as hematologists who typically review their patient's peripheral blood smears often need to contact an offsite hematology hospital laboratory for this purpose, frequently during evening or weekend hours. To overcome this barrier, our institution sought to make CellaVision blood smear images available to clinicians and trainees in the electronic medical record (EMR). The images could therefore be viewed at any time and from any computer or mobile device which could access the EMR.

Technology
CellaVision DM96 (CellaVision AB, Lund, Sweden) digital hematology analyzers. Images hosted on a Microsoft SQL Server. Microsoft Internet Information Services 7 web server and ColdFusion 9 middleware. Sunquest laboratory information system. Cerner PowerChart EMR.

Design
Image sharing was accomplished in 2 phases. For phase 1, a secure web portal (called "HemaVue") was created to allow clinicians to access CellaVision digital images with associated metadata (i.e. patient unique identifiers, blood counts). CellaVision image data was archived daily and stored for 6 months. For phase 2, CellaVision instrument results were tagged with the test code "Image Differential Performed". This code appeared in the patient result to inform the clinician this type of differential had been performed, as opposed to a manual or automated differential code. The HL7 message router transmitting results with this tag created a link in the EMR to the HemaVue website. This allowed clinicians to access CellaVision images from a patient's chart within the EMR.

Results
The CellaVision image database contained 3.38 million images for 23,000 patients, comprising 12TB of data on per 6-month temporal storage. Database and website maintenance had to be internally supported. While clinicians were pleased with having access to blood smear images, they expressed dissatisfaction that images were not always available immediately, not retained indefinitely, not offered on all patients, and that the images were of isolated white blood cells only.

Conclusion
CellaVision images were able to be successfully unlocked from the vendor's server and subsequently made accessible for remote viewing by linking patients' laboratory results in the EMR to a custom built website. While such enterprise image sharing of digital blood images offered some improvement for clinicians seeking to review peripheral blood smears, enhancements will be required to make this more readily available for all patients at our institution.

PathXL in an Academic Hospital Setting: Lessons of Implementation

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Content
Our department has used whole slide images (WSI) for many educational uses such as digital teaching sets and unknown conferences. However, most of these offerings required homegrown solutions, were not standardized across our department, and thus made it difficult to manage and search content. Therefore, we acquired PathXL to address pathology education and training needs. We required a web-based platform that allowed multiple users to easily incorporate new and archived WSI with media content (e.g. gross photos, documents, videos), publish virtual teaching sets online, and create tests. Our aim was to deploy PathXL on internal servers instead of hosting it on the vendor's cloud environment.

Technology
PathXL Tutor web-based educational management system. Microsoft Azure and Microsoft OneDrive for Business cloud solution.

Design
PathXL tutor was deployed in a private Azure cloud behind a demilitarized zone (DMZ) using an application server, database server, and network storage. Development, test, and production virtual environments were created. The production instance is built on-premise to avoid latency issues while transferring large image files to the cloud server (**Figure 1**). Implementation addressed computing architecture, user authentication, data transfer, as well as roles and permissions. Allocation of 7TB for image storage was made available.

Results
The default Client-Server model of PathXL was reconfigured to employ the Business-To-Consumer (B2C) Azure Active Directory to provide increased security, as well as allow internal and external user registration, authentication, and authorization. Internal institutional accounts were authenticated at the application level in PathXL, whereas external accounts required external authentication via Azure. OneDrive was used for data storage and uploading files to be accessed via PathXL. Large WSI file transfers were mediated by Quality of Service (QoS) to maximize network performance and decrease latency of data uploading. Institution wide accounts were granted access to private and public content while external users were only granted access to public content.

