Pathology Informatics Education during the COVID-19 Pandemic at Memorial Sloan Kettering Cancer Center (MSKCC)

David Kim[1], Matthew G. Hanna[2], Chad Vanderbilt[2], S. Joseph Sirintrapun[2]

[1]Department of Pathology and Laboratory Medicine, Weill Cornell Medicine, New York, NY, United States, [2]Department of Pathology and Warren Alpert Center for Computational and Digital Pathology, Memorial Sloan Kettering Cancer Center, New York, NY, United States

Correspondence: *dak9117@nyp.org*; Tel.: + 1 212 746 2832; Fax: + 1 212 746 8545

Abstract

This review details the development and structure of a four-week rotation in pathology informatics for a resident trainee at Memorial Sloan Kettering Cancer Center (MSKCC) in New York City so that other programs interested in such a rotation can refer to. The role of pathology informatics is exponentially increasing in research and clinical practice. With an ever-expanding role, training in pathology informatics is paramount as pathology training programs and training accreditation bodies recognize the need for pathology informatics in training future pathologists. However, due to its novelty, many training programs are unfamiliar with implementing pathology informatics training. The rotation incorporates educational resources for pathology informatics, guidance in the development, and general topics relevant to pathology informatics training. Informatics topics include anatomic pathology related aspects such as whole slide imaging, laboratory information systems, image analysis, and molecular pathology associated issues such as the bioinformatics pipeline and data processing. Additionally, we highlight how the rotation pivoted to meet the department's informatics needs while still providing an educational experience during the onset of the COVID-19 pandemic. **Conclusion.** As pathology informatics continues to grow and integrate itself into practice, informatics education must also grow to meet the future needs of pathology. As informatics programs develop across institutions, such as the one detailed in this paper, these programs will better equip future pathologists with informatics to approach disease and pathology.

Key Words: Informatics Education ▪ Residency ▪ Digital Pathology ▪ Whole Slide Imaging ▪ Molecular and Genomic Pathology Education.

Introduction

Informatics in medicine and pathology has a long history. Medical informatics began in the 1950s as the "science of information" with pathology informatics introduced as a field a few decades later in the 1990s. Many pathologist informaticians argue however, that technology and information management has been a part of pathology since its inception (1). Pathology at its core involves the identification, collection, and interpretation of data, information, and knowledge in order to diagnose, predict disease behavior, and guide treatment. The College of American Pathology (CAP)

identifies informatics as the application of information management in healthcare to promote safe, efficient, effective, personalized, and responsive care (2). The recent advent of electronic health records and the digitization of medical information pushed medical informatics into the forefront as a critical and necessary aspect for education and practice. Similarly, in recent years, pathology informatics is placed in the lead with exponential and broad integration of advancements in molecular pathology, genomics, digital imaging, and artificial intelligence. Therefore, education in pathology informatics is crucial now more than

ever for future clinical practice in pathology. The current gap, however, is the limited amount of online pathology informatics training resources and the few "hands-on" experiences in pathology informatics. Online pathology informatics training resources are evolving, and pathology residencies still need training frameworks to keep up with the rapid advancements and ever shifting landscape of informatics education. Only a handful of articles guideline pathology informatics education (3-6). Moreover, the few "hands-on" opportunities include a few U.S. academic centers and pathology informatics fellowships where the focus is more towards pathology informatics such as laboratory information systems (LIS) maintenance, whole slide imaging (WSI), and bioinformatics compared to the more general field of medical informatics (7).

In our review, we detail the pathology informatics rotation in New York City at Memorial Sloan Kettering Cancer Center (MSKCC), as a "hands-on" experience that supplements existing pathology informatics training resources. We detail the rotation's construction, development, and implementation at the trainee (e.g. resident/fellow) level, and also how the implementation of the rotation adapted because of the COVID-19 pandemic in early 2020 to support remote pathologists and clinical services. We provide our review as an example of a successful framework for a pathology informatics rotation so that other institutions, formulating informatics curricula for their trainees, can leverage. Highlighted in this review are the online pathology informatics training resources available to use by any institution for their trainees. Such broad integration of pathology informatics training assures the dissemination of necessary knowledge and empowerment of informatics to the future pathologist community.

Construction and Development of the Pathology Informatics Rotation

The setting for the pathology informatics rotation was in the pathology department of MSKCC which has the experience of attendings who have completed pathology informatics training or have en-

gaged in pathology informatics activities. Through input from these attendings, construction of the rotation began with the objective of maximizing the exposure of the resident to pathology informatics related aspects in a four-week period. MSKCC, as an institution, also has many well-developed pathology informatics resources such as WSI and molecular bioinformatics, combined with clinical and research initiatives to abundantly supplement a well-rounded experience in pathology informatics for the trainee.

