Original Article

Whole Slide Imaging for Teleconsultation: The Mount Sinai Hospital, Labcorp Dianon, and Philips Collaborative Experience

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Abstract

Background: With the emergence of whole slide imaging (WSI) and widespread access to high-speed Internet, pathology labs are now poised to implement digital pathology as a way to access diagnostic pathology expertise. This paper describes a collaborative partnership between a high-volume reference diagnostic laboratory (Labcorp) and an academic pathology department (Mount Sinai Hospital) in the transition from a traditional glass slide service to a digital platform. Using the standard framework of implementation science, we evaluate the consistency and quality of the Philips IntelliSite Pathology Solution (PIPS) in delivering save and efficient diagnostic services. **Materials and Methods:** Digital and glass slide diagnoses of all consult cases were documented over a 12-month period. The Proctor guideline was used to quantitatively and qualitatively measure (e.g., focus group studies, field notes, and administrative data) implementation success. Lean techniques (e.g., value stream mapping) were applied to measure changes in efficiency with the transition to a digital platform. **Results:** Our study supports the acceptability, high adoption, appropriateness, feasibility, fidelity, and sustainability of the digital pathology platform. The digital portal also improved the quality of patient care by increasing efficiency, effectiveness, safety, and timeliness. The intraobserver concordance rate was 100%. The digital transition resulted in a reduction in turnaround time from 86 h to an average 35 min and a 20-fold increase in efficiency of the consultation process. **Conclusion:** As the pathology community contemplates digital pathology as a transformational tool in providing broad access to diagnostic expertise across time and space, our study provides an implementation strategy along with evidence that the digital platform is safe, effective, and efficient.

Keywords: Digital consult, Philips, telepathology, whole slide imaging

Background

Digital pathology is poised for substantial integration into the practice of diagnostic surgical pathology. As per the market research report published in October 2020, the global digital pathology market is estimated to increase from 553 million U.S. dollars (USD) in 2020 to 1054 million USD by 2025, at a compound annual growth rate of 13.8% during this period.[1] The coronavirus disease-2019 (COVID-19) pandemic is only accelerating this growth as it compels fuller integration of pathology services into the domain of "telehealth" in an effort to provide health care virtually.[2] Although the cost and complexity of implementing digital pathology into diagnostic workflow is high, strategic execution of digital pathology platforms can result in significant cost savings over time.[3]

One area of diagnostic pathology that is particularly amenable to a digital approach is the diagnostic pathology consult. Accurate pathology diagnosis is absolutely essential for guiding therapeutic management, and

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seeking expert consultation, particularly for complex or unusual cases, is a common quality assurance practice for reducing diagnostic error and optimizing patient care.[4] Conventional pathology consult practice requires the time-consuming and precarious navigation of fragile glass slides between laboratories through the mail delivery system. Whole slide imaging (WSI) with high-speed Internet transmission could provide broad access to pathology expertise while simultaneously improving the safety, speed, and efficiency of the consultation practice.[5-7]

The purpose of this paper was to describe the impact of transition from a conventional glass slide-based service to a digital image-based practice based on the collaborative experience of a high-volume commercial diagnostic laboratory (Labcorp) with a team of academic-based expert pathologists (Mount Sinai Hospital [MSH]). The study focuses on the consistency and quality of the Philips IntelliSite Pathology Solution (PIPS), applying Lean techniques such as value stream mapping (VSM) to optimize workflow algorithms, quantified improvements in efficiency, and underscore major challenges in moving away from historical practices.

Materials and Methods

Project partners

In June 2019, Mount Sinai Health System and Labcorp announced a collaboration to establish "The Mount Sinai Digital and AI-Enabled Pathology Center of Excellence" using the PIPS to expand digital pathology capabilities. As early adopters of digital pathology, MSH, Labcorp Dianon (LCD), and Philips Digital and Computational Pathology (PDCP) shared a vision for a comprehensive digital pathology program to replace a glass slide-based approach to diagnostic surgical pathology. As an important first step, these three organizations joined forces to implement a WSI-based teleconsultation network between the LCD facility in Shelton, CT, and the Department of Pathology at MSH in New York, NY, using the technology and technical expertise of PDCP. The goals of the initial teleconsultation program were to (1) design and implement a well-functioning teleconsultation workflow, (2) identify and measure the clinical and operational benefits of using digitized images over glass slides for consultations, and (3) pinpoint areas for modification to improve the digital pathology platform as a transformational tool in diagnostic pathology.

The Department of Pathology at MSH provides pathology support to a vast and complex medical system comprised of nine academic medical centers and community hospitals. Its Division of Surgical Pathology is organized into 16 site-specific divisions (e.g., thoracic, gastrointestinal, genitourinary); and each division is staffed by academic pathologists with subspecialized expertise. Annually, the Department accessions approximately 315,000 surgical pathology cases and receives 6000 consults from other health care centers and diagnostic laboratories.

Table 1: Fundamental steps in constructing a safe, reliable, and efficient digital pathology consultation platform

- Build an informational technology platform to support sharing of digital images
- Design an optimal digital workflow
- Define essential users (e.g., case manager, principal pathologist), assign user tasks, and authorize user access
- Issue standard operating procedures
- Implement an appropriate quality control process to ensure reliability and safety, and meet regulatory mandates
- Devise mock scenarios to test and validate the new workflow

LCD pathology provides anatomic pathology services with subspecialty expertise in dermatopathology, gastrointestinal pathology, genitourinary pathology, hematopathology, breast pathology, head and neck pathology, and uropathology. LCD's Shelton, CT facility processes approximately 300,000 accessions annually and has 15 dedicated pathologists on staff.

