J Pathol Inform

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Research Article

Needs and workflow assessment prior to implementation of a digital pathology infrastructure for the US Air Force Medical Service

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Received: 06 September 13 Accepted: 23 October 13 Published: 29 November 13

This article may be cited as:
Ho J, Aridor O, Glinski DW, Saylor CD, Pelletier JP, Selby DM, *et al*. Needs and workflow assessment prior to implementation of a digital pathology infrastructure for the US Air Force Medical Service. J Pathol Inform 2013;4:32.

Available FREE in open access from: http://www.jpathinformatics.org/text.asp?2013/4/1/32/122388

Abstract

Background: Advances in digital pathology are accelerating integration of this technology into anatomic pathology (AP). To optimize implementation and adoption of digital pathology systems within a large healthcare organization, initial assessment of both end user (pathologist) needs and organizational infrastructure are required. Contextual inquiry is a qualitative, user-centered tool for collecting, interpreting, and aggregating such detailed data about work practices that can be employed to help identify specific needs and requirements. **Aim:** Using contextual inquiry, the objective of this study was to identify the unique work practices and requirements in AP for the United States (US) Air Force Medical Service (AFMS) that had to be targeted in order to support their transition to digital pathology. **Subjects and Methods:** A pathology-centered observer team conducted 1.5 h interviews with a total of 24 AFMS pathologists and histology lab personnel at three large regional centers and one smaller peripheral AFMS pathology center using contextual inquiry guidelines. Findings were documented as notes and arranged into a hierarchal organization of common themes based on user-provided data, defined as an affinity diagram. These data were also organized into consolidated graphic models that characterized AFMS pathology work practices, structure, and requirements. **Results:** Over 1,200 recorded notes were grouped into an affinity diagram composed of 27 third-level, 10 second-level, and five main-level (workflow and workload distribution, quality, communication, military culture, and technology) categories. When combined with workflow and cultural models, the findings revealed that AFMS pathologists had needs that were unique to their military setting, when compared to civilian pathologists. These unique needs included having to serve a globally distributed patient population, transient staff, but a uniform information technology (IT) structure. **Conclusions:** The contextual inquiry method helped reveal similarities and key differences with civilian pathologists. Such an analysis helped identify specific instances that would benefit from implementing

digital pathology in a military environment. Employing digital pathology to facilitate workload distribution, secondary consultations, and quality assurance (over-reads) could help the AFMS deliver more accurate, efficient, and timely AP services at a global level.

Key words: Air force, anatomic pathology, consultation, contextual inquiry, digital pathology, informatics, workflow, workload distribution

Access this article online

Website: www.jpathinformatics.org

DOI: 10.4103/2153-3539.122388

Quick Response Code:

INTRODUCTION

Anatomic pathology (AP) has traditionally used a manual and complex batch workflow process. Recent efforts have been directed at automating and digitizing AP workflow and the mode of rendering a pathology diagnosis. These include the introduction of barcoding for labeling and tracking pathology assets[1] and computerization such as use of a laboratory information system (LIS).[2] A major recent transformation in AP has been triggered by the introduction of digital imaging, particularly the digitization of whole glass slides (i.e. scanning entire glass slides to create high-resolution digital images), also known as whole slide imaging (WSI) or virtual microscopy. Ongoing technology improvements in digital image acquisition and scanner devices, the development of user-friendly software for managing and viewing digital slides, emergence of computer-assisted image tools, and advances in information technology (IT) capabilities (such as increased computational power, mobile network connectivity, and increasingly affordable storage) are promoting the acceptance of digital slides into pathology practice.[3,4]

Use of digitized slides for managing, interpreting, analyzing, and archiving pathology information in digital format (i.e., digital pathology) can be leveraged to optimize workflow efficiency while maintaining diagnostic accuracy, thereby improving patient care and reducing costs. Digital pathology is currently used for a variety of diagnostic, educational, quality assurance (QA), and research applications.[5,6] Diagnostic use of digital images in the US is currently limited to validated clinical applications other than primary diagnosis that include niche, low-volume workflow processes such as secondary consultations (teleconsultations), remote interpretation of frozen sections, and archiving or sharing digital images for QA.[7-10] However, routine use of digital pathology for primary diagnosis in clinical practice in the United States (US) awaits approval/clearance by the Food and Drug Administration (FDA).[5,11]

Prior to introducing new technology such as digital pathology into a large healthcare organization, it is important to (1) analyze the existing environment including current workflow practices which may require modification, (2) assess potential benefits and any conceivable negative impact this technology may introduce, and (3) determine upfront the specific needs of key stakeholders to ensure their subsequent buy-in of this technology. This approach can help solve current limitations and optimize the future use of digital pathology within the organization. Therefore, it is important to document the tasks pathologists conduct throughout the AP workflow to achieve their clinical goals; identify the pathologist and pathology organization needs; and understand their unique technological, social, and organizational environment. The focus on people and their concerns related to anticipated transitions in their organization during the introduction of a "change" such as a new technology, known as "change management",[12,13] is becoming a significant factor for successful implementation and adoption of informatics systems within the healthcare setting.[14,15]

