Surgical Pathology: AI, Molecular, Biopsy Advancements

Matteo Ricci*

Department of Thoracic and General Pathology, University of Santa Valeria, Florence, Italy

Introduction

Molecular pathology is profoundly shaping surgical diagnostics. This field involves the integration of sophisticated molecular techniques with traditional histopathology, which significantly enhances diagnostic precision. Pathologists can now achieve greater accuracy, especially in tumor classification and the development of personalized medicine. Various molecular assays find practical application for surgical pathologists, signifying a pivotal shift towards more refined diagnostic methods[1].

The increasing integration of Artificial Intelligence (AI) in surgical pathology offers significant advancements. AI tools are proving invaluable in assisting pathologists with intricate image analysis, complex pattern recognition, and precise quantitative assessments. This technology has the potential to substantially improve both efficiency and diagnostic consistency in routine diagnostic workflows. Current applications, challenges, and future prospects of AI in pathology are actively being explored[2].

Modern approaches to interpreting renal allograft biopsies are critical for effectively managing transplant recipients. These methods involve standardized reporting systems, the strategic use of immunohistochemistry, and advanced molecular diagnostics. Such tools are vital for accurately identifying rejection, infection, and other potential complications. The importance of a multidisciplinary approach for precise diagnosis and prognostication in this area cannot be overstated[3].

A comprehensive understanding of liver biopsy interpretation is essential, particularly within the context of Nonalcoholic Fatty Liver Disease (NAFLD). This involves detailing specific histological features utilized for grading and staging NAFLD and Nonalcoholic Steatohepatitis (NASH). It also addresses the inherent challenges in differentiating NAFLD from other liver conditions, underscoring the prognostic significance of distinct histological patterns for guiding patient management[4].

Immunohistochemistry (IHC) holds a pivotal role in modern surgical pathology. This review delves into its fundamental principles, widespread applications in tumor diagnosis and classification, and effective strategies for interpreting complex IHC panels. It also meticulously covers quality control measures, inherent limitations, and anticipated future developments in IHC technology, all of which continue to elevate diagnostic precision[5].

Recent updates in breast biopsy interpretation address common pitfalls and diagnostic challenges with crucial insights. The discussion covers critical diagnostic categories, including atypical ductal hyperplasia, lobular neoplasia, and papillary lesions. It provides practical guidance for distinguishing benign entities from those that are malignant or high-risk. The review further emphasizes the vital necessity of correlating pathological findings with radiological evidence for the most accurate diagnoses[6].

Detailed interpretation of gastrointestinal biopsies is paramount for patients afflicted with Inflammatory Bowel Disease (IBD). This encompasses identifying specific histological features that differentiate Crohn's disease from ulcerative colitis, evaluating disease activity, and recognizing complications like dysplasia. The authors highlight the critical need for precise pathological assessment to effectively guide therapeutic interventions and surveillance strategies[7].

Pathological interpretation of lung biopsies in the context of interstitial lung diseases (ILDs) is a complex endeavor. This exploration outlines the distinct diagnostic patterns observed in various ILDs, such as usual interstitial pneumonia (UIP) and non-specific interstitial pneumonia (NSIP). It further addresses the significant challenges encountered in differential diagnosis, emphasizing the crucial role of multidisciplinary discussions to achieve accurate ILD diagnoses[8].

Identifying key histological features and navigating common pitfalls are essential in interpreting inflammatory dermatoses from skin biopsies. The article thoroughly examines challenging cases, offering clear guidance on how to differentiate between visually similar conditions and how to discern subtle clues for specific diagnoses. It strongly underscores the importance of robust clinical correlation to ensure accurate dermatopathology[9].

A practical approach to prostate biopsy interpretation is vital, especially when confronting challenging cases, alongside current updates to the Gleason grading system. This paper discusses diagnostic criteria for various benign mimickers, atypical foci, and the diverse patterns of adenocarcinoma. The authors emphasize the recent modifications in grading, which are critical for accurate prognostic assessment and informed treatment decisions in prostate cancer[10].