In 2010 Philips started the development of a digital pathology system which was adopted for primary diagnosis at the Netherlands-based LabPON clinical site by 2015.[8] In 2017, the PIPS was the first digital pathology system marketed for primary diagnostic use in the USA.[9] The PIPS has obtained market access as *in vitro* diagnostics (IVD) for primary diagnosis in approximately 50 countries, including EEA (European Economic Area), USA, Canada, Japan, South Korea, and other countries in Asia, Middle East, and South America project partners

Initiation and planning

The project was designed to sequentially progress along with four strategic phases. Accordingly, the project blueprint included the description of these phases, establishment of a development timeline, and the identification of appropriate milestones to monitor progress. The project phases consisted of preinstallation, platform installation, preproduction (training and validation), and full production.

Preinstallation

The preinstallation phase addressed those activities related to the construction of necessary infrastructure [Table 1].

Four essential interdependent components were identified consisting of information technology (IT), laboratory workflow operations, quality assurance practices, and pathology expertise. In designing IT infrastructure, a major goal and challenge was to provide a highly functional, efficient, and accessible digital pathology platform between two independent sites (MSH and LCD) while meeting stringent cybersecurity requirements. To securely connect these two sites, a central portal solution was designed that included a Single Sign On feature allowing

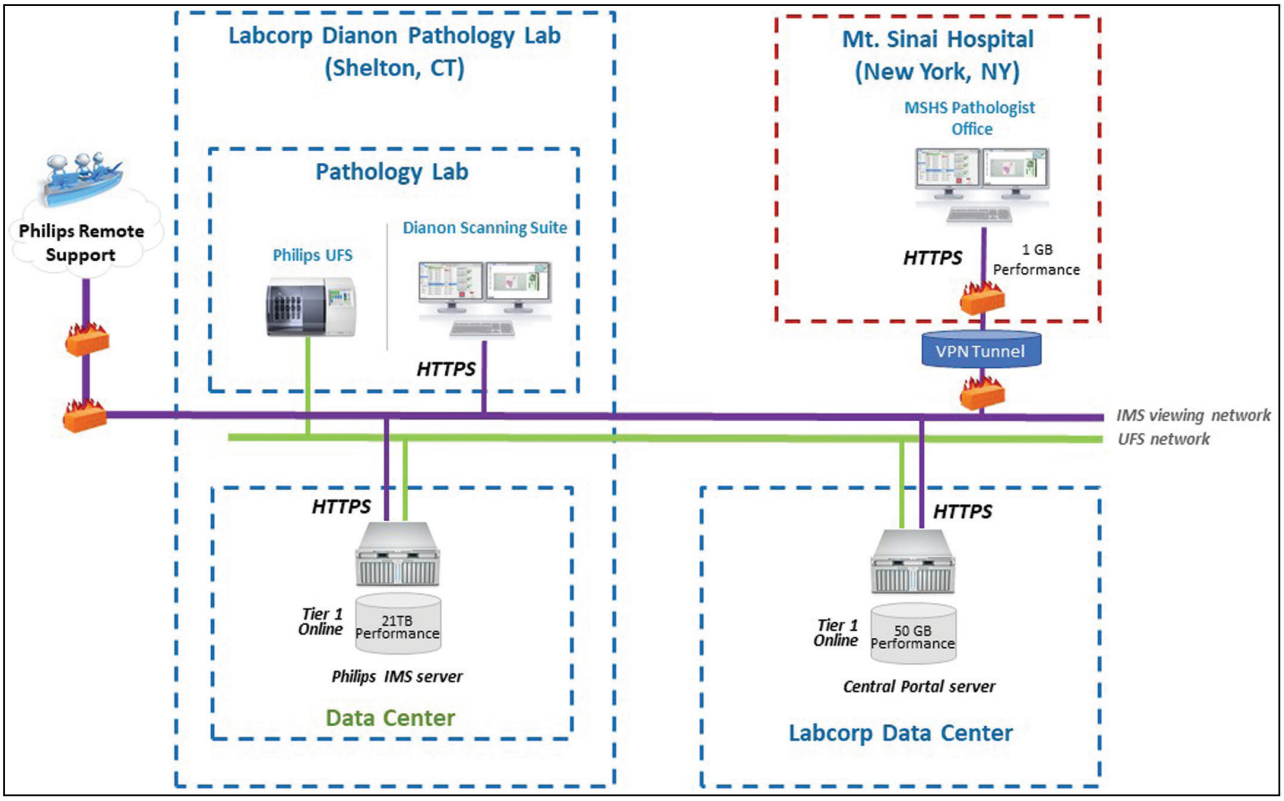

Figure 1: IT architecture diagram

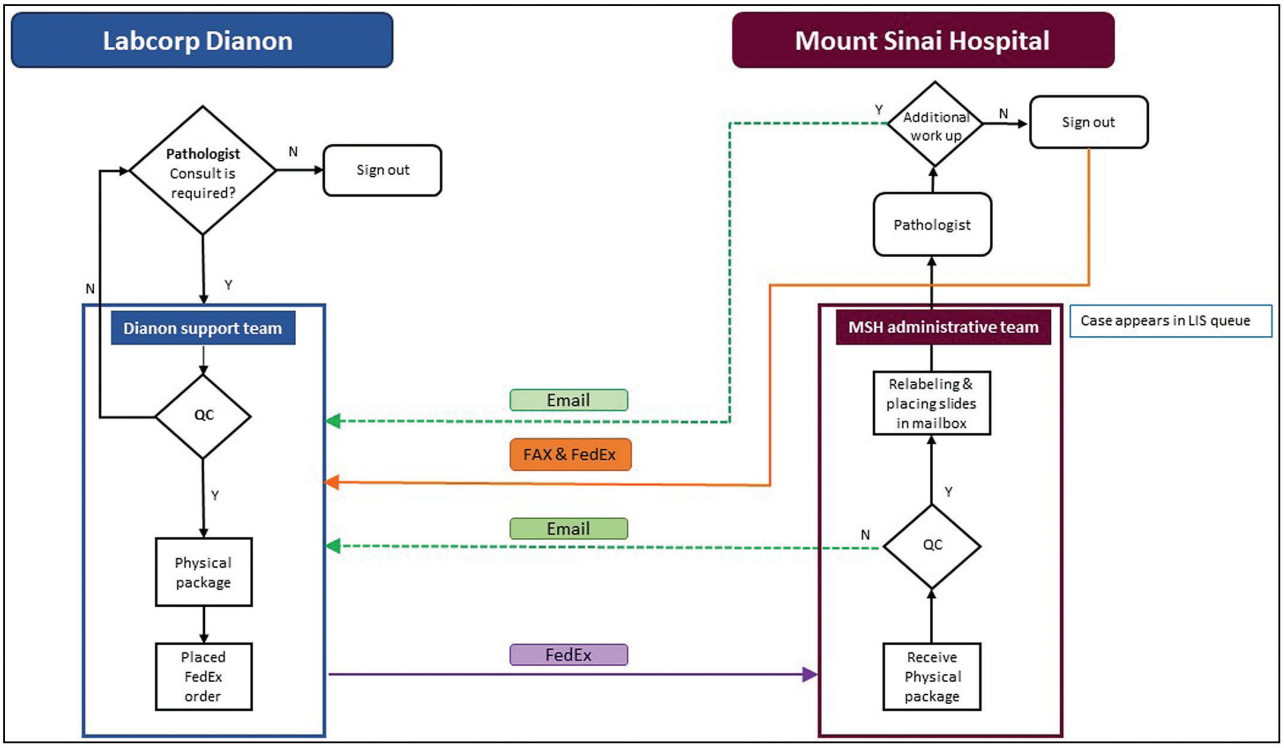

Figure 2: Workflow diagram for glass slide consultation

MSH staff to access the portal using the standard MSH login username and password. A schematic highlighting the IT architecture is shown in Figure 1.

Workflow design

When the LCD pathologist is confronted with a difficult and/or unusual case that requires access to specialized diagnostic expertise, the traditional glass slide consultation process is initiated by notifying the LCD support team [Figure 2].