A variety of qualitative methods are available for understanding and capturing users' needs, including interviews, focus groups, and surveys or questionnaires. However, these methods can be complicated by interview bias, are subject to "political" manipulations, and require that users be aware and articulate their needs, problems, and work processes in detail. Contextual inquiry provides a qualitative methodology for understanding and capturing in detail aspects of work from the perspective of the user. Unlike other methods, contextual inquiry enables interviewers to uncover unarticulated, habitual work, knowledge, issues, and needs of the user.[16] The method focuses on four main principles: (1) Context—a team of observers (interviewers/researchers) visits the users' work place and carefully observes them performing their work; (2) Partnership—the observers and users obtain apprentice-master roles, respectively, as the users "teach" the observers how they do their work, while the observers ask questions about the work and their actions to help understand the users' motivation and strategy; (3) Interpretation—observers' understanding of the large number of notes/data documented during the visit via a structured analysis; (4) Focus—attention to observer team topics of interest.

Contextual inquiry has been applied as a user-centered support tool for the design and development of software, devices, and systems in various industries and settings. The medical/clinical setting is typically a complex work environment that may require and justify, even more so than in other industries, detailed evaluations of the actual work setting and needs prior to development of software, devices, and systems.[17] However, to date, contextual inquiry has been reported infrequently in the healthcare setting.[17] A few reports have documented the use of the contextual inquiry method to support design of medical devices[18] and clinical information software utilized by physicians, such as an antibiotic decision support system, a dictation system, and other IT tools.[19-23] A contextual inquiry study focusing on the workflow of pathologists within a large academic hospital network setting was recently reported and demonstrated how this methodology could support the design of digital pathology systems.[24]

As part of anticipated changes in the practice of pathology and intent to capitalize on the rapid advances being made in digital pathology, the United States (US) Air Force Medical Service (AFMS) is exploring efforts to introduce digital pathology to its pathology practice. As a first step in these efforts, under a congressional appropriations award to the University of Pittsburgh Medical Center, a model digital pathology network comprised of WSI systems was proposed for the larger AFMS pathology centers with the potential to expand to additional and smaller AFMS pathology centers in the future. To strategically design this model network, the contextual inquiry method was used to first explore and identify the unique needs and requirements of potential digital pathology system users—individual AFMS pathologists and their military healthcare organization. Needs and requirements revealed by this method were used to help target specific clinical applications that will likely benefit from adoption of digital pathology within the AFMS.

SUBJECTS AND METHODS

Context of Research: Study Population—AFMS Pathology

The AFMS pathology organization supports medical care for over 2.6 million patients. Pathology specimens are collected at 75 AFMS medical treatment facilities ranging from small clinics to larger US Air Force (USAF) base hospitals which are distributed across the US and abroad.[25] Specimens are typically centralized for processing and interpretation at one of 11 larger AFMS medical treatment facilities that have histology laboratories and pathologists on site. Four of the 11 labs are designated as larger regional centers that handle work from their USAF base hospital as well as specimens sent from several smaller medical facilities within the region that have no histology or pathology services of their own. The largest regional center serves as the main AFMS subspecialty/consulting center and supports the AFMS pathology residency training program. Approximately 50% of AFMS pathologists staff this consulting center and the majority of AFMS subspecialists are located at this facility [Table 1]. The three other regional centers are each staffed by five to eight pathologists, and occasionally may include one to three subspecialists. The seven smaller pathology centers are staffed by a minimum of two (typically two to four) general pathologists [Table 1].

Contextual Inquiry Study

Contextual inquiry interviews were conducted at four AFMS pathology laboratories/centers: Three regional pathology centers, including the AFMS subspecialty/teaching center; and one smaller, peripheral pathology center. Interviews and data interpretation were conducted by a research team consisting of an academic pathologist and up to five trained researchers from various backgrounds. The study focused on the main users within the AP workflow, AFMS pathologists, with an emphasis on their potential future use of digital pathology. The team followed contextual inquiry guidelines, data collection (interview/observation), and data interpretation, as published by Holtzblatt and Beyer.[16] This contextual inquiry study was part of a project approved as a quality improvement initiative by the AFMS and the University of Pittsburgh Medical Center quality improvement committees.

Data Collection: Interviews/Observations

Each research team member interviewed and observed three to six AFMS histology and pathology laboratory personnel (i.e. defined as users) during 2-day visits at each pathology center. Each contextual inquiry interview lasted approximately 90 min and typically a minimum of two observers attended each interview. During interviews, researchers collected general demographic information about the user (e.g., medical/pathology education, years of experience, subspecialty, and familiarity with digital pathology) and then they observed and questioned the users as they performed their daily routine within the AP lab. Researchers documented their findings using notes representing user-provided data. Anything that interrupted the user from accomplishing his work, such as breakdowns in communication, coordination, and operability of physical artifacts that interfered with the user's work, were captured as "breakdown" notes. In addition, design ideas were captured and generated based on user-provided insights about their needs. Following each interview, all notes documented during the observation session were collated into "affinity notes."