Conclusions
PathXL was successfully deployed in our institution's on-premise and Azure cloud platform that allowed us to easily store, sync, and share digital files. Implementation in Azure was challenging, required significant local information services and vendor input, and delayed going live for this project. The benefits of hosting PathXL on our own data center include running multiple virtual environments such as test and production systems, secure mediation of external user authentication, and secure file upload and storage.
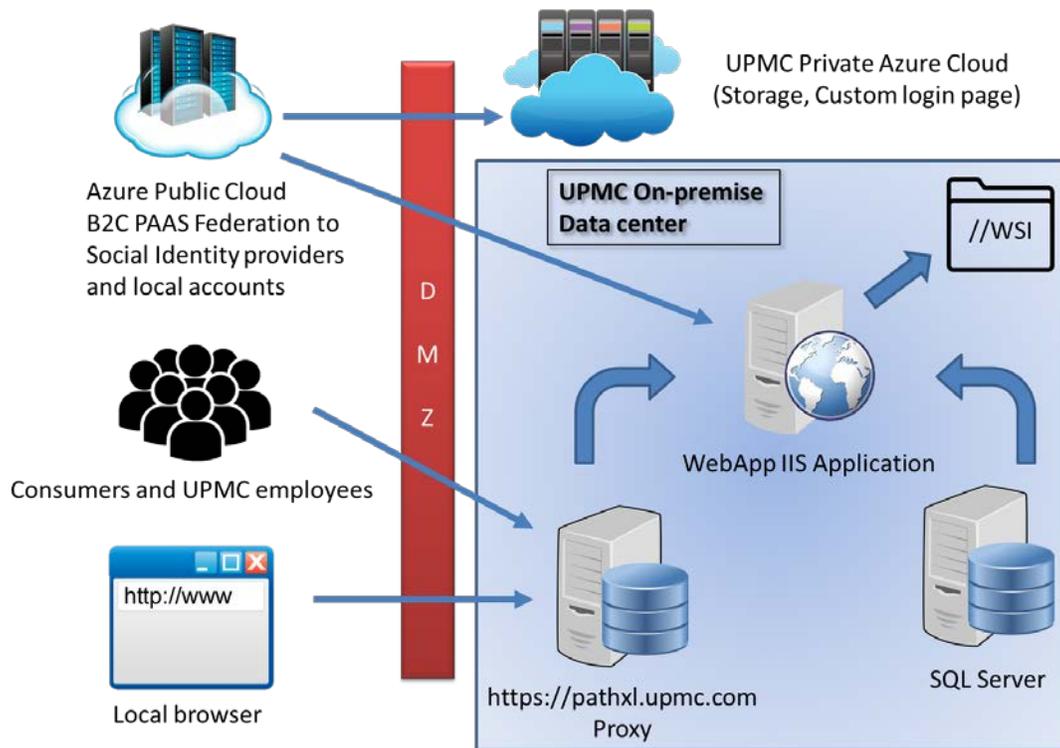

Figure 1 next page

Figure 1. Schematic architecture of the PathXL production environment at UPMC

Federated Laboratory Information Systems Trending Away from the Tower of Babel

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Content
The laboratory information system (LIS) depends on data tables and dictionaries for relational database management. Large, integrated hospital systems may have various dictionary elements to describe identical entities for each individual LIS. Standardization of these data tables may be difficult to ascertain due to the complexity of testing at different laboratories and varying clinical workflows that demand different lab test naming conventions. Our institution aimed to review and standardize all anatomic pathology part types for 14 internal hospital sites.

Technology
The anatomic pathology LIS utilized at 14 hospitals within our healthcare system is Cerner CoPath Plus. The American Medical Association Current Procedural Terminology (CPT®) was used to determine specimen part types.

Design
The specimen part type dictionary was reviewed in conjunction with the CPT manual by specimen part type level (from I to III of VI). All part type entries were iteratively identified. Entries were either merged into a standardized part type, inactivated, or newer part types added for all laboratory sites.

Results
A total of 388 original part type dictionary entries were identified and assessed. Levels I, II, and III part type dictionaries were consolidated by 94%, 67%, and 69%, respectively (Table 1). The most significant reduction occurred with bone fragments, which were reduced from 18 to 2 entries. Related billing errors were also resolved, resulting in a 10% overall correction.

Conclusions
Ongoing maintenance to standardize dictionaries within the LIS database for an integrated delivery network is a worthwhile endeavor that may significantly reduce redundant dictionary entries and related billing errors. Education of stakeholders at each hospital is required to employ consistent data elements and maintain consolidated LIS dictionaries.

Table 1. Part type dictionary consolidation results

Part type level	I	II	III
Total original	79	53	256
Total current	5	12	80
Corrected billing	1	11	25

Analysis of Influence of Additional Diagnostic Clues During Pathology Diagnosis

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Content
Traditional pathology diagnostic process routinely relies on disease-specific diagnostic clues. While in majority of clinical cases these clues result in accurate diagnosis, in other cases they can lead to diagnostic pitfalls. Our ongoing research is focused on revealing diagnosis-related details and heuristics that can be used to quantify and potentially improve the diagnostic process in pathology using whole-slide imaging (WSI) and analytical tools. Specifically, in this work we propose an informatics pipeline to identify and quantify additional diagnostic clues that, in addition to traditional disease-specific clues, can improve diagnostic outcomes and decrease the chance of diagnostic pitfalls.