This team assembles the glass slides and completes a requisition form. The requisition form includes a detailed description of package content including number and labeling of slides, patient identifiers (e.g., name, medical record number), relevant patient demographics (e.g., date of birth, gender), pertinent clinical information (e.g., medical history, surgical procedure, date of surgery, anatomic site), the reason for consultation and the designated pathologist. Slides and supporting documents are reviewed to ensure that the glass slide collection is complete and matches patient identification. Following packaging of the case, an electronic order is placed in the FedEx system and the package is dispatched at the end of the business day for delivery to the MSH.

On receipt, the MSH administrative team conducts quality control by certifying that all slides listed on the consult requisition form are present and match the corresponding documents. The slides are then accessioned into the MSH Department of Pathology laboratory information system (LIS) and assigned to the specified pathologist. The glass slides are delivered to the pathologist's mailbox for pickup and review. If the consulting pathologist requires additional immunohistochemical studies, a request for unstained slides from a specific block is made to the administrative staff at MSH and communicated to the staff at LCD. Following processing of the selected block(s), unstained slides are sent from LCD to MSH by FedEx. After the case is signed out in the MSH LIS, the final report is faxed to LCD. The physical glass slides and a copy of the final report are retrieved by the MSH support administrative team, re-packaged and then returned by US mail service back to LCD.

This time-honored glass-slide workflow served as a framework for creating a functional workflow for a digital consultation service [Figure 3].

As with the traditional glass slide service, digital consult workflow is initiated when the referring pathologist at LCD alerts the technical and administrative support teams of the need to send a case for sending the case to the support team to be submitted for the consultation. The LCD technical support team: (1) creates a 2D barcode for each slide, (2) performs prescan quality check of slides, (3) scans the glass slides as Whole Slide Images (WSI), (4) conducts a postscan quality check, and (5) uploads the WSI and consult documentation into the shared IMS portal.

The LCD administrative support team assigns the case to a designated consulting subspecialty MSH pathologist.