Data Interpretation

After completing the observation sessions, researchers met and analyzed the data. To help interpret and characterize the structure of the work practice at each

Table 1: Current distribution of pathologists across AFMS pathology centers

AFMS pathology centers	Pathologists (No.)									
	Total	General	Subspecialty							
			Forensic	Trans	Derm	GI	Oral	Hem	Mol	Neuro	Cyto
Regional centers											
Regional center 1 (teaching/ subspecialty center)	20	4	2	1	2	1	3	3		1	3
Regional center 2	8	5			1		1				1
Regional center 3	7	4		1	1		1				
Regional center 4	5	2					1		1		1
Total (regional centers)	40	15	2	2	4	1	6	3	1	1	5
Peripheral centers											
Peripheral center 1	5	5									
Peripheral center 2	2	2									
Peripheral center 3	2	2									
Peripheral center 4	2	2									
Peripheral center 5	2	2									
Peripheral center 6	2	2									
Peripheral center 7	2	2									
Total (peripheral centers)	17	17	0	0	0	0	0	0	0	0	0
Total (AFMS pathology)	**57**	**32**	**2**	**2**	**4**	**1**	**6**	**3**	**1**	**1**	**5**

AFMS: Air force medical service, Cyto: Cytopathology, Derm: Dermatopathology, GI: Gastrointesntinal, Hem: Hematopathology, Neuro: Neuropathology, Trans: Transfusion.

center, graphic models and a hierarchal organization of the affinity notes, termed an "affinity diagram", were developed. At the conclusion of all site visits and completion of all data interpretation consolidated graphic models and a consolidated affinity diagram were created to represent the structure of work practices for the AFMS pathology population as a whole.

Graphic Models

Five graphical models were created and included sequence, flow, artifact, physical, and cultural models. Each model represented a different perspective of the users' work practices.

The sequence model documented in a step-by-step manner the tasks (either observed or mentioned during the interviews) required for completing the work. This model represented the key strategies and order of activities required to complete the job. The artifact model illustrated with actual pictures and/or forms the equipment and documents required to do the job. The *physical* model represented the physical layout of the work environment via drawings or photographs. The flow model captured and visualized the various users' responsibilities, communication, and coordination of data, and strategies required to do their job. The cultural model revealed influences on a person conducting the work by either people or policies external or internal to the organization/ population. Both the cultural and flow models helped illustrate and understand the users' environment and aided in revealing the unique needs and practices of the AFMS pathologists and the AFMS pathology organization as a whole. As the main intent of this study was to identify the unique needs and requirements of pathologists in a military setting, only the cultural and flow models and the affinity diagram are provided in this report.

Affinity Diagram

The "affinity diagram" was used to identify common issues, work patterns, and needs of users (i.e., AFMS pathologists) and the organization (i.e., AFMS pathology). Affinity notes documented during the first site visit were placed on "post-its", posted on a wall, and organized into various categories and subcategories based on common, emerging themes. Affinity notes documented during subsequent site visits were placed on post-its and organized under the main categories developed following the first site visit. Following all site visits, hierarchal categories created after the first visit were modified slightly to represent observations common to all four sites. To create the final consolidated AFMS affinity diagram, team members created general statements that encompassed the information obtained at all sites. Affinity notes from each site that supported each general statement were organized underneath the statement.

RESULTS

Demographics of Study Participants

A total of 24 pathologists were observed at the four participating AFMS pathology centers. The majority

of pathologists who participated in the study were general pathologists with less than 5 years of pathology experience [Table 2].

Affinity Diagram

A total of 1,255 affinity notes were documented during visits to the four AFMS pathology centers (572 notes at the first site, followed by 322, 238, and 123 notes at the second, third, and fourth sites, respectively). From these original affinity notes, 74 generalized statements were created. The generalized statements were catalogued into 26 third-level, 10 second-level, and finally into five main-level categories. The five main-level categories included: Workflow and workload distribution, quality, communication, military culture, and technology.

A condensed version of the AFMS consolidated affinity diagram, including the three levels of categories, is provided in Supplement 1. Within the affinity diagram, third-level categories that represent needs and requirements that may be supported and improved by digital pathology are labeled in Italics.

Flow Model

The consolidated flow model described the flow of responsibilities, communication, and coordination of data between all users and systems within the AP workflow. The AP workflow was broken down into preanalytic (specimen collected by clinicians), analytic (specimen processing and evaluation to provide a diagnosis), and postanalytic (delivery of a final report to the clinician) phases. Figure 1 represents a schematic presentation of the consolidated flow model. The AP workflow centered on the pathologist. The pathologist interacted with all other individuals and groups within the AP workflow, including histotechnologists, clinicians, residents/fellows at the teaching center, other pathologists located on site or at other AFMS pathology centers, and administrative support staff (assistants and transcriptionists). In addition, pathologists also interacted with individuals and groups outside of the organization (i.e., commercial reference laboratories and external pathology experts at the Joint Pathology Center (JPC), the federal government's pathology reference center, or in academia).