An outline of general goals and objectives, though not necessary, is highly recommended in developing an educational curriculum for the trainee. An outline allows the trainee and faculty to gauge the experience and address specific benchmarks throughout the rotation. Our outline of the rotation goals and objectives of the four-week rotation is shown in Table 1. The authors recognize that not every training environment has access to such resources. Two accessible, free and comprehensive online pathology informatics training resources formed the starting point for the rotation and is recommended for training programs with and without resources. The two resources (Table 2) are the Pathology Informatics Essentials for Residents (PIER) curriculum (3) and Training Residents in Genomics (TRIG) (4). Both online curricula provide interactive modules and recorded lectures but also serve as helpful guides for content and structure to approach and teach the material during the rotation.

PIER is an online informatics curriculum, developed by informatics experts, and focused towards residents in helping meet the Accreditation Council for Graduate Medication Education (ACGME) milestones in resident education/training in pathology informatics. Developed in cooperation by the College of American Pathologists (CAP), Association of Pathology Chairs (APC), and Association for Pathology Informatics (API), PIER details essential topics in informatics that are essential for future pathologists. Topics and objectives addressed by PIER include fundamental principles of databases, data and communication standards, digital imaging, laboratory information systems, and the health care information ecosystem to more advanced

Table 1. The Listed Goals and Objectives to Be Met by the Resident Throughout the Rotation[*]

General Goals and Objectives
Informatics Knowledge:
Handling and management of medical data storage
Familiarity with basic information system terminology
Familiarity with different data structures and database architecture
Data analysis fundamentals
Digital imaging fundamentals
Whole slide imaging fundamentals
Information Systems:
User interface design
Familiarity of pathology workflows and processes
Structure of laboratory information systems and electronic medical/health record (EMR/EHR) systems
Familiarity of how data is stored, transferred, and accessed for information systems
Interpretation and analysis of molecular/genomic data of bioinformatics pipelines
Management:
Management of laboratory information systems and electronic medical/health record (EMR/EHR) systems
Management of operations and flow in pathology practice
Laboratory finance principles
Professionalism:
Proficiency in communicating with and presenting to clinicians and pathologists about informatics related matters
Education:
Prepare a 30-minute informatics based presentation to be presented at the Weill Cornell Clinical Pathology Resident Lecture

[*]Having such an outline allows the resident and faculty involved in the rotation to have a clear goal as to the goals of the rotation. Therefore, by the end of the rotation the trainee is able to concretely identify what they have gained through the experience.

Table 2. Easily accessible pathology informatics online curricula with their respective URL links

Henricks et al. (3)	https://apc.memberclicks.net/index.php?option=com_content&view=article&id=152:pier&catid=20:site-content&Itemid=156Many
Haspel RL. (4)	https://www.pathologylearning.org/trig

concepts like project management, clinical decision support, image analysis, and artificial intelligence. In addition, participatory interactions with pathology informatics attendings at MSKCC helped solidify the didactic content of PIER through actual "hands-on" practice in the rotation.

Similarly, TRIG is an online curriculum, developed by an expert group in medical education, molecular pathology, and clinical genetics, that promotes genomic pathology education in molecular testing approaches and scenarios. TRIG is a unique collaborative effort with major pathology organizations and representatives from the National Society of Genetic Counselors and the American College of Medical Genetics and Genomics. Through continual grant support from the National Cancer Institute, the TRIG working group holds workshops and courses at annual meetings of major pathology and oncology organizations. This four-week rotation was constructed and developed for anatomic pathology related informatics objectives. Clinical pathology related aspects were not highlighted in the curriculum except for molecular and genomic pathology. Laboratory medicine related informatics activities in clinical chemistry, microbiology, and blood banking were

not highlighted in the curriculum, because of the limited four-week time constraint, which was insufficient to encompass those activities adequately. More time would have unlocked even more potential for learning opportunities in these laboratory medicine related areas in informatics as millions of data points are generated and interpreted for patient care. The focus on anatomic pathology informatics as well as molecular genomic pathology likewise fit the rotating residents' interests. Given the time constraint and the diversity of pathology informatics rotations in informatics training can be tailored to the trainee or pathologists' interests.

Each week in the four-week rotation was devoted to a rotations/topic shown in Table 3. The first and last weeks were situated so the trainee would work with whole slide imaging in the WSI scanner facilities to understand concepts, challenges, the processes of digitizing diagnostic slides and their utilization. In addition, the first and last weeks were set up so that the trainee would also be integrated with the anatomic pathology laboratory information system (AP-LIS) team. In this instance, MSKCC utilizes Cerner CoPathPlus for its AP-LIS. In these weeks the aspects of WSI, AP-LIS support, automation of lab processes in anatomic pathology, computer vision/artificial intelligence (AI) for WSI were addressed; further solidifying the didactic concepts serving as an adjunct to PIER.