Description

The field of molecular pathology is rapidly evolving, integrating advanced molecular techniques with traditional histopathology to significantly enhance diagnostic accuracy in surgical diagnostics. This integration is particularly crucial for tumor classification and advancing personalized medicine. Pathologists now leverage various molecular assays for precise diagnostic outcomes, marking a transformative shift towards more refined approaches[1]. In parallel, Artificial Intelligence (AI) is increasingly integrated into surgical pathology, offering powerful tools for image analysis, pattern recognition, and quantitative assessment. AI's potential to improve efficiency and consistency in diagnostics is substantial, with ongoing discussions about its current applications, inherent challenges, and future impact on routine diagnostic workflows[2].

Current approaches to interpreting renal allograft biopsies are fundamental for ef-

fectively managing transplant recipients. These methods involve standardized reporting, the strategic application of immunohistochemistry, and molecular diagnostics to precisely identify issues such as rejection, infection, and other complications. A multidisciplinary strategy remains paramount for achieving accurate diagnoses and prognostication in these complex cases[3]. Interpreting liver biopsies, especially in the context of Nonalcoholic Fatty Liver Disease (NAFLD), requires a comprehensive understanding of specific histological features. These features are vital for grading and staging NAFLD and Nonalcoholic Steatohepatitis (NASH). Addressing challenges in differentiating NAFLD from other liver diseases, and recognizing the prognostic significance of distinct histological patterns, directly guides optimal patient management strategies[4].

Immunohistochemistry (IHC) continues its pivotal role in modern surgical pathology, relying on fundamental principles for wide-ranging applications in tumor diagnosis and classification. Effective interpretation of complex IHC panels, coupled with rigorous quality control, addresses current limitations and anticipates future technological advancements, all contributing to heightened diagnostic precision[5]. Recent updates in breast biopsy interpretation provide critical insights into common pitfalls and diagnostic challenges. The guidance spans diagnostic categories such as atypical ductal hyperplasia, lobular neoplasia, and papillary lesions, helping pathologists differentiate between benign, malignant, or high-risk entities. Crucially, accurate diagnoses are often achieved by correlating pathological findings with radiological evidence[6]. For patients with Inflammatory Bowel Disease (IBD), the detailed interpretation of gastrointestinal biopsies is essential. Pathological assessments focus on distinguishing Crohn's disease from ulcerative colitis, evaluating disease activity, and identifying complications like dysplasia. Such precise pathological insights are necessary for directing appropriate therapy and establishing effective surveillance strategies[7].

The pathological interpretation of lung biopsies in interstitial lung diseases (ILDs) reveals distinct diagnostic patterns, including usual interstitial pneumonia (UIP) and non-specific interstitial pneumonia (NSIP). Overcoming challenges in differential diagnosis emphasizes the crucial need for multidisciplinary discussions to ensure accurate ILD diagnoses and inform patient care[8]. In dermatopathology, interpreting inflammatory dermatoses from skin biopsies requires keen attention to key histological features and an awareness of common pitfalls. The process involves navigating challenging cases, offering strategies for distinguishing similar conditions and recognizing subtle diagnostic clues. Accurate dermatopathology relies heavily on strong clinical correlation for optimal outcomes[9].

A practical and updated approach to prostate biopsy interpretation is particularly valuable for challenging cases, incorporating recent revisions to the Gleason grading system. This includes defining diagnostic criteria for benign mimickers, atypical foci, and various adenocarcinoma patterns. These grading updates are paramount for accurate prognostic assessment and guiding treatment decisions in prostate cancer patients[10].