Table 2: Demographics (AFMS participants)

	No.
Pathologists, total[a]	24
General	15
Subspecialists	
Dermatopathology	3
Cytopathology[a]	3
Hematopathology	1
Gastrointestinal	1
Oral	1
Pathology residents	4
Histotechnologist/histology supervisors	8
Administrative support	1
Experience (pathologists)[a,b]	
<5 years	16
5-10 years	1
>10 years	7

[a]Including fellows in training, [b]For subspecialists: Years of experience as a subspecialist.

The consolidated flow model [Figure 1] documents the key events involved in the AFMS AP workflow, including the routine, daily sign-out workflow, as well as two additional workflows used by the AFMS pathologists to help assure accurate and quality diagnoses—consultations and QA. Routine sign-out workflow within the AFMS was not significantly different than routine sign-out workflows in civilian academic centers, which were previously documented in detail,[24] and therefore not detailed in this report. However, additional details are provided in this report for other, non-routine but commonly used AP workflows—consultations and QA workflows.

Consultations Workflow

Pathologists frequently provided and/or requested second opinions/consultations on unusual, complex, and/or challenging cases. Internal, informal peer-review consultations were conducted with pathologists at each site. Cases were shared informally during routine daily or weekly pathology/histology team or subspecialty/multidisciplinary team conferences, with glass slides relevant to the case viewed with other pathologists using a multiple headed microscope. "Curbside" consultations were requested on an as-needed basis; pathologists typically walked to the office of another pathology colleague, requesting him/her to view the slides and provide his/her opinion.

Formal requests for second opinion consultations by external expert subspecialty pathologists were conducted on 2-4% of all AFMS cases. These formal requests required shipping of the relevant glass slides and their supporting case documentation (i.e., clinical history and paper requisition sheet) from the originating pathologist to the external expert pathologist. These requests were sent either to experts located within the AFMS network (typically located at the AFMS pathology subspecialty/teaching center or occasionally at one of the other regional centers), the JPC, or a preferred civilian/academic medical center. Consultation requests sent to the JPC or to AFMS subspecialists were performed without cost. Each pathology center determined its own list of "preferred" consulting institutions and expert subspecialty pathologists within the AFMS and with civilian medical centers. Formal consult requests were manually tracked by an administrative assistant, a histotechnologist, or the requesting pathologist, using a paper shipping log.

