

From Glass Slides to Gigapixels: The Promising Outlook of Digital Pathology in Pakistan

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Digital pathology (DP) is poised to drive a major shift from analog to digital histopathology in Pakistan. It enhances workflow efficiency, enables remote case sharing and collaboration without logistical barriers, supports education and training, and is expected to further advance through increasing integration of AI-driven tools [1, 2].

As with radiology, DP implementation can benefit from Teleradiology.pk's experience in teleradiology services, which enable remote reporting and rapid turnaround times [2-4].

As Pakistan comprises a predominantly rural population (approximately 63% to total population resides in rural areas), and the facilities of specialist services in histopathology, including expensive testing with immunostains and molecular studies, are by and large confined to a few large city centers, DP, when used with its full potential, can be the realistic answer and objective remedy for capacity building and expedited diagnosis. Digital triaging and prioritization can inform the selective use of immunostains and cases requiring further IHC or molecular testing. By identifying cases with high diagnostic certainty on H&E alone, laboratories can reduce unnecessary use of expensive stains. AI models trained on digitized H&E slides can predict certain biomarker statuses (e.g., Ki-67, HER2, PD-L1) with high accuracy, thereby complementing conventional IHC and guiding selective testing as demonstrated by recent studies [1, 2, 5].

It can help not only Pakistan but also the world if the nations' workforce capacity and expertise are shared with other countries through skill exchanges. There is a substantial shortage of histopathologists in Pakistan, with some estimates suggesting that the country has approximately 1 pathologist / 100,000-150,000 population, which is considerably lower than high-income countries such as the USA and the UK, with approximate ratios of 1/15,000-20,000 population. This

disparity highlights the urgent need for greater access to specialist expertise. Owing to the rapid, expedited quality diagnoses seen in other specialties, there is a need to invest in training and technological advancements [1, 3, 6].

WHY IS IT SO IMPORTANT TO CONSIDER THIS EXPENSIVE TECHNOLOGY?

A fully digital pathology workflow extends beyond slide scanning. It requires integrating multiple components, including laboratory information system (LIMS) integration, data storage and archiving, IT infrastructure, quality assurance processes, and training that covers both technical and clinical aspects [4, 7].

Implementing digital pathology is a significant investment, often ranging from \$100,000 to over \$1,000,000 for larger institutions, with high upfront costs for scanners, IT infrastructure, and software. Although initial expenditures are high, it can generate savings of roughly \$1,300,000 over 5 years due to improved efficiency, fewer logistics costs, and quick turnaround times [3, 8, 9].

A recent analysis indicates that there are approximately 18 major histopathology laboratories in the country, with the majority located in large urban centers such as Karachi, Lahore, and Islamabad. These labs serve extensive referral networks, while smaller laboratories in peripheral regions often lack advanced diagnostic capabilities, hence highlighting the importance of digital pathology (remote consultations). Key institutions on the DP adoption journey include the Aga Khan University Hospital, Liaquat National Hospital, Holy Family Hospital (Rawalpindi), AFIP, and Jinnah Sindh Medical University, as well as private-sector laboratories such as Chughtai's Lab. These institutions are better positioned to adopt and validate digital pathology workflows due to stronger IT infrastructure, available subspecialty expertise, and their involvement in research and training [3, 8, 10].

WHY AND HOW?

Short- to medium-term implementation goals (1-5 years) can include developing and expanding infrastructure and establishing workflows. These workflows can be related

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to specialist opinions, consultation conferences, support for frozen sections, and, last but not least, teaching and training. These hubs can also serve as validation centers, and professional societies' guidance documents can shed light on national standards for DP validation for diagnostic use, accreditation, and information governance. Digital image database and AI validation are currently emerging in Pakistan, as they are worldwide, with a prime example being HistoVault v1, Pakistan's largest open-access histopathology dataset launched in February 2025 by Precision Medicine Lab (PMLab) and Rehman Medical Institute (RMI). It contains more than 17k local histopathology images for AI-powered cancer research. Long-term goals (more than 5 years) for AI implementation can include the Nationwide Center's integration and wider adoption across regional centers [5, 6, 11] (**Fig. 1**).

Part of the solution could be public-private sector cooperation, international alliances, and the staged, piecemeal acquisition of refurbished or lower-cost scanners and cloud-based storage solutions to help break down upfront cost hurdles.

In alignment with international studies, local experience also reports a similar story: initial pilot studies have applied deep learning models to Ki-67 quantification and tumor segmentation on digitized slides, providing proof-of-concept for local AI validation and workflow integration, as reported by Zehra *et al.* [1]. Some international organizations, such as the Digital Pathology Association (DPA) and the Royal College of Pathologists (UK), have published detailed recommendations on validating AI-assisted tools for clinical use; similar guidelines should be developed in Pakistan [3-5].

Countries such as India, the Philippines, and Kenya, which are comparably resource-constrained as Pakistan, have demonstrated that incremental adoption strategies, supported by institutional partnerships, can facilitate successful DP implementation. India focused particularly on large private diagnostic networks and tertiary care centers where telepathology services are being used. The implementation has largely followed a hub-and-spoke model. Similarly, Kenya's "The Kenya Open Telepathology Project" has utilized low-cost digital microscopes and AI algorithms. This has enabled remote case review and significantly reduced diagnostic delays [6-8].

In conclusion, while Pakistan is still in the early stages of digital readiness, DP offers a transformative opportunity to improve diagnostic services. Through structured pilot programs, investment in training, local validation of AI

tools, and the development of national guidelines, DP can enhance access to high-quality pathology services nationwide. A thoughtful, phased approach will be essential to ensure sustainable implementation and improved patient care.

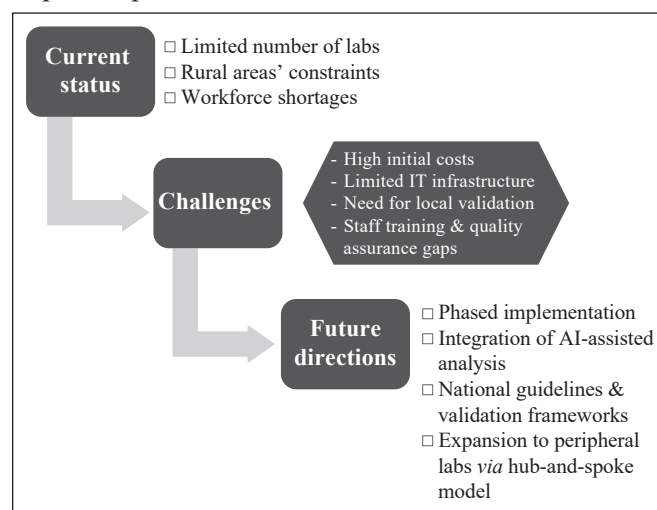


Fig. (1): Digital pathology in Pakistan: current status, challenges, and future directions.

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