Technology
We used our PathEdEx WSI platform with realistic diagnostic workflow, WSI viewing capability, and gaze tracking to record user activities related to diagnosing a cancerous tissue slide.

Design
As a step towards better understanding of mental actions that are required to produce a diagnosis, we looked into patterns produced by diagnostic clues during tissue examination. At this initial stage, we only considered biological features that were noted in the tissue by the examining pathologist as types of cells relevant to the diagnosis. To identify and quantify additional diagnostic clues that can improve diagnosis, we extended association rule mining techniques to measure information gain of the additional diagnostic clues. We induced association rules based on the collections of cell types covered by a user's gaze track and the resulting diagnostic decision made by pathologist in a simulated session.

Results
When interesting rules for a particular diagnosis were considered, we observed that an additional tissue feature (diagnostic clue) increases the likelihood of a correct diagnosis. Rules using only two diagnostic clues showed better *support* (were used more frequently), as would be expected. However, adding another diagnostic clue to the same rule would increase *confidence* that that rule would result in a correct diagnosis up to 79% with a similar improvement in *lift*. To validate our findings, we computed *Kullback-Leibler divergence* that indicates information gain generated by additional diagnostic clues.

Conclusions
We believe that with such an increase the chances of an occurrence of a diagnostic pitfall are correspondingly reduced. Further research is needed to ensure our findings are consistent across a wider range of tissues and diagnoses. This may lead to a closer look at current recommended diagnostic procedures and more specific recommendations for pathologists on diagnostic pitfall avoidance.

Adaptive Pathology Laboratory Teaching System

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Content
In order to use the allotted time more efficiently, we adapted lab time by devoting less time to concepts that students easily grasped and more time to difficult concepts by using a web basedclicker system to assess student comprehension.

Technology
A web services solution stack consisting of Apache web server, MySQL database and PHP (hereinafter, web stack) was used to develop a clicker system to evaluate student comprehension. Initially Uniform Server (www.uniformserver.com) and later Bitnami web stacks (https://bitnami.com/stacks) were employed. The Uniform Server, a Microsoft Windows operating system web stack, is portable and can run from a thumb drive or any USB storage device. It requires no installation. Thus the system can simply be used on any computer with windows operating system and a static IP address. The Bitnami web stack can run in Windows, Mac OS X or Linux environments as well as VMware or VirtualBox virtualized environments, and popular cloud platforms such as Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform.

Design
A web based clicker system in conjunction with Aperio virtual microscopes (http://www.leicabiosystems.com/digital-pathology/aperio-digital-pathology-slide-scanners) was developed to actively engage second year medical students in pathology laboratories and to evaluate their comprehension. No more time was devoted to concepts that students easily grasped and more time was devoted to difficult concepts until most students had a good understanding of the concept. Thus the flow of the pathology laboratory adapted to how well students understood the objectives of the laboratory session.

Results
We were unable to determine the effect adaptive teaching had on student performance. However, student attitudes of the use of the web based adaptive approach system in laboratory were very favorable. From a faculty point of view, this approach highlighted areas that needed more emphasis and use the time more efficiently.

Conclusion
By adapting to student comprehension of the learning objectives, the allotted time was used more efficiently and more effectively.

Evaluation of a Natural Language Processing Platform for Rapid Development of Medical Information Retrieval Resources

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Content
Critical information in cancer case surgical pathology, cytopathology and molecular testing reports are primarily contained in narrative "free text" sections that limit the ability to implement similarity based case retrieval systems used in modern pathology informatics. This work describes a flexible Natural Language Processing (NLP) framework based on open-source tools for the reliable identification and extraction of biomedically relevant information in cancer case reports.

Technology
We evaluated a web services-oriented NLP platform, the Inspirata NLP Server (INS), developed at Inspirata, Inc., in Tampa, Florida. The architecture is open-source and pipeline-based with annotators, operating on a wide variety of document source formats, for linguistic manipulation, named-entity recognition, negation detection and classification.