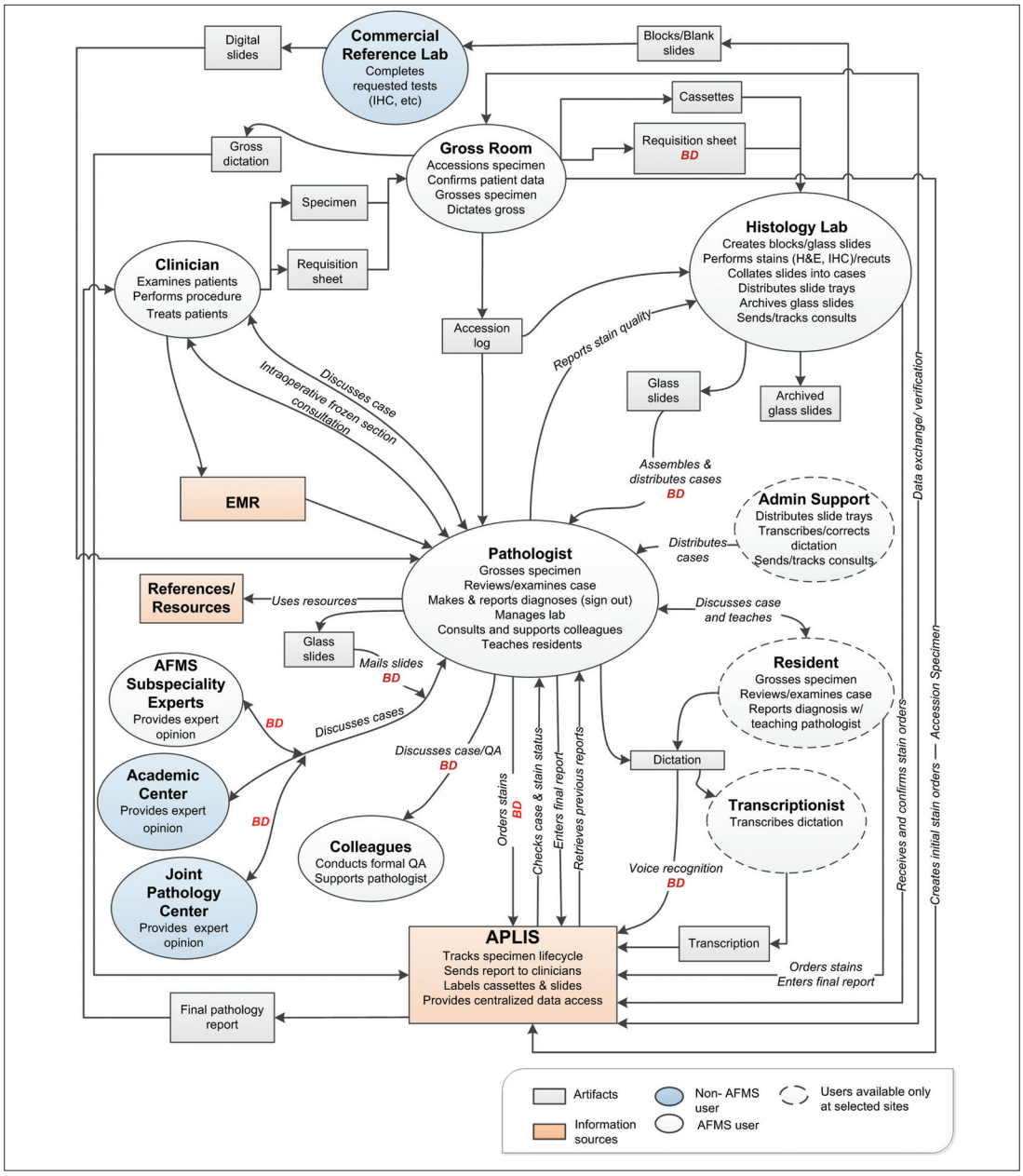

Figure 1: Consolidated flow model. The consolidated flow model documents the flow of information and artifacts between all users involved in the AP workflow. Breakdowns are indicated as BD (red). Circles represent individuals and/or well-defined user groups; rectangles represent information sources and artifacts/items of communication. APLIS= Anatomic pathology laboratory information system; EMR=Electronic medical record; QA=Quality assurance

Breakdowns in communication, coordination, and operability that interrupted or delayed the pathologist review and interpretation of slides were documented and highlighted areas of the AP workflow that may need improvement. The following breakdowns were noted: (1) Long turnaround time for formal consultations due to the current time-consuming practice of packing and shipping glass slides via mail followed by a manual tracking of consults; (2) AFMS "legacy" LIS and limited manpower/resources—although formal consults were documented in the LIS, tracking consults and obtaining reports for this data was challenging; and (3) lack of onsite pathology experience and/or subspecialty expertise—pathologists with less experience occasionally conducted formal consultations on less complex cases because they did not have easy access to a second opinion from a more experienced or subspecialty pathologist. As noted by one pathologist, "for the majority of consult requests, I am 95% confident about the diagnosis; however, without anyone to consult with on site, I may feel the need to request a consult on a case that is not necessarily complex"; (4) isolation—occasionally lack of familiarity with AFMS subspecialty pathology experts at other pathology centers (see cultural model) led to

limited use of no-cost AFMS resources, thereby involving costly consultations with external experts; and (5) lost glass slides—glass slides sent out for formal consultations were occasionally lost in the mail or not returned to the original pathologist/pathology center.

QA Program Workflow

To reduce the rate of diagnostic discrepancy and ensure "standard of care" in AP, QA programs are frequently conducted both prior to and after providing a diagnosis. Throughout the AFMS organization, a formal prospective QA review process was implemented requiring mandatory second opinion reviews, typically of a pathology colleague on site, prior to sign-out of first-time cancer diagnoses, fine needle aspirations, and core biopsies. Random retrospective auditing of 10% of AP cases reviewed at each pathology center was conducted as well.

Each center conducted QA processes for cases processed and interpreted by pathologists available on site; QA processes were not shared between the various AFMS pathology centers. At some centers QA was managed by a pathologist assigned to perform the daily QA functions, while at other centers any pathologist on site provided QA as needed.

Breakdowns: Isolation—pathologists currently do not feel at ease with an AFMS-wide QA process due to unfamiliarity of pathologists at other bases.

Cultural Model

The consolidated cultural model [Figure 2] represents the influences of individuals and groups as well as the unique infrastructure, policies, and values of the organization (i.e., the USAF and its healthcare organization, the AFMS) on the AFMS pathologist. This model provided the most essential information for our study: It provided key details about the unique limitations and distinct advantages of the USAF/military culture on AFMS pathologists and the pathology organization. It also underscored the opportunity for digital pathology to improve many current AFMS pathology limitations.

AFMS pathologists, similar to pathologists in civilian healthcare organizations,[24] were influenced by other users within the specimen lifecycle (e.g. the histology lab, commercial reference labs, and clinicians) and by hospital information systems such as the LIS. Unlike pathologists in civilian healthcare organizations, however, AFMS pathologists were also influenced by the unique and complex organizational structure and staff recruitment patterns of the USAF and the AFMS.

