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Review
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Digital Pathology – Practicing Pathology Without Borders

ABSTRACT:

Digital Pathology (DP) is the capture of high-quality images of glass slides as a whole slide imaging (WSI) with the help of scanners followed by analysis and interpretation of images by Pathologists utilizing image management software (IMS) with or without the help of artificial intelligence (AI) tools and algorithms. These images are digitally stored (usually in the cloud) and available instantaneously, archived for short term and long-term storage. Based on organizational goals; the DP has been utilized in primary diagnosis, frozen sections interpretation, second opinion/consultation, workflow efficiency, teaching, education, research and data analytics. Like any other new healthcare technology; it has some limitations and challenges. In this article, we will review how pathology groups can adopt DP in routine clinical practice, what are barriers that can be avoided and factors that will help understand the digital roadmap readiness making its adoption seamless by Pathologists.

KEYWORDS: *Digital Pathology, Artificial Intelligence, Anatomic Pathology, Whole Slide Imaging, Image Management Software*

INTRODUCTION:

Anatomic Pathology is an integral part of clinical medicine and impacts patient care with diagnosis, treatment, prognosis and recurrence of diseases. Decades ago three simple diagnoses of carcinomas, lymphomas and sarcomas were rendered using routine single eyepiece light microscope to the current day and age technology with precision medicine and expectation to diagnose various cancer subtypes utilizing genomic data and smart AI driven algorithms; the field of pathology has evolved immensely. Pathologists have adapted to technologies over the period time starting from electron microscope, immunohistochemistry, flow cytometry, polymerase chain reaction (PCR) and to next generation sequencing (NGS). In recent years, the traditional practice of pathology of making and reading slides by on-site pathologists is changing due to not keeping up with supply and demand balance in healthcare thus impacting efficiency, delay in care and limited access to consultants. As information technology (IT) has evolved into cloud-based solutions for various health care fields such as radiology; there is paradigm shift of DP, with pathology practices are on path to digitization. Even though the investment is significant and at this time there is no direct reimbursement; the workflow/staffing efficiency, minimizing human errors, improving productivity in revenue cycle management (RCM) and data analytics are valuable factors and organizations are taking adoption of DP as a priority and aligning with future in health care (see Table 1).

Table 1: Why Do We Need Digital Pathology?

1. Organizational Goals
2. Pathologists' shortage and centralized hub of slides
3. Consultation and second opinion
4. Shipping cost/delays
5. Cloud based archiving of slides and data analytics
6. Expansion without borders
7. Stay on top of technology

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Light Microscopy and Current Practice

Traditionally, pathology labs gross tissue samples and make Hematoxylin and Eosin (H&E) glass slides that are reviewed by on-site pathologists. Microscopic evaluation performed, diagnosis rendered, and reports are generated. This practice has been accompanied by inherent limitations such as the physical nature of glass slides, transportation, storage and retrieval of slides. In addition, underserved areas have limited access to expertise for second opinion that adds shipment and delay. Even though pathologists are well trained, the presence of subjectivity leads to potential human error and variability among different observers that includes variations in the interpretation of slides by other pathologists, resulting in diagnosis discrepancies.

Foundation of Digital Pathology

Even though the concept and use of DP have been in the literature for past two decades; recent COVID-19 pandemic have brought the need and awareness of DP to the forefront (1, 2). The combination of technological advancements, diagnostic accuracy and workflow efficiency have led many to believe to invest in DP that is revolutionizing the field of pathology (Table 2).

Table 2: Components for Successful Launch of Digital Pathology

1. Cloud based Laboratory Information System
2. Anatomic Pathology Tracking
3. Barcode implementation
4. Immunohistochemistry
5. Scanners
6. Software - Information Management System
7. Cloud Based Storage
8. IT – Integration and Data management

Two major aspects that are critical in DP are whole slide imagining (WSI), image analysis with AI application.

a) Whole Slide Imaging is a critical component of DP and a key factor in embracing the technology by Pathologists. WSI technology utilizes high quality scanners (hardware) to capture entire tissue sections on glass slides into digital images that are analyzed and interpreted by pathologists using various Image Management Systems - IMSs (software). The digitized images preserve the fine cellular structures evaluated observed on physical slides, replicating the experience of using a conventional microscope. The DP has ability to navigate microscopic depth at different magnifications digitally. This eliminates the limitations imposed by physical slides and improves diagnostic accuracy.

b) Image Analysis is the second essential component of DP, when evaluating WSI images. By leveraging the capabilities of AI and machine learning, algorithms can detect, quantify, and classify disease and abnormalities present in digital images. The importance of image analysis is superior to manual evaluation, as AI algorithms can quickly process large datasets, leading to efficient and unbiased evaluation. This technological advancement can potentially decrease interobserver variability, thereby enhancing diagnostic precision.