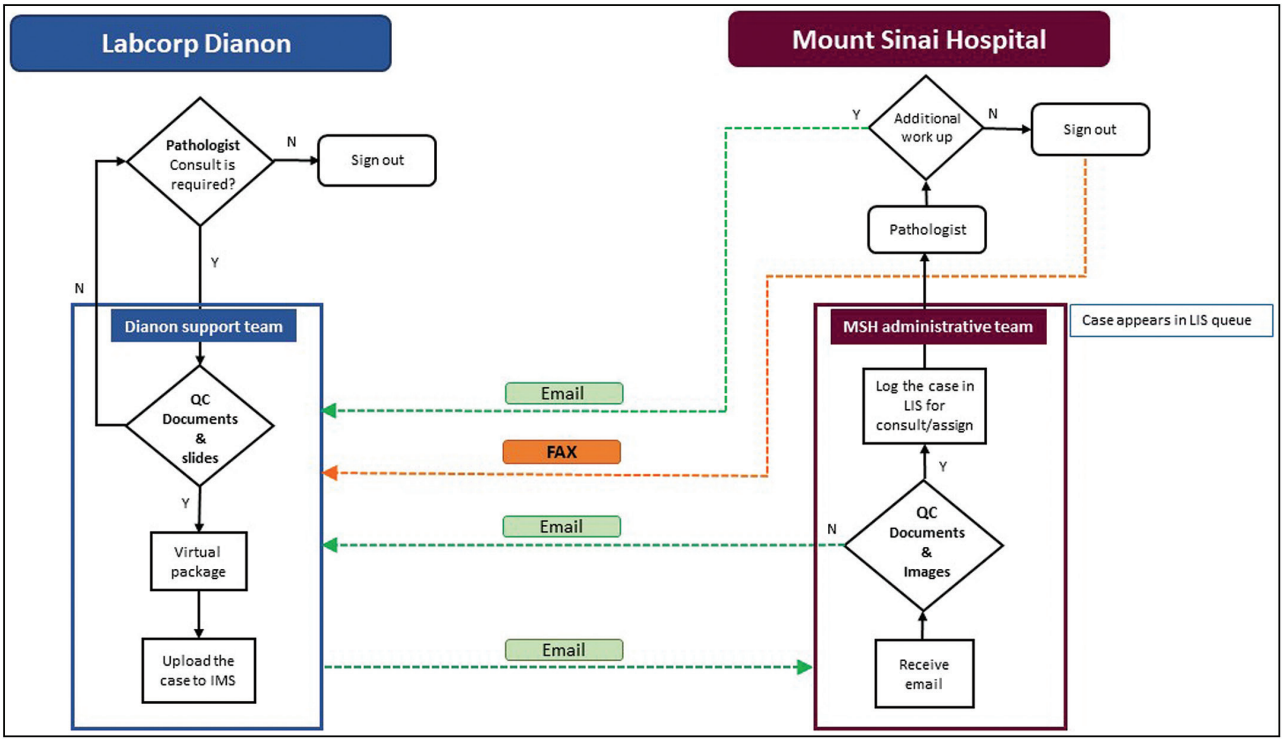

Figure 3: Workflow diagram for digital consultation

A defined MSH contact group is then notified by a predefined email template including subject content (i.e., "Labcorp Dianon Consult") and the LCD unique accession number. MSH administrative staff has access to the IMS allowing them to view slide labels and requisition forms to ensure slide number and identification match the case information. Any identified errors/discrepancies are resolved with the LCD team before the case is formally accessioned into the MSH LIS with MSH accession number to appear in the active case queue of the consulting pathologist. The digital slides are not re-labeled with MSH case number. However, the LCD unique accession number is entered into a designated field called" Consult accession number" in MSH LIS. The designated MSH pathologist can log into IMS, matches the LCD unique number on the labels with number entered into MSH LIS, instantly review the documents and images and sign-out the case in the MSH LIS. The finalized consultation report is automatically faxed to LCD.

MSH pathologists are provided with a complete list of the immunohistochemical stains offered by LCD. In those instances where additional immunohistochemical studies are required, the MSH consulting pathologist completes an email request form that is submitted to the LCD administrative team. Immunohistochemical studies are performed at LCD and then transmitted to the requesting MSH pathologist as scanned digital images through the shared IMS portal.

Platform installation

As summarized in Table 2, platform installation occurred concurrently at the two sites and included the assembly of the physical platform, virtual platform, and the IT network infrastructure.

For the Digital Pathology scanning solution, LCD adopted PIPS. The PIPS is a complete digital pathology system that allows the acquisition of a WSI from surgical pathology slides prepared from formalin-fixed paraffin-embedded tissue. PIPS is intended for creation and viewing of digital images of glass slides that would otherwise be appropriate for manual visualization by conventional light microscopy.

Table 2: Key system elements of digital pathology consult solution

	Labcorp (referring)	Mount Sinai Hospital (consulting)
Physical platform	UFS scanner	IVD monitors
	Scanner table	PCs
	IVD monitor (for QA)	
Virtual platform	IMS server and license	
	IMS software	
	Image storage	
IT network infrastructure	Central portal	
	VPN tunnel	
	Single Sign On	
	SSL certificate (https secure connection)	

This PIPS solution includes the following main components: (1) ultra-fast scanner (UFS), (2) image management system (IMS) software, (3) IVD clinical monitor and pathologist workstation, and (4) IMS image server and storage.

Installation of the scanning solution was completed in about 2 weeks following delivery of all system components. Prior to full clinical use, the Phillips and LCD project teams completed a detailed workflow assessment and digital transformation plan, which included a review of the glass slide histology operation, assessment of slide preparation and labels and mapping of digital pathology workflow.

MSH identified a select number of diagnostic pathology experts who were already equipped with digital pathology workstations based on their use of digital pathology for primary diagnoses. These workstations were equipped with a Philips IVD Clinical Monitor and connected to the LCD central portal via a secure B2B virtual private network (VPN) tunnel. From their offices at the MSH, the consulting pathologists could use the PDCP IMS web client to connect to the IMS application server over a secure https connection. This secure connection ensures confidentiality and integrity of the transmitted information to meet privacy laws and regulations requirements.

After careful planning and reviews completed by the LCD, MSH, and PDCP IT teams, the IT architecture described above (see Phase 1: Preinstall preparation; IT Design) was successfully implemented.