Organizational Structure

The primary mission of the USAF organization was "Fly and Fight." Therefore, the goal of its medical organization, the AFMS was to support the well-being and medical treatment of those who fly and flight and to ensure quick return to active duty. In addition to

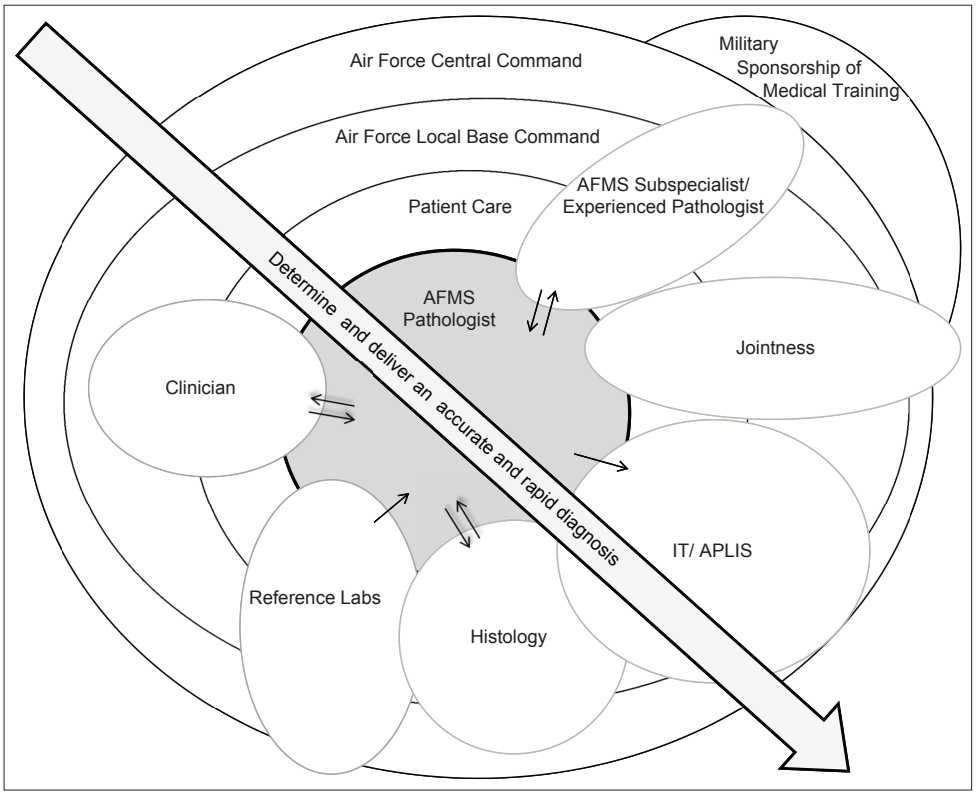

Figure 2: Consolidated cultural model. The cultural model shows the influences on the AFMS pathologist. The arrow represents the main goal of the pathologist. The various values, policies, users and other factors that influence the pathologist are represented as overlapping circles.

their clinical/lab responsibilities, both pathologists and histotechnologists, as enlisted USAF servicemen, were expected to continuously perform other military duties and trainings.

The AFMS pathology organization was influenced and functioned under multiple USAF organization leadership levels (i.e., command levels) and responsibilities. For example, AFMS-wide policies and long-term plans, such as long-range staffing practices for pathologists and histotechnologists (see details below), were created at the central command level. However, local commanders of AFMS medical treatment facilities as well as commanders of the USAF bases where the medical facilities were located had flexibility to determine the method of implementing central command level policies within their medical facility/base. As such, AFMS pathology centers operated independently and this seemed to reinforce pathologists' lack of familiarity with pathologists and routines at other centers. One pathologist mentioned, "I don't know why we don't send our dermatopathology consults in house (i.e., to AFMS dermatopathologists located at other bases); sending them out is the legacy way it's been done at this base."

Unique Staffing / Personnel

The AFMS had a unique staffing pipeline with complicated long-term pathology and histology staffing practices. This impacted demographics and staff turnover levels for both histotechnologists and pathologists. Histotechnologists were either enlisted or civilian contractors. Enlisted histotechnologists were generally very young with an assigned cycle of 3-4 years within the histology lab, prior to being transferred to other military-appointed assignments. All AFMS pathologists were active duty commissioned officers. Their commitment to military service was based on pay-back time for medical training sponsorship by the USAF and/or other military scholarship programs. After meeting their minimal service commitment, typically after 4-8 years of service, most AFMS pathologists left the USAF and moved into civilian practice. Some AFMS pathologists chose to continue to serve in the USAF, commonly until retirement from the military (at least 20 years of service). At any point in time, it was difficult to predict the number of current AFMS pathologists who would continue to serve in the USAF beyond their required commitment. To replace the departing pathologists, new pathologists needed to be recruited to serve in the USAF at least about 4–8 years in advance. This resulted in fluctuations between overstaffing and understaffing of pathologists, subspecialty expertise, and histotechnologists. Therefore, it was difficult to maintain a consistent specimen to pathologist ratio within the AFMS pathology organization compared to a civilian healthcare organization. At times of overstaffing, pathologists were under-utilized and worried that they would not be able to maintain their pathology skills with one pathologist commenting, "we need to have enough cases to keep up proficiency as pathologists."