Design
We created six RESTful resources for processing surgical synoptic, cytopathology and molecular testing reports in PDF, RTF and Excel formatted documents. We evaluated two of these resources against 3144 de-identified cases: a cancer/non-cancer classifier resource and a resource for retrieving 12 concepts in breast and lung specific surgical synoptic reports, "Case Number", "Primary Site", "Procedure", "Diagnosis", "UMLS Code", "Location, "Laterality", "IHC Test", "IHC Result", "IHC%", "IHC Intensity", "IHC Score". The classifier resource performance was compared to human performance for 1092 cases, consisting of 429 surgical pathology, 619 cytopathology and 44 molecular testing reports. The synoptic report resource performance was compared to human performance for 250 breast and lung cases. Individual points were awarded for each correctly identified concept and negation of concept.

Results
The INS cancer classifier resource matched human performance in all 1092 cases, showing 100% accuracy. The synoptic report resource was able to retrieve data in 223 cases, thus showing 89% accuracy in retrieval. Of these, 95% returned the correct diagnosis and IHC data accuracy was 97% overall.

Conclusions
INS is able to facilitate rapid development of biomedical information retrieval resources with high accuracy. We find that this system is able to correctly match a high percentage of pathology concepts, using INS architecture to integrate new annotators and tune performance of the negation annotator. We plan to add more general pathology annotators to address the issues that caused matching failures in the current analysis.

A Sandboxed Web Development Environment for Trainee-Driven Software Design and Prototyping

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Content
Pathology informatics draws from a broad set of information technology disciplines. This includes web-based, cloud-computing solutions which are being increasingly utilized for medical informatics purposes. Today, web technology is ubiquitous and it provides a relatively accessible entry point into the world of computer programming and user interface design. An abundance of free online tools and tutorials are available, enabling anyone with a browser to begin web development with minimal overhead costs. Our aim was to establish a sandbox server that encouraged residents to develop pathology-related applications.

Technology
A networked server and database, equipped with a suite of resource management software, was attained. An integrated development environment was installed on a virtual machine to provide users with remote access to software development tools.

Design
Desirable characteristics we included in this trainee-driven software development platform were: 1) support for a variety of client-side, server-side and data management tools; 2) full containment behind the institutional firewall, with a mechanism to limit potential access to protected health information; and 3) isolation from other information services resources, to ensure any mistakes in server management by clinical trainees do not have the ability to adversely impact the larger organization.

Results
With the support of our Information Services Division, a "sandboxed" web development environment was created. Pathology residents so far have developed a variety of web-based tools, including an editable library of pathology reports demonstrating appropriate diagnostic verbiage and formatting, a wiki-style database for trainees to share institutional knowledge, tools for longitudinal tracking of educational objectives, whole-slide imaging applications, and interactive javascript-based widgets for visualizing molecular pathology data. Clinical trainees with a wide range of prior computer science/programming backgrounds have used the system to gain hands-on experience while implementing novel pathology informatics solutions.

Conclusion
The sandboxed web development environment is an effective, secure mechanism that provides trainees with the ability to design and implement novel clinical and educational applications, and to gain practical experience in the domain of pathology informatics. Our department has established a mechanism to adopt and maintain some of these vetted applications for clinical practice or educational use.

Implementation of A Whole Slide Imaging Repository and Platform Using Open Source Software for Undergraduate, Graduate, and Continuing Medical Education

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Content
Over the past 15 years, whole slide imaging (WSI) has proven itself an invaluable tool in pathology education. At our institution, a need arose for a WSI repository that could satisfy the needs of undergraduate, graduate, and continuing medical education. The goals of this repository were to provide 1) a secure, access-controlled online platform for viewing slides on multiple platforms (iOS, Android, Windows, MacOS, etc.), 2) an ontology for creating use-appropriate metadata for each slide, and 3) an easy-to-use import tool for adding slides to the repository. Finally, our aim was to organize and filter the slides for both directed teaching and open discovery.

Technology
Multiple software tools were used, including: VIPS (free image processing system, vips.ecs.soton.ac.uk); Openseadragon (web-based viewer for high-res zoomable images, openseadragon.github.io); Visual Studio, .NET Framework, and MS SQL Server (Microsoft), Grouper (enterprise access management system) and Shibboleth (enterprise federated identity system).

Design
An agile software development methodology was used to create our WSI repository composed of: 1) a database server for course groups, a slide ontology, and guest ticket information; 2) a slide importer allowing WSIs to be imported by different course managers; 3) a slide manager for editing WSI metadata; 4) a slide category manager for organizing course groupings and editing the slide ontology; and 5) a course manager for editing user roles and issuing guest tickets for outside access.