Preproduction

User training was part of project priority to ensure that each user felt competent and confident with the digital platform before the go-live date. Toward this end, an application specialist from PDCP provided 30-min individual hands-on training sessions with nine pathologists and five administrative users. This practical training included all aspects of navigating the IMS system from logging into the system, controlling field selection and image magnification, using the annotation tools, changing case status (e.g., reassigning case status from active to complete), bookmarking images with public or private tags and searching for cases by identifiers. In an effort to provide ongoing and readily available throughout the preproduction phase and after the go-live date, a qualified pathologist with informatics expertise was designated as the "user champion".

The system was challenged by several real case scenarios in an attempt to validate the functionality of the digital pathology platform as a replacement for conventional glass service, and to identify any flaws in new workflow that would require modifications. User acceptance testing included two components. The first involved beta testing of the system functionality using vendor checklists to test

all application features. A limited number of cases were used to test the basic functionalities required for finalizing a consult case. The IT analysts from LCD and MSH participated in this end-user testing.

The second component involved an analysis of the integrated workflow. This process was guided by the development of standard operating procedures (SOP) to instruct the administrative teams and the pathology users and to provide standardization and coordination of the entire workflow process across the different sites for current and future participants. The LCD support team, MSH administrative team, IT managers, quality managers from both organizations, and MSH pathologists participated in a limited number of dry runs. We repeated the execution of test cases a few times on different occasions to ensure that any defects were identified and mitigated. Based on these dry runs, the SOPs were modified as needed and then the final documents were certified by the administrative managers.

The American Telemedicine Association clinical guidelines for telepathology (2014) were used to guide development of a validation plan.[10] To streamline the process and eliminate delays linked to a washout period, 42 archived consult cases from the prior year were selected for validation. For each individual pathologist, diagnosis was rendered from digitalized images of archived cases without knowledge of the original diagnosis. The diagnosis from the digital images was then compared to that pathologist's original reading of the glass slides. All consulting pathologists participated in the process. In an effort to emulate the live diagnostic consultation process and acclimatize the pathologists to the new workflow, the digital images of the validation cases were accessioned into the MSH LIS system.

Phase 4: full production

The full production phase was initiated with a parallel system where digital images were reviewed together, but asynchronously, with the glass slides. This method served two purposes. First, it provided a transition time for the consulting pathologists to become fully confident with digital pathology. Second, it allowed the acquisition of data relating to diagnostic discrepancies and turnaround time between the two platforms.

Cases included all LCD consults sent to MSH for review by the head and neck, liver and gastro-intestinal services from December 2019 to December 2020. Glass slides were first scanned at LCD and then shipped via FedEx to MSH. The consulting pathologist were instructed to document their digital diagnosis by entering it into a separate tab of the LIS and then finalize the diagnostic report once the glass slides were received and reviewed. The initial diagnosis (digital) and final diagnosis were compared to measure the intra-observer concordance rate. To create the VSM, timestamps from FedEx transport and the LIS were extracted. A combination of qualitative and quantitative methods was used to evaluate implementation outcomes. Qualitative methods included focus group studies, users' feedback, and field notes. Quantitative data such as the total number of cases, processing time, process cycle efficiency and incidence rate were used to assess implementation and service outcomes.

Table 3: Taxonomy of implementation outcome

Implementation outcome	Method of measurement
Acceptability	Administrative data
Adoption	Administrative data
Feasibility	Administrative data
Fidelity	Self-report
Coverage	Case audit
Sustainability	Questionnaires

Results

Implementation outcomes

The modified Proctor *et al.*[11] framework was used to evaluate implementation outcomes, service outcomes, and client outcomes. Because a digital pathology platform will not be effective if it is not effectively implemented, implementation outcomes serve as necessary preconditions for attaining subsequent desired changes in the diagnostic consultation practice. As summarized in Table 3, six implementation parameters were measured.

1. Acceptability: Qualitative interviews of stakeholders including the consulting pathologists and administrative staff were undertaken to assess level of satisfaction with the core features of the consult portal. Without exception, users found the new platform simple, fast, and easy to use. The user interface design was acknowledged as easy to navigate with high interactive efficiency.
2. Adoption: The adoption rate was high and occurred over a relatively short period of time. All users were comfortable using the digital pathology platform within weeks of the go-live date. Even though glass slides were provided during a 3-month transition period from the go-live date, diagnoses were entered during initial review of the digital images without postponement due to a need to review the glass slides.
3. Feasibility: Based on the surveys and administrative data, the telepathology portal provided a highly feasible system for providing expert consultations. Analysis of LIS data showed that all the digital images were reviewed by the MSH pathologists within hours after the consults were placed into the IMS viewing network by the LCD team. Pathologists found the platform intuitive and easy to use. Using telepathology

Table 4: Consultation cases from Labcorp Dianon

Organ	Biopsy	Resection	Total
Head and neck	30	9	39
Salivary gland	0	8	8
Breast	6	0	6
Thyroid	0	3	3
Soft tissue	2	1	3
Gastrointestinal	1	0	1
Total cases			60

eliminates time spent on organizing and filing forms and glass slides. Users can repurpose that time to focus on diagnosis and teaching.

4. Fidelity: The quality of the image delivery process was closely monitored over a 12-month period. The quality of the images was reported to be optimal for diagnosis, and there were no requests for rescans during this 12-month period. All users from both organizations consistently adhered to the instructional procedures. On review and comparison of the diagnoses made from the digital images and the glass slides, there were no major discrepancies. The diagnostic correlation rate was 100%.

Two detrimental incidents were noted over the 12-month period. The first involved mismatched documents were discovered by the consulting pathologist at the time of review. The second involved delayed case assignment by the MSH accessioning team. Failure to promptly assign the case to a designated pathologist resulted in unnecessary delay in issuing a finalized report. Prompted by an inquiry from the LCD support team, the delay in accessioning was quickly recognized and corrected by the MSH support team. In both instances, the established SOP double-check protocols allowed the errors to be quickly recognized and corrected without any patient harm.