The second week was dedicated to informatics in molecular and genomic pathology including the bioinformatics pipeline and scripting. Understanding how sequencing data is processed and analyzed is integral to the future of pathology practice as molecular and genomic pathology expands in testing and complexity. At MSKCC there

is a robust and well-integrated molecular/genomics bioinformatics service within the department of pathology. This service allowed for an environment in which a trainee could easily integrate themselves and identify individuals to enrich their experience in molecular bioinformatics. This second week exposes the trainee to how informatics aids in the organization and interpretation of molecular/genomic data and its practical role in clinical care and patient treatments. Through the integration of the bioinformatics pipeline, training includes the understanding of the strengths and weaknesses of molecular/genomic testing.

During this second week, the resident would attend molecular/genomic sign outs, rotate with the bioinformatics group, and attend quality assurance (QA)/quality control (QC) molecular/genomic meetings. MSKCC molecular/genomic sign out is held with a bioinformatician, a molecular fellow, and a molecular attending. In reviewing molecular/genomic reports and the associated molecular/genomic data output, a fluid dynamic dialogue exists as any QA/QC issues are addressed at the time of sign out. This fosters a learning environment to how data is extracted as well as issues that may arise in the process. Additionally, the weekly QA/QC meetings allows the trainee to see how the molecular/genomic data output from molecular platforms are filtered and analyzed computationally as well as the challenges and pitfalls. Also scheduled for the resident during this second week, was one-on-one didactics with a molecular/genomics attending. These didactic sessions further delved into the bioinformatics pipeline by going over the code and architecture in further detail. Didactic topics included next generation sequencing (NGS)

Table 3. The Rotations and Topics Addressed for Each Week of the Rotation[*]

Week	Rotations/Topics
Week 1	AP-LIS support and automation, WSI, computer vision/AI
Week 2	Molecular and genomic informatics including bioinformatics pipeline and scripting
Week 3	Rotations in Machine Learning Labs and Pathology Imaging Labs
Week 4	AP-LIS, WSI, Surgical Pathology Informatics, and Previous Rotations of Interest

[*]Didactic lectures in pathology informatics by attending were performed throughout all the weeks. Any informatics related meetings were also attended to when possible throughout the weeks (i.e., QA/QC meetings, molecular sign out, lab meetings, and vendor meetings).

file formats, QA pitfalls, filtering variants, and introductions to using the programming language R for analyzing data.

The third week was designed as an anatomic pathology informatics research week in which the trainee would rotate through the Thomas Fuchs Lab and the Yukako Yagi Lab. The Fuchs Lab is focused on computer vision and AI applications to either WSI, tissue-micro arrays, and medical imaging. The Yagi Lab investigates novel innovative approaches to tissue processing and imaging such as 3D tissue imaging, multispectral image enhancement, and telepathology. During this third week, the trainee would attend lab meetings and team up with research scientists to help on their projects. Experience in both labs immerses the trainee in innovative approaches for pathology and in fostering inspiration in academic pursuits in pathology informatics.

The entire four-week rotation was overseen by multiple pathology informatics attendings. Integrated throughout the four-week rotation is practice experience supplemented by individual one on one didactic lectures with informatics attendings on various informatics topics, informatics research projects, vendor meetings, and hospital wide informatics meetings. Two specific informatics projects were slated for involvement by the trainee during the four-week rotation. The first project was the validation of the Leica Aperio LV1 for remote frozen section diagnosis. The Leica Aperio LV1 (Leica Biosystems, Buffalo Grove, IL) is a small footprint (e.g. 4 slide) hybrid robotic microscope/whole slide scanner providing both WSI capabilities and dynamic robotic telepathology ideal for frozen sections (5). The second project was analyzing component differences across different WSI platforms to further investigate high power field quantification in digital pathology (6).

Implementation and Adaptation of the Rotation to the Covid-19 Pandemic

In December of 2019, cases of an unknown viral pneumonia were reported in Wuhan, China, later identified as SARS-CoV-2 or COVID-19.

On January 20th 2020, the first reported case of COVID-19 infection was identified in the United States (8). On March 20th 2020, stay at home orders were placed in New York City with strict gathering and social distancing measures in order to hinder the spread of COVID-19 (9). By early April 2020, hospitals in New York City were overwhelmed, as intensive care units were expanded and healthcare workers redeployed to meet the increasing number of individuals infected with COVID-19. Pathology departments in New York City also faced difficulties in moving forward safely with clinical operations.

