Impact of Artificial Intelligence-Assisted Pathology on Patient Healthcare: Literature Review

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Abstract: Artificial Intelligence (AI) in pathology, especially in immunohistochemistry (IHC), exceeds human visual capabilities, enhancing precision and incorporating geographical aspects. Our research reviews the impact of AI, focusing on improved diagnostic accuracy and speed. Digital pathology emerges as an innovative solution, employing AI algorithms for tasks like segmentation and prognosis. Despite their benefits, challenges arise in adopting AI and digital pathology in pathology labs. In conclusion, these advancements offer significant benefits, enabling spatial analysis and providing accurate, impartial results, accessible remotely by pathologists.

1 INTRODUCTION

Artificial intelligence (AI)–based pathology has enabled us to investigate and obtain information that goes beyond what humans can see with their eyes. It enhances the precision of measurements and makes it possible to consider the geographical aspects of data by using special mathematical techniques (Jubb, A. M., et al., 2014). Including spatial measurements in immunohistochemistry (IHC) can enhance the practical significance of methods for identifying biomarkers (Carbone, D. P. et al., 2017).

2 METHODOLOGY

Our research consists of a thorough examination of existing literature to explore the outcomes of integrating artificial intelligence into pathology. Our goal is to clarify how artificial intelligence affects the accuracy and speed of diagnosing and predicting outcomes in pathology.

3 RESULTS AND DISCUSSION

3.1 Digital Pathology Era

Efforts to address the difficulties encountered with conventional pathology techniques have given rise to the creation and acceptance of digital pathology, an innovative imaging system in the digital age. Recent advancements in pathology address challenges through innovative imaging technologies and whole slide image (WSI) scanners. These systems, exemplified by Philips IntelliSite Pathology Solution and Leica Aperio AT2 DX System, facilitate the digitalization of pathology. WSI scanners rapidly capture and digitally stitch multiple tissue section images, allowing pathologists to review comprehensive WSIs on computer monitors, marking a transformative shift toward digital pathology (Pantanowitz, L. et al., 2013) - (Food and Drug Administration, 2019).

3.2 Quantitative Analysis of WSI

Digital image analysis in pathology swiftly and accurately identifies and quantifies cell types,

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evaluating histological features, morphological patterns, and biologically relevant regions. This surpasses manual assessments, saving time and reducing human errors associated with tasks like counting fatigue (Barisoni, L., et al., 2020), Neltner, J. H. et al., 2012).

3.3 Artificial Intelligence and Machine Learning

The increasing demand for data reproducibility and the complexity of pathology analyses have driven the integration of AI (Artificial Intelligence). AI, employing algorithms, extracts information beyond human visual perception (Aeffner, F. et al., 2019).

It rapidly analyzes extensive data, expediting the discovery of novel histopathology features. In breast cancer, unsupervised learning models differentiate between tumor grades and assess prognostically relevant morphological features. Deep learning, applied to IHC- and H&E-stained specimens, impacts various tumor types, including prostate cancer grading, biomarker identification in melanoma, breast cancer region detection, prediction of response to therapy, and recurrence prediction in lung cancer. It enhances interpretability through graph neural networks, providing comprehensive tissue representations (Aeffner, F. et al., 2019)-Vamathevan, J. et al., 2019).

To assess AI's utility, comparisons with pathologists are crucial. In classifying melanoma, a CNN outperformed histopathologists. In detecting breast cancer metastases, deep learning matched top pathologists and excelled in finding micrometastases. Machine learning aids tumor purity assessment, surpassing visual estimates in accuracy. Combining WSI with machine learning offers insights in translational research, but requires vast, high-quality data. Challenges arise from variability in histological data across labs, impacting algorithm development. Robust AI algorithms could mitigate inter-reader variability, but further research is needed to understand their impact fully (Tizhoosh, H. R. & Pantanowitz, L., 2018).

3.3.1 Stratification of Patients

Digital pathology aids in predicting treatment response and identifying responsive patients. Spatial analysis, utilizing machine learning models, extracts morphological details to distinguish responders to therapies like nivolumab in NSCLC. Digital image analysis quantifies CD8 and PD-L1 positive cell densities, revealing potential predictive composite biomarkers. AI and machine learning assist in tumor classification and staging, with deep learning models predicting patient survival more accurately than traditional pathology practices (Wang X. et al., 2018), (Barrera C. et al., 2018).

3.3.2 Applications in Diagnosis

Biomarker research in immune-oncology explores predictive values in solid tumors, particularly the role of PD-L1 expression in response to immune checkpoint inhibitors (ICIs). Challenges in accurate patient stratification using visual interpretation lead to a shift towards digital scoring, aiding pathologists with standardized metrics. Studies reveal AI and digital techniques outperform or equal manual assessments across tumor types. AI's role extends to morphological assessments in nonalcoholic liver diseases. FDA-approved platforms support quantitative image analysis, showcasing potential in molecular epidemiology studies and expanding beyond HER2 detection to classify ER- and PR-positive breast cancer subtypes (Langer, C. J. et al., 2016).

3.3.3 Applications in Clinical Practice

Several resources provide guidelines for pathologists and physicians in digital pathology, covering image handling, WSI device standards, validation, AI concepts, and reimbursement considerations. The College of American Pathologists offers comprehensive guidelines for WSI system validation, emphasizing emulation, sample size, concordance, and documentation. AI performance relies on dataset size and quality, requiring diverse, well-curated images for training and validation, with pathologists playing a crucial role in ensuring accuracy and relevance to clinical applications (Pantanowitz, L. et al., 2014), (Janowczyk, A. & Madabhushi, A., 2016).

4 COPYRIGHT FORM

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5 CONCLUSIONS

Digital pathology advancements provide practical benefits, enhancing accuracy and enabling remote image review. In immuno-oncology, AI and machine learning contribute to a comprehensive understanding of the tumor microenvironment (TME) by consistently analyzing and validating large datasets. This has implications for drug development and clinical trial design. These technologies, applied in clinical settings, describe features across patient samples, facilitating more precise immune-oncology therapies and enhancing diagnostic, prognostic, and predictive decision-making in cancer treatment, ultimately improving patient care.

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