5. Coverage: The digital consult service initially provided consultative expertise for head and neck (n = 39), salivary gland (n = 8), breast (n = 6), thyroid (n = 3), soft tissue (n = 3), and gastrointestinal and hepatobiliary pathology (n = 1). Table 4 shows the description of consult cases types. The majority of cases were diagnosed as neoplastic entities and only six cases include inflammatory diseases. The collection of 60 consult cases encompasses 532 hematoxylin and eosin (H&E) slides and 17 immunostains (including nuclear, cytoplasmic, and membranous). The average number of slides per cases was approximately 9; ranging from 1 to 31 slides. Majority of cases include neoplastic entities and only 6 cases were diagnosed as inflammatory diseases.

The LCD and MSH teams are currently involved in discussions regarding future expansion into other subspecialty areas (e.g., dermatopathology, neuropathology) and boutique services (e.g., ophthalmic pathology) as guided by (1) greatest need among the LCD Dianon pathologist for access to diagnostic expertise and (2) availability of diagnostic expertise at MSH. Cytological specimens and bone marrow smears have not been included in any expansion plans for the near future.

Table 5: Digital pathology system failure incidents

Root cause	Fix	Outage duration
Failure 1: Firewall hardware upgrade		
Firewall infrastructure hardware upgrade at LCD resulting in loss of MSH workstation workstation natt'd IP addresses	MSH workstation natt'd IP addresses added back to the LCD system restoring access to the IMS	3 days
Failure 2: Expiration of security certificate		
Expiration of security certificate allowing for https encryption	Renewal of security certificate	2 days

6. Sustainability: The system and developed process have been durable. Following withdrawal of the initial implementation support, the operation has continued to effectively deliver the desired outcome and has been seamlessly integrated into daily routine workflow without significant and sustained breakdowns.

Since initiating digital pathology for consults in January of 2020, however, the system was temporarily disrupted by two system outages. In each instance, the outage was discovered by the consulting MSH pathologist who was unable to log into the digital pathology IMS. A coordinated effort from the teams at MSH, LCD, and PDCP was used to identify the root cause and determine the fix [Table 5].

In each instance, the "fix" proved to be simple and straightforward once the "root cause" had been identified.

Service outcomes

Analytic framework models for quality assessment, including the framework put forth by the Institute of Medicine, have focused on six primary values for health care delivery: efficiency, effectiveness, safety, timeliness, patient-centeredness, and equitability. Although the implementation of the digital consult platform addresses all cited quality aims, our experience primarily focused on efficiency, effectiveness, safety, and timeliness.

Efficiency

To evaluate the impact of telepathology on efficiency, the flow of glass slides and digital images for each case were tracked through the various points of movement through the workflow system between 2019 (preimplementation) and 2020 (postimplementation). For the glass slides, detailed shipment information, including timestamps, was collected using the registered FedEx numbers. We then applied

Table 6: VSM key definitions

Term	Definition
Value-added activity	An activity in workflow process that somehow changes the product or service in some manner and customer is willing to pay for it.
Nonvalue-added activity	An activity that does not increase the value of what is delivered to the customer.
Process-cycle efficiency	This parameter, which measures what percentage of a process is considered to constitute value-added activity, is calculated by dividing the total value-added time in a process by the total process time. Perfect efficiency (100% process cycle efficiency) is the goal, although that is virtually impossible to achieve.