Pathology and Subspecialty Experience and Coverage Imbalance

Most AFMS pathologists engaged with the AFMS service immediately after completing their medical training. Therefore, the majority of AFMS pathologists were young, general pathologists with less than 5 years of experience. Pathology subspecialists were also recruited by the AFMS; the majority of subspecialists were located at the largest center, the AFMS subspecialty/consulting center. It was difficult to maintain proper subspecialty coverage within AFMS as at times certain surgical pathology subspecialties were over or under-represented. For example, currently the AFMS does not have an obstetrics/gynecologic subspecialist [Table 1].

Other Factors

An additional factor that complicated AFMS pathology staffing was the trend of "jointness" between the USAF and other US military branches, resulting in ongoing efforts to strategically merge and share healthcare services and practices as well as resources throughout the military.

DISCUSSION

This study used the contextual inquiry method to evaluate existing AP workflow and user needs in order to support the future implementation of a WSI-based digital pathology network within the AFMS. This method was constructive in documenting current unique practices and identifying the needs and constraints of the AFMS pathology organization and the pathologists who work within this organization. Data about AP workflow practices and needs within the AFMS pathology department compiled according to this method permitted our workgroup to determine which pathology workflow applications were most appropriate to convert to a digital-based system.

New technologies such as WSI and digital image analysis are poised to fundamentally change the way pathology is practiced, for both the pathology organization and the pathologists who work within the organization.[26] However, before this can happen an understanding of AP workflow science and pathologists' needs are necessary to help pathologists better prepare to adopt the technology.[1,27-33] Understanding the unique healthcare and pathology organization setting should be taken in consideration in order to better support the design and implementation of digital pathology throughout an organization, especially a large healthcare setting.

Our study showed that the contextual inquiry method revealed current needs and challenges of AFMS pathologists that can be potentially supported and/

or improved by the adoption of digital pathology. As anticipated, many needs were very similar to those of their colleagues in a large civilian academic healthcare setting, as identified using the same contextual inquiry method.[24] Similar needs were having to deliver accurate diagnoses in a timely fashion, as well as to conduct QA (over-reads) and consult with other pathologists, particularly expert subspecialists. In addition, similar to academic civilian pathologists, the main challenges within the current AP workflow included a highly manual tracking process of cases and specimens.

The main advantage of using the contextual inquiry method in our study was the ability to uncover unarticulated issues and work practices unique to the culture and structure of the military. Attention to the culture of an organization and its people are key components of "change management" theory, involving effective strategies to facilitate adoption of new technologies in organizations, including healthcare.[14,15] The AFMS organization is a large healthcare organization with a global reach; it provides services over a large geographical area, with pathology centers and pathologists distributed worldwide. The USAF has a uniform IT infrastructure that includes a common enterprise-wide hospital information system enabling electronic physician order entry, a single electronic medical record (EMR), and a common LIS system. Contextual inquiry revealed that each of the pathology labs within this large organization operated as independent centers, typically underutilizing the resources, strengths, and expertise of other pathologists and pathology centers within the AFMS organization. Use of digital pathology may help streamline and increase utilization of internal AFMS resources, thereby offering cost savings. Contextual inquiry also showed an uneven distribution of experience and subspecialist expertise across the globally distributed organization. The majority of young, general pathologists were located at the smaller peripheral pathology centers, while the more experienced and subspecialty expert pathologists were located at one pathology center, the teaching/subspecialty center. The ability of digital pathology to improve the uneven distribution of pathology expertise was previously reported within pathology departments supporting healthcare services in large and widespread rural areas in Canada.[34]

Other key, and mainly unarticulated, AFMS pathology issues were uncovered by the contextual inquiry method, including the unique demographics of AFMS pathology and histology personnel (i.e., pathologists and histotechnologists) and the influence of these demographics and the military/USAF culture and organizational structure on the AP workflow. We uncovered a high and unpredictable turnover of histotechnologists and pathologists as compared to civilian healthcare settings. In addition, we found that the unique demographics of the AFMS pathologists, (i.e. mostly young, general pathologists) was, in part, an outcome of the unique recruitment process of pathologists and physicians into AFMS. Both findings complicate the AFMS's ability to predict the number of pathologists that will depart from service, and therefore this complicates the preparation of long-term histology and pathology staffing plans required to support future AFMS pathology needs. The ability to maintain a consistent ratio of pathologists to pathology specimens within the AFMS is limited as compared to pathology labs within large civilian healthcare organizations. As such, the AFMS experiences a greater fluctuation between times of overstaffing and understaffing of pathologists and subspecialty expertise. Digital pathology can offer solutions to improve and ensure a consistent pathologist-to-specimen ratio (see below).