Results
Typical use for the WSI platform consisted of authorized users either 1) accessing slides from external course sites (direct links), 2) reviewing course content by filtering for course/section, or 3) reviewing content by body system, organ, condition, sub-condition, species, stain, magnification, or diagnosis. This system, although only very recently implemented, has thus far been received well and has increased both course manager and end-user satisfaction (verbal reports).

Conclusion
As compared to vendor-based solutions, we believe that the low development and operating costs, in addition to the flexibility of being able to customize our WSI repository to our undergraduate, graduate, and CME course needs, has vastly improved the WSI experience at our institution.

Peripheral Blood Smear and Bone Marrow Templates

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Content
The microscopic description component of peripheral blood smear (PBSM) and bone marrow (BM) reports is often written in lengthy paragraphs, which may not easily convey important information. Written paragraphs are also time-consuming to compose and, additionally, manifest in a wide variety of reporting styles that are to be read by practicing clinicians and physicians at various levels of training. These aforementioned issues can be reduced with easy-to-use PBSM and BM templates that generate list format reports.

Technology
HTML (hypertext markup language), CSS (cascading style sheets) and JavaScript were used to design PBSM and BM templates.

Design
The PBSM and BM templates are integrated into one HTML page on the end-user side. The input elements, located in the left half of the page, compose of four types: text, checkbox, radio button and submit button. The input contains the entire structure of typical PBSM and BM reports in our institution, as well as comments, most common ICD-10 codes, resident/pathologist signature, and current date. The output, located in the right half, displays the exact appearance of the final report in our laboratory information system so that additional format-related changes are not needed. Elements of the output can also be uniquely edited for convenience. A "Hematology" navigation button allows easy switching from PBSM and BM templates. Subsections of the BM template can be accessed via that navigation button as well to avoid scrolling. Input subsections can also be minimized so that the text output aligns with its input counterpart. Normal findings were designed to appear as default.

Results
The template with user-friendly appearance and easy-to-use features is shown in the **figure 1**.

Conclusions
Implementing PBSM and BM templates in hematopathology daily work will increase efficiency for pathologists and help clinicians find details more easily. This format also creates a uniform report from different pathologists. This reduces clinician reviewing time and allows pathology trainees to appreciate the most important elements of the final report. Additionally, this synoptic-like reporting will facilitate structured data extraction for future research.

figure 1. PBSM and BM templates in hematopathology

Economics of Cloud-based GPU

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Content
As whole slide imaging (WSI) enters clinical workflow, the opportunities for integrated image-based analytics will increase. To satisfy the need for increasing scale of high-performance hardware supporting complex algorithms, Graphical Processing Units (GPUs) will become essential. GPUs designed expressly for high performance computing can accelerate processing significantly, but such hardware is significantly more expensive than standard components and harder to support. To mitigate this incremental burden, we propose the utilization of GPU hardware residing in either the local datacenter or the cloud.

Technology
We utilize GPU hardware from Nvidia Corporation (Santa Clara, CA) to realize a scaleable and generalizable solution. Operating system virtualization, provided by Docker (San Francisco, CA), allowed for further simplification of the algorithm scale-out process, with this approach enabled by use of the Amazon Web Services platform (AWS; Seattle, WA).

Design
A high-performance image analysis algorithm was implemented as a typical web service. Slides were initially stored in AWS and subsequently made available to the algorithm. Requests for analysis from the web client, along with specific user parameters and the specific field of view under interrogation were forwarded to the computational pipeline. Results were returned in the form of a superimposed overlay channel of highlighted pixels, in near-real-time, providing decision support information.

Results
Execution of high-throughput analytical image-based computational pipelines and associated machine vision analytics on the web, as opposed to use of a local server, is an improved approach that reduces or even eliminates user response delay, while at the same time providing an elevated level of computational capability. When compared to a stationary work station that is heavily utilized, using cloud resources is unquestionably the more expensive option. However, for average computational load settings, cloud resources utilized by multiple users can be a more economical, and thus attractive solution.

Conclusions
While there is retained misconception that resources realized in the cloud are inherently less expensive, due to "economies of scale," we have found that this is not necessarily the case. Nevertheless, convenience and ability to scale to demand offer significant benefits that are worth the cost, in some settings.