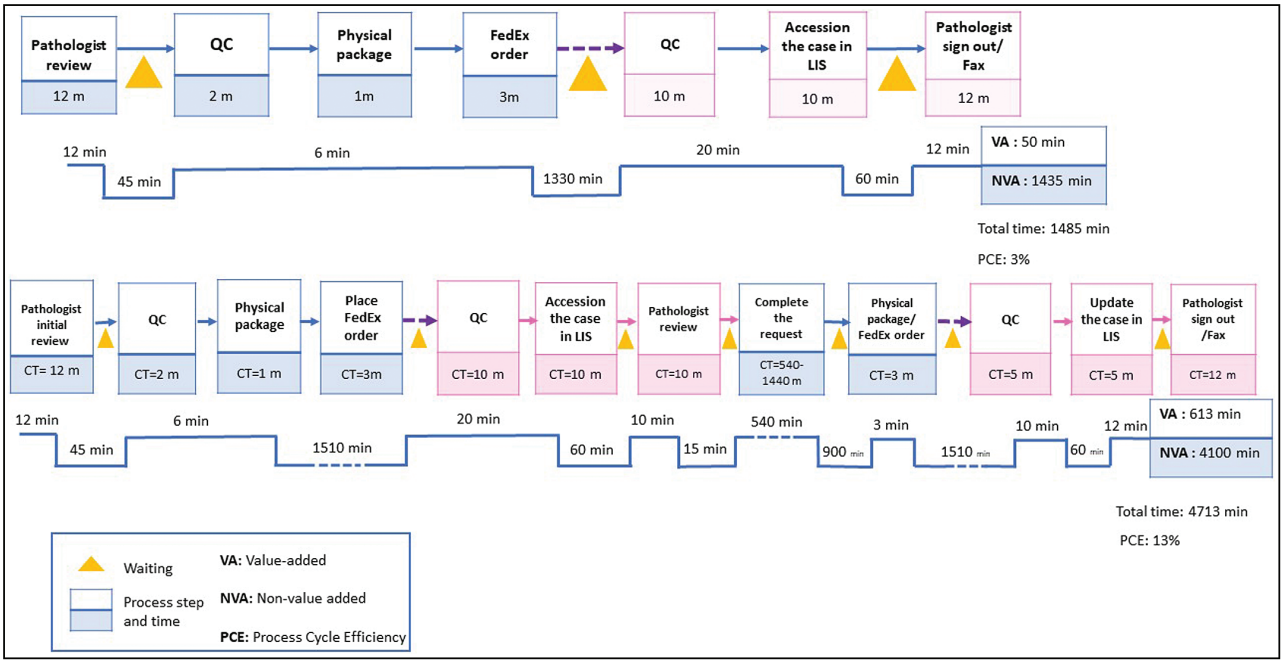

Figure 4: (A) Value stream mapping of simple traditional glass slide consult. (B) Value stream mapping of traditional consult with additional workup

value-stream mapping, a lean management tool to better illustrate the steps of current (mail-in) and future (digital) processes. A summary of key terms in lean management and value-stream mapping is provided in Table 6.

Figure 4A shows the VSM of the conventional mail-in glass slide consult. The average total processing time is 1485 min (i.e., 24 h and 45 min). Nonvalue-added activities (1435 min) compromise 97% of the total processing time. In effect, the process-cycle efficiency is only a paltry 3% of the consult processing time. Evaluation of the value stream map determines that most of the nonvalue activity time reflects travel time of materials through the mail delivery system. The remaining nonvalue activity time is due to the lack of instantaneous access to the slides and corresponding documents.

In those consult cases where an additional case workup is needed such as immunohistochemistry requiring access to tissue blocks for further process, the processing time was 4713 min (i.e., 78 h, 33 min, or 3.3 days) [Figure 4B]. Even though the overall processing time was much longer compared to the simple glass slide consult, the process was relatively more efficient with a cycle efficiency of 13%. As expected, nonvalue activity was primarily related to transit time of sending tissue blocks or unstained slides through the mail delivery system. Time required by administrative staff to acquire and package materials, typically necessitating overnight postponements to accommodate staff working hours, resulted in additional delays up to 900 min.

The digital pathology platform dramatically reduced process time by 92% (from 1485 min to 130 min) [Figure 5A]. Only 55 min of the processing time was attributed to nonvalue activity. The value-added time was marginally increased due to the additional time required for scanning of the glass slides. The process cycle efficiency was 57%, representing a 20-fold increase over the glass slide platform. For complex cases requiring additional workup, the process efficiency cycle decreased to 48% because of 600 min' delay in scanning the additional slides due to administrative working hours.

Table 7 shows the comparison of efficiency parameters for glass slide vs. digital consult workflow shown in Figures 4 and 5.

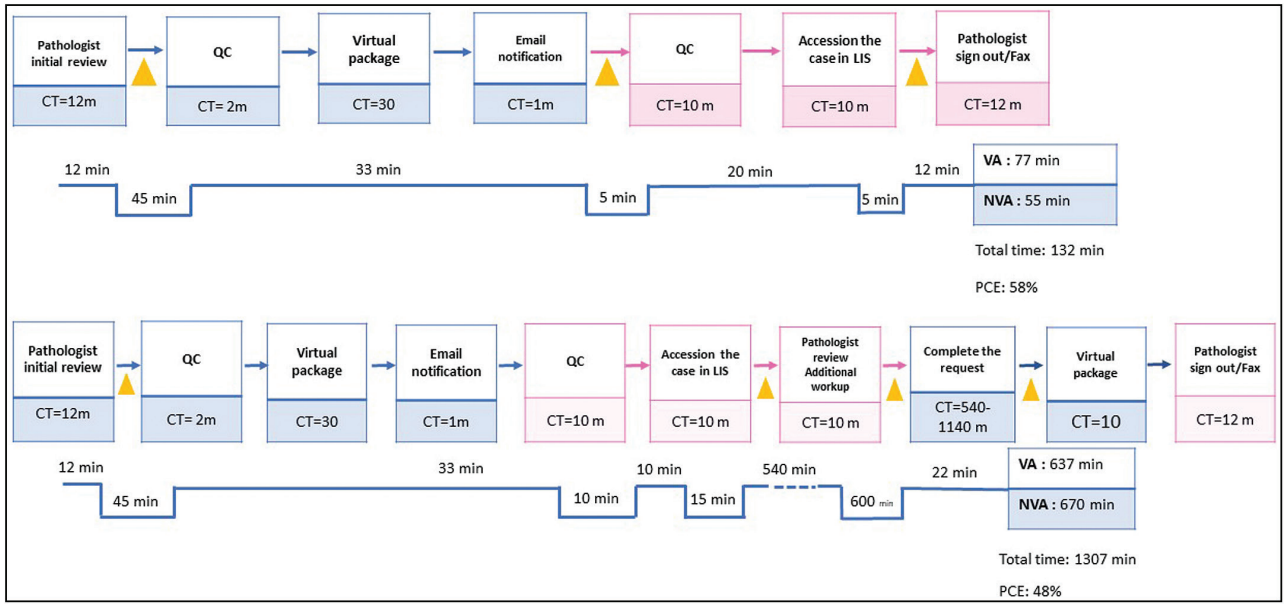

Figure 5: (A) Value stream mapping of simple digital consult. (B) Value stream mapping of digital consult with additional workup

Table 7: Summary of efficiency parameters shown in the value stream mapping [Figures 4 and 5]

		VA (min)	NVA (min)	Total time (min)	PCE (%)
Glass slide consult	Simple	50	1435	1485	3
	Additional work up	613	4100	4713	13
Digital consult	Simple	75	55	130	57
	Additional work up	633	670	1303	48

VA = value-added activity, NVA = nonvalue activity, PCE = process-cycle efficiency

Effectiveness and safety

For a 1-year period from December 2019 to December 2020, a preliminary diagnosis based on the digital images was entered into the LIS and then the diagnosis was finalized after subsequent receipt and review of the corresponding glass slide. In every instance, receipt of the glass slides did not alter in any significant way the preliminary diagnoses based on the digital images. In effect, the intra-observer concordance rate was 100%. Not a single glass slide was lost or broken.