Targets for Future Digital-Based AP Workflow and Clinical Applications within AFMS Pathology

Study findings suggest that the AFMS pathology organization is positioned to benefit greatly from the adoption and implementation of digital pathology. Although digital pathology will enhance AP workflow efficiency for the individual AFMS pathologist by eliminating manual steps such as "case assembly",[35] major efficiency benefits and enhancement of AP workflow can be experienced within the AFMS pathology organization because digital images are easy to share and transmit. Establishment of a digital pathology network will increase organization-wide efficiency as it will help leverage histology and pathology personnel and laboratory resources across the entire AFMS pathology organization. Pathologists will have the ability to retain a high level of pathology proficiency through access to cases not available in their day-to-day practice. More frequent communications among AFMS pathologists can foster an increased sense of community, potentially enhancing job satisfaction. This may lead to higher retention rates of AFMS pathologists following completion of their required service commitment—decreasing personnel turnaround and capturing developmental experience within the organization. AP workflows and clinical applications within the AFMS that will achieve the greatest benefits were identified as a global workload distribution, secondary consultations, and QA.

Global Workload Distribution

The introduction of digital pathology could enable a global work distribution model for AFMS pathology, independent of the geographical location of its pathology centers and location-related staffing needs and expertise. As digital pathology has the capability to decouple pathologists from histology labs and support a more efficient workload distribution, it may offer new opportunities to improve workflow and staffing plans. Introduction of a digital

pathology network can possibly eliminate the need to staff AFMS pathology centers according to each center's volume and type of specimens. It may also allow centralization of histology lab services, mainly immunohistochemical tests, thereby reducing needs and costs to maintain multiple histology labs across the organization as well as reducing the needs for costly commercial reference laboratories. Digitized cases could easily be shared with multiple subspecialists located at any AFMS pathology lab, permitting decentralization of the increasing number of subspecialists across the AFMS. It may also eliminate the need to staff a minimum of two pathologists at each site, currently required to ensure coverage and the ability to conduct quick informal consults as well as QA (e.g., first time malignancy diagnoses). With implementation of digital pathology and a workload distribution model, centers could reduce the minimal number of pathologists on site to one (for frozen sections, etc.). For example, currently 57 pathologists and subspecialists are distributed across 11 centers located worldwide [Table 1] based on the type and number of specimen processed at each center, with a wide variation in specimen to pathologist ratio between centers. Approximately a total of 70,000 specimens were accessioned within the AFMS during 2012. At a ratio of 2,000 specimens per pathologist, the AFMS requires 35 pathologists, thereby giving an overage of 12 pathologists. The overage is partly due to the difficulty predicting future pathologist pipeline, but is also partly due to the general requirement to employ at least two pathologists per histology lab. Following implementation of digital pathology network, a workload distribution model will enable a more uniform ratio of pathologist-to-specimen across the organization. Administrators could either decrease or increase the number of pathologists at each particular lab based on the needs of the AFMS as a whole rather than the volume of specimens at each lab.

Secondary Consultations

Adoption of digital pathology within the AFMS will enable remote viewing of digital slides, thereby offering consultation and collaboration between AFMS pathologists regardless of location. Younger, less experienced pathologists will have rapid access to more experienced AFMS pathologists and subspecialty expertise, in consequence promoting increased requests for informal consultations within the AFMS as well as increased utilization of AFMS experience and subspecialty expertise. Digital pathology will further support the practice of virtual centers of excellence model within the AFMS, a trend currently used at various academic pathology centers throughout the US. Subspecialists will be able to conduct quick consultations on a regular basis or through routine virtual conferences between domain experts located at various labs across the AFMS.

QA

Digital pathology can be utilized to distribute work for QA purposes (over-reads) across the entire AFMS pathology organization. This will promote standardization of diagnoses, reduce errors, and improve accuracy.

In conclusion, based on contextual inquiry findings, adoption of digital pathology within the AFMS pathology organization, which serves a large and globally distributed healthcare service, will significantly benefit pathologists, their pathology/healthcare organization, and their patients. Digital pathology will allow better utilization of internal resources within the AFMS, prevent the need for purposeful overstaffing, and reduce the need for utilization of reference laboratories. Based on the unique needs of the AFMS, the AP clinical applications and workflow processes best positioned to benefit from digital pathology are consultations, QA, and an AFMS pathology organization-wide workload distribution model.

ACKNOWLEDGMENT

This material is based on research sponsored by 711th Human Performance Wing, Air Force Research Laboratory under agreement number FA7014-10-2-0004. The US government is authorized to reproduce and distribute reprints for government purposes notwithstanding any copyright notation thereon. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of 711th Human Performance Wing, Air Force Research Laboratory or the U.S. Government.

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