MAYO CLINIC PROCEEDINGS: DIGITAL HEALTH

Digital and Computational Pathology: What a Time to Be Alive!

There is no doubt that the field of pathology is undergoing radical transformation, thanks to its digitalization and the emergence of artificial intelligence (AI). What was once a discipline that was heavily reliant on manual examination and interpretation under the microscope is rapidly entering an era where vast amounts of data will increasingly be managed in entirely digital workflows and analyzed with unprecedented precision and efficiency. The incorporation of AI and other digital tools is reshaping the specialty in a way that is not merely an incremental change, but a revolutionary leap forward.

The rise of fully digital laboratory environments, coupled with a growing array of AI-driven diagnostic tools, is set to streamline tasks for pathologists by expediting turnaround times, minimizing errors, and offering a comprehensive view of patient data. These advancements promise to boost the efficiency of pathology workflows and enhance patient care quality by providing more quantitative, accurate, and consistent diagnoses.[1] Furthermore, the incursion of digitalization and AI into pathology is set to reshape the very structure of pathology departments and their workforce dynamics, bestowing new roles upon both pathologists and technicians.

In the vast tapestry of medical evolution, it is a rare spectacle to witness a discipline undergo a transformation as fast and as profound as the one we are currently seeing with pathology. This rapid metamorphosis can be attributed to a synchrony of technological advances: the emergence of new hardware tools, such as digital slide scanners, alongside improvements in software, specifically neural networks that are specialized in analysis and interpretation of imaging data. Coupled with enhanced solutions for efficient storage and management of whole-slide images (WSI), these advancements are almost simultaneous and push the discipline into uncharted territories.

The timely article by Qureshi et al[2] published in this issue of *Mayo Clinic Proceedings: Digital Health* offers a valuable compass for navigating this journey. It combs through the literature, casting light on areas that are primed for an early adoption of Digital and Computational Pathology (DCP), while also highlighting the most pressing challenges on the horizon.

After reviewing the current landscape of digital slide scanners and WSI viewers and formats, the authors delve into the recent literature and identify the hottest areas of research in DCP, which suggest a potential for an earlier adoption in clinical settings. Among these, their work discusses applications such as case prioritization and abnormality detection for guiding pathologists' focus to more urgent cases and crucial image regions, quality control of scanned WSIs, detection and quantification of cells and prognostic biomarkers, or content-based image retrieval,[3] ie, retrieval of similar cases for a particular query study, with potential to provide statistical data as well as prognostic information.

Yet, intertwined with these promising arenas are inherent challenges that the field must face. The dearth of algorithms currently available in regular clinical use makes it very difficult to accurately evaluate their real impact in a hospital setting.[4] Nonetheless, ethical concerns regarding the possibility of breaches in data privacy, inherent biases in algorithms, potential harm caused by incorrect AI-generated results, aggravation of disparities in healthcare, and possibility of AI use leading to deskilling of pathologists have been raised.[5] Qureshi et al[6] further comment on issues such as ensuring reproducibility of AI outcomes across different labs, addressing cross-scanner discrepancies and variations in display, common hurdles in digitalization adoption which prominently include staff training, and legal and regulatory implications of computational pathology tools, such as

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those involved in explainability of AI outcomes. Moreover, it is essential to address the economic implications of the implementation of AI in hospital settings. The process encompasses not only the deployment of the actual algorithms, but also the potential acquisition of specific hardware and software, training of the staff operating the newly acquired technology, integration of the new tools with the already existing workflow, and additional costs related to system updates, maintenance, and monitoring. These considerations might exacerbate the existing disparities within the healthcare systems, as some hospitals will inevitably find it challenging to bear the considerable upfront costs of DCP implementation. Nonetheless, this investment can prove profitable, as shown in the analysis by Griffin and Treanor[7] and as reported by the increased efficiency of results obtained at the Granada University Hospitals[8] and the Memorial Sloan Kettering Cancer Center[9] after implementing digital pathology.

The potential benefits of widespread adoption of DCP are compelling, making it well worth the effort to overcome the associated challenges. The efficiencies of DCP promise to bridge the growing gap between the escalating demand for studies and the scarcity of pathologists, whereas the potential for more quantitative, precise, and reproducible diagnoses will definitely impact patient management for the better. Also, speeding up manual, repetitive tasks, such as cell counting, will ensure the optimal allocation of human expertise where it is most needed, allowing pathologists to participate in more valuable tasks, such as analysis of complex cases and engaging in multidisciplinary boards or research activities. Additionally, as highlighted by Qureshi et al, the quantitative capabilities of DCP might unveil new biomarkers in pathology images that remain imperceptible to the human eye. This concept, referred to as "pathomics,"[10,11] might hold significant potential for diagnostic and prognostic insights.

Although all of this may sound like a vision from the distant future, it is not as far off as one might think. In fact, experts in the field believe that by 2030, this will be the day-to-day reality for most pathology departments.[12] In the midst of all these breakthroughs, one cannot help but echo the sentiment, "What a time to be alive!" The novelties poised to emerge in DCP in the near future are electrifying. This journal, committed to its mission *to provide a platform for investigators, clinicians, and investigators to share in the disruptive transformation of medical practice through digital health advances*,[13] will undoubtedly be a leading platform for chronicling the advancements and breakthroughs within the realm of DCP.

The current advancements are paving the way for this transformative change. In this regard, the article by Qureshi et al very nicely serves as a foundational touchstone, capturing the current state of DCP in the inaugural year of this Journal. Assuredly, this publication will remain at the forefront, closely monitoring the evolution of this discipline.

What an era to witness, and indeed, what a time to be alive in the world of Digital and Computational Pathology.

POTENTIAL COMPETING INTERESTS

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