Timeliness

The digital consult portal's implementation decreased the turn-around time (TAT). The average TAT for the glass slide service was 5,160 min (86 h or 3.5 days) compared to 35 min (0.58 h or 0.2 days) for the digital pathology service. The overriding factor in this remarkable time reduction was the elimination of physical slide transportation through the mail delivery system (average 22 h). For those cases where glass slides sent on a Friday and involved nonworking hours, delivery times were extended up to 72 h.

To a lesser degree, changes in workflow once the cases reached MSH also contributed to a reduction in TAT. Elimination of physical glass slide preparation (i.e., labeling the individual slides) and delivery to the staff pathologists further reduced TAT from 60 min for the traditional glass slides to 5 min for the digital consults. Upon receipt of email notification by the LCD support team, the consulting pathologists had instantaneous access to all images and documents and could review cases without workflow-related delays.

Client outcomes

In this study, administrative staff and pathologists from referring and consulting laboratories are considered front-line clients or customers. Our findings from qualitative interviews showed a high satisfaction rate among all users. Three main factors were cited as being most important in promoting high satisfaction with the new digital pathology platform: speed, convenience, and high-quality images.

Discussion

The utility of digital pathology for establishing primary pathologic diagnosis is now well established.[12-14] The use of digital pathology for secondary pathology consult diagnosis has yet to be fully validated but holds much promise as an approach for providing far-reaching access to diagnostic expertise unfettered by distance and organizational constraints.[15] To date, experience confirming the effectiveness of remote pathology consultation has largely been confined to large

multi-facility healthcare organizations.[16-18] Moving beyond a single organizational framework, we share an ongoing experience in the development and implementation of a consultation service based on a partnership between a technologic leader in a digital pathology system, a high-volume diagnostic company, and an academic pathology department with organ-specific diagnostic expertise. The success of this partnership carries profound implications regarding universal healthcare access including outreach to underserved regions.

To the best of our knowledge, this is the first paper to apply the Proctor framework to digital pathology consultation—a unified model that provides quantifiable metrics and consistent terminology to better assess implementation processes. Using Proctor framework criteria such as acceptability, adoption, fidelity, and sustainability, this study confirms that digital pathology is a highly effective platform for providing surgical pathology consultations.

Implementation of a digital pathology consultation service significantly enhanced the efficiency of surgical pathology consults by reducing turnaround times. The average TAT for the glass slide service was 5,160 min (86 h or 3.5 days) compared to 35 min (0.58 h or 0.2 days) for digital pathology, an improvement almost entirely attributed to elimination of slide transportation through the mail delivery system. In this experience, transportation of glass slides through the mail delivery system was relatively short (average 22 h) reflecting the close proximity of the two partners (approximately 70 miles) and proficient use of existing mail delivery systems (i.e., FedEx). As broader implementation of digital pathology pushes the boundaries of service zones to more remote sites, the TAT disparity is expected to further widen as digital platforms circumvent distance barriers and other impediments that prolong mail delivery times.

Designing a digital consultation workflow system modeled after a time-proven conventional glass slide system that was familiar to administrative staff, the newly introduced digital pathology platform was readily adapted into the consultation workflow without resistance from administrative personnel. The digital platform was also rapidly embraced by the expert pathologists, even those with limited experience with viewing whole slide images. Each of the diagnostic experts became comfortable and confident making diagnosis from the WSIs within the 3-month transition period. This is not unexpected as published surveys have noted that surgical pathologists require no more than 2 weeks to adapt to digital pathology.[19]

The ease of implementation and the speed of case delivery did not compromise diagnostic precision of the digital pathology platform. Adaptation from a glass slide service to a digital image service involved a transition period where a diagnosis based on the digital images was held until the matching glass slides were received and reviewed. There were no cases where review of the glass slides changed the preliminary diagnosis based on the digital images. Our experience with consult diagnoses does more than just corroborate the experience with primary diagnosis where digital pathology has been confirmed as noninferior to conventional microscopy.[20,21] It shows that high concordance can be achieved even for those difficult and complex cases that are concentrated in the consultation practice. Indeed, our study was heavily weighted towards head and neck consult cases–a particularly challenging area of diagnostic pathology where the unparalleled diversity and complexity of head and neck tumors renders this anatomic region highly vulnerable to diagnostic error.[4,22] It is assuring that the complexity, diversity, and subtly of difficult head and neck cases did not affect the reliability of consultation diagnoses when using a digital platform.

Conclusion

We adopted Proctor guidelines to describe the implementation strategies and outcomes of teleconsultation experience between Labcorp, MSH,, and Philips. Our study supported the acceptability, high adoption, appropriateness, feasibility, fidelity, and sustainability of implementing the telepathology platform. The digital consult portal also improved the quality of patient care by increasing efficiency, safety, and timeliness. With further advancement of technology and cost reduction, telepathology will grow increasingly and is expected to become the best practice for a consultation.

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Conflicts of interest

There are no conflicts of interest.

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