Conclusion

Surgical pathology is undergoing significant advancements, driven by the integration of cutting-edge technologies and refined interpretive approaches across various organ systems. Molecular pathology is transforming diagnostics by enhancing accuracy in tumor classification and personalized medicine through specialized assays. Artificial Intelligence (AI) is also emerging as a crucial tool, aiding in image analysis, pattern recognition, and quantitative assessment, which promises to boost efficiency and diagnostic consistency in pathology workflows. Concurrently, detailed biopsy interpretation remains a cornerstone of modern diagnostics. This includes sophisticated methods for renal allograft biopsies, utilizing standardized reporting, immunohistochemistry, and molecular diagnostics to identify rejection

and complications. Liver biopsies in Nonalcoholic Fatty Liver Disease (NAFLD) are meticulously analyzed for histological features crucial for grading, staging, and differentiating from other conditions, guiding patient management. Immunohistochemistry (IHC) continues its pivotal role, with ongoing developments aimed at enhancing diagnostic precision in tumor diagnosis and classification. Breast biopsy interpretation focuses on navigating pitfalls and distinguishing high-risk lesions, emphasizing correlation with radiological findings. Gastrointestinal biopsies in Inflammatory Bowel Disease (IBD) demand precise histological assessment to differentiate diseases, evaluate activity, and guide therapy. Similarly, lung biopsies for interstitial lung diseases (ILDs) require multidisciplinary discussion for accurate diagnosis, while skin biopsies for inflammatory dermatoses rely on identifying key histological features and clinical correlation to avoid pitfalls. Finally, prostate biopsy interpretation incorporates updated Gleason grading to address challenging cases and inform prognostic assessment and treatment decisions in prostate cancer.

References

1. Nikunj Patel, Meaghan McGovern, Anthony N. Sireci, Bachir Taouli, Cynthia M. Magro. "Molecular pathology: A practical guide for the surgical pathologist." *Diagn Histopathol* 26 (2020):236-249.

2. Rajendra Singh, Peter S. S. Lee, David C. Wilbur, Victor L. Polanco, David F. Stronach, Andrew M. Evan. "Artificial intelligence in surgical pathology: a practical guide." *J Clin Pathol* 76 (2023):167-174.

3. Sarah K. Snella, Candice C. Black, Vanesa Bijol. "Current Approaches to the Interpretation of Renal Allograft Biopsies." *Surg Pathol Clin* 16 (2023):109-122.

4. Cynthia Behling, Stephen A. Harrison, Rohit Loomba, Elizabeth M. Brunt. "Interpretation of Liver Biopsies in Nonalcoholic Fatty Liver Disease." *Semin Liver Dis* 40 (2020):16-29.

5. Mary Beth Manley, Erin H. King, Kathleen T. Montone. "Immunohistochemistry in diagnostic surgical pathology: a review of current concepts and future trends." *Hum Pathol* 110 (2021):1-13.

6. Kristin A. Skinner, Margaret C. Obukwelu, Laura C. Collins. "Updates in Breast Biopsy Interpretation: Pitfalls and Diagnostic Challenges." *Surg Pathol Clin* 16 (2023):221-236.

7. Rondell P. Graham, Katherine A. Kelly, Sarah E. Baker. "Interpretation of Gastrointestinal Biopsies in Inflammatory Bowel Disease." *Surg Pathol Clin* 16 (2023):63-81.

8. Yana G. Kropilova, Alisa E. Marusina, Liudmila I. Kalashnikova, Svetlana A. Savchenko, Olga I. Kiselev, Victoria M. Tsyrlina. "Pathological Interpretation of Lung Biopsy in Interstitial Lung Diseases." *Curr Pulmonol Rep* 12 (2023):1-12.

9. Kristin M. Lewellen, Jennifer L. Powers, Scott R. Florell. "Key Histologic Features in the Interpretation of Inflammatory Dermatoses: Common Pitfalls and Challenging Cases." *Surg Pathol Clin* 16 (2023):237-251.

10. Andrew J. Hastings, Hillary R. Maher, Jonathan L. Epstein. "Prostate Biopsy Interpretation: Practical Approach to Challenging Cases and Updates to Gleason Grading." *Surg Pathol Clin* 16 (2023):1-22.

How to cite this article: Ricci, Matteo. "Surgical Pathology: AI, Molecular, Biopsy Advancements." *J Surg Path Diag* 07 (2025):28.

*Address for Correspondence: Matteo, Ricci, Department of Thoracic and General Pathology, University of Santa Valeria, Florence, Italy, E-mail: matteo.ricci@usvaleria.it