Though carefully developed and planned prior, the informatics rotation began right as COVID-19 hit New York City. By the second week of the rotation, all research labs had suspended in person activity with individuals working from home to decrease exposure. At the same time discussions as to how pathology informatics could help in not only data collection and investigation of COVID-19 but also remote sign out of WSI were discussed. MSKCC had in place a robust WSI lab and operation that was situated to aid pathology workflow in a safe manner (10, 11). The focus of the trainee's rotation adjusted towards testing and validation of operational processes adapted for pathologists to review and sign-out pathology specimens remotely through WSI. Accomplishing such an endeavor meant promoting the safety of individuals in the lab and digital scanning, as well as pathologists, while continuing clinical operations and responsibilities. The adaptation of the rotation during the pandemic highlights the flexibility as well as the wide applicability of pathology informatics for training.

Testing and Validation of Remote Sign out Through WSI

MSKCC has numerous WSI technologies, digital scanning staffing, and existing processes to pilot a larger WSI operation for remote sign out. Incorporating WSI at scale during the pandemic for remote sign out became the priority, though many operational questions remained that required tremendous efforts by the trainee in testing and validation in real time. In addition to these testing

and validation efforts, one on one didactic lectures with informatics attendings continued via web conferencing platforms (e.g. WebEx, Zoom Microsoft Teams) on informatics topics such as molecular/genomic bioinformatics, WSI, and laboratory information systems.

For the validation, the Leica Aperio GT450 and Philips UltraFast Scanner were selected as high throughput instruments to pilot remote sign out of surgical pathology specimens. Initially, a select group of attendings began a remote sign out pilot using WSI for one specialty. Shortly after the initial pilot, a study protocol was developed to encompass all surgical pathology subspecialties on randomly selected service days (11). WSI was then expanded to other services/specialties and attendings with the eventual intent to scale operations to all glass slides produced by the lab and all slides of cases received as consultations. The trainee worked as part of the team including digital imaging staff and operational directors to test and address issues that arose. As there was no precedent, the trainee was actively involved in developing process frameworks for slide scanning operations and workflows, addressing slide-reading errors; continual optimization of slide scanning workflows were addressed firsthand without guidance from prior established examples. Additionally, how digital slides were viewed and how to best optimize the required components for WSI viewing, were also addressed directly without guidance from prior established examples.

Regulatory considerations were addressed in the validation for remote WSI sign out. With the need for WSI remote sign out during COVID-19, Centers for Medicare and Medicaid Services (CMS) temporarily used their enforcement discretion to allow remote sites meeting specific criteria to not require dedicated CLIA certifications; in order for pathologists to work remotely (12). Other regulatory bodies in other countries also followed suit (13-15). The FDA also further provided guidance with a temporary enforcement discretion on the use of non-510(k) cleared devices, with validation prior to use (16).

In New York State (NYS), the NYS Department of Health is the CLIA-deemed entity that requires all CLIA-certified laboratories in NYS to have approval for laboratory developed testing (LDT). LDT validation documentation was required for submission and approval, in order to perform remote sign out using WSI. The application for validation by NYS was written and submitted during the validation process and eventually granted approval. By developing the process for remote WSI sign out along with participation in testing, validation, and handling regulation around remote WSI sign out, the education of the trainee was greatly enhanced. Familiarity with all the nuances around digitization of glass slides, the steps required, and the regulations of government and professional societies, brought unforeseen practical experience that would not have occurred without the pandemic forcing adaptions by MSKCC.

Conclusions

Pathology informatics continues to evolve with process-driven technological solutions for an increasingly complex healthcare field. Advances in WSI, computer vision/AI, and digital imaging innovations allow pathologists to not only work efficiently, but also yield new approaches to disease diagnostics and management. Likewise, informatics in molecular and genomic pathology plays a key role in disease diagnostics and management with generations of insights through breakthroughs in data analysis. Future pathologists need to know these aspects of informatics in in their practice. Therefore, training pathology residents and fellows in pathology informatics concepts are essential for the future pathologist workforce. Such essential training is acknowledged by the ACGME and CAP by their efforts to bolster informatics education for trainees. The pathology informatics rotation constructed, developed, and implemented at MSKCC serves as a guide and example in structuring a resident/fellow pathology informatics rotation. While the general goals, objectives, and designed activities pivoted to fit the needs of the department during the COVID-19 pandemic for remote WSI sign out, the rotation still yielded valuable experience in learning about informatics

processes and core concepts. Having clear and well thought out objectives prior to the rotation as well as dedicated mentors and attendings enhanced the education experience.

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