Advantages of Digitizing Pathology Slides

1. Digitization can help with logistical challenges regarding physical storage of slides
2. Efficient retrieval of digitized slides from the cloud
3. Enhanced remote access of slides by pathologists irrespective of geographical location
4. Effective platform for second opinion and consultation and collaboration with various sub-specialties
5. Digital repositories of pathological images for education and teaching

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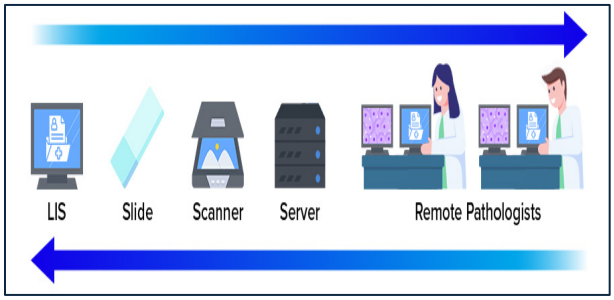
6. Research Opportunities. Integration of images with image analysis and AI tools has the potential to discover new biomarkers, prognostic indicators, and therapeutic targets.

Hardware and Software

The application of DP requires integration with high quality/high throughput scanners, cloud-based Laboratory Information System (LIS), use of barcode technology, and IMS software. This integration is typically bidirectional so the information between LIS and IMS flows seamlessly. This will help adopting of DP by pathologists and end users. Scanners, IMS and LIS need to be agnostics to each other and planning ahead with comprehensive technical map with the help of IT team and other stakeholders is critical for a meaningful experience and better outcome. (See Figure 1).

Figure 1: High Level Technical Overview of Digital Pathology



DIGITAL PATHOLOGY AND APPLICATION OF ARTIFICIAL INTELLIGENCE

Power AI in DP has significantly transformed pathologic diagnosis with precision and avoid diagnostic discrepancies. The fundamental aspect of this machine learning is the capability of AI to analyze extensive datasets, evaluate complex patterns, enhance diagnosis and predict prognosis that is beyond human brain and comprehension thus optimizing the process of making informed decisions. Pathological images can be overlaid with immunostains for precise evaluation of lesions. Increasing number of pathology practices are adopting AI tools especially in the fields of breast, prostate, GI, dermatopathology and other tumor prognostic markers. In addition, AI algorithms can analyze patient histories, images of pathological slides and predict prognosis assisting pathologists in determining the most effective treatment and clinical outcome (3,4)

CHALLENGES AND CONSIDERATIONS

With technological advancement, the DP presents significant opportunities for transformative advancements in pathology diagnosis before it can be implemented in routine clinical care. Such considerations include – validation for primary diagnosis, standardization of the process, regulatory compliance, data security, pathologists training and competency, integration with LIS and understanding AI-drive recommendation and establishing training program (5). (See Table 3).

Table 3: Questions and Challenges

1. Diagnostic accuracy
2. Validation
3. Smart Algorithm and Bias
4. Ethics
5. Compliance
6. Data Management
7. Data Security

CONCLUSION

The future of DP is bright. A well-planned roadmap with all stakeholders (health care providers, staff, executives and technical team) involved is an important first step when setting expectations. Careful selection of scanners, IMS software and its integration with LIS are key components for successful end-user experience. With proper validation, understanding AI tools, securing data, good training program, ensuring compliance and addressing ethical concerns – the use of DP have a potential of positive impact in patient care and diagnosis and will improve workflow efficiency for pathology groups. The DP is not going to replace

pathologists but sure will replace those who will fail to embrace this technology.

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Disclosures: None