Technology and applications of whole slide imaging

Whole slide imaging (WSI) is a cutting-edge method of producing digital images by scanning glass slides. With significant advancements in whole slide scanning hardware and software, accessing entire slide images has become easier than ever before. These images, also known as full slide images, can be thought of as glass slides in a microscope. The number of pathologists, pathology departments, and scientists using WSI for clinical, educational, and research purposes has increased globally. WSI has received approval from the US Food and Drug Administration for use in initial diagnosis, and pathology regulatory organizations such as The College of American Pathologists have established standards for clinical validation.[1]

The implementation of digital technologies often requires the use of WSI, which is a significant shift in the field of pathology. WSI involves converting glass slides into digital slides, which pathologists can examine using virtual microscopy. This has major implications for the workflow of pathologists, the distribution of teaching materials, and the care of underprivileged areas, among other benefits. WSI is becoming more widely used in daily life, as it has recently been approved by the US Food and Drug Administration for primary surgical pathology diagnosis. Ongoing advancements in technology, such as digital scanners, image visualization techniques, and artificial intelligence algorithms, can further improve WSI systems. Some of the advantages of WSI include easy online access, less physical storage space required, and protection against slide breakage and stain quality deterioration.[2]

WSI allows multiple viewers to access and view digital images of microscope slides remotely. Typically, digital annotation and the computational processing of WSI require a whole slide scanner, scanning personnel, image viewer software, a high-resolution screen, and a pointer device such as a mouse, joystick, or touchpad. WSI consists of two main components: software and hardware. Hardware includes microscope objectives, bright field or fluorescent light sources, robotics for loading slides, and other items. In addition to the x- and y-axes, digital scanners must use the z-axis to produce an image like that seen through a microscope. High-throughput scanners can process up to 400 slides thanks to continued technological advancements. They specialize in digitizing complete tissue mounts, larger glass slides, fluorescently marked sections, or smears, and have shorter scanning times. The digitization of pathology and other medical specialties has made healthcare facilities more digitalized. Pathologists can browse virtual ultrathin slides in their office using electron microscopy and note the precise placement of different features. Traditional pathology training and examination have shifted away from physical microscope-based sessions to focus on the ability to detect and interpret specimens. WSI offers standardization of pathology education across the country by allowing all participants to use the same set of slides. WSI also allows experts to teach pathology residents in remote areas and with little exposure to specialized fields on how to interpret immunohistochemistry or electron microscopy. The use of WSI eliminates the need for large classrooms with numerous microscopes or multi-headers for instruction. WSI provides benefits such as the ability to compare normal and atypical behavior on the same screen, the freedom to interact at their own pace, and the encouragement of a team-based learning environment. Virtual slide sets are accessible for instruction and learning through online WSI sites. In the field of pathology, virtual slides are also used in seminars and meetings to promote interactive learning and facilitate the visualization of multiple images of different stains along with relevant clinical data. Two reasons why biotechnology and pharmaceutical companies are interested in WSI are its capacity to understand the spatial interaction of various biological phenotypes and its support in the creation of IHC-based biomarkers that could be utilized further in translational research studies. With WSI and image analysis technologies, researchers can quickly and objectively assess and score biomarkers in all specimens. Fluorescent

WSI or multispectral imaging enables multiplexed analysis in situations where there may be biomarker heterogeneity. This technology can also be applied to the development of oncologic biomarker techniques and advancing drug discovery. Contemporary WSI scanners can work in fluorescent and transmitted light modes to increase their range.[3]

Whole slide images have opened new possibilities for clinical, non-clinical, and research applications in pathology. WSI solutions can improve diagnostic accuracy, balance workloads, increase workflow efficiency, offer better financial returns on investment, and enable better integration of images with information systems. As new image analysis algorithms and computer-assisted diagnosis tools are developed and approved for clinical use, pathologists will be able to quantify prognostic biomarkers with greater efficiency, accuracy, and reproducibility. Standardization in the process is essential, including consistent staining, ideal slide preparation without artifacts, appropriate resolution, number of z-stacks, interval space, and color calibration for image acquisition. Vendor-neutral viewers are also necessary to share and transmit digital images. However, the global adoption of WSI by pathologists has been slow due to various reasons like outdated technology, poor image quality, inability to scan all materials like cytology and microbiology, high cost of devices and digital slide storage, incapacity to manage routine work with high throughput, regulatory obstacles in some nations, and difficulty in using these devices ergonomically. Pathologists have also been reluctant to employ WSI. However, these issues can be resolved, and it is likely that WSI will continue to transform the field.[4]

When it comes to tissue handling, fixation, processing, and staining, technical expertise is essential. Moreover, specialized knowledge in biology, histology, pathology, pathophysiology, biomarker expression, comparative anatomy, and more is also required. It is crucial to involve a pathologist in these processes. Pathologists should be aware of the value and quality of the generated data. Poor tissue or histology slides or improperly optimized staining can greatly reduce the validity of image analysis data. Therefore, the pathologist's involvement is necessary to ensure the accuracy and validity of the results.[5]

SUMMARY

Whole slide scanning for virtual microscopy is a rapidly advancing technology with a wide range of applications in pathology. It has numerous clinical contexts such as diagnosis, remote interpretation of immunostains and frozen sections, pathology slide display at tumor boards, image analysis, archiving and retrieval, proficiency training, and more. There are also many non-clinical applications such as data mining, clinical trials, personalized reporting, and teaching. The technology provides comprehensive solutions in various medical and non-medical fields.[4]

Despite its numerous advantages and claims of superiority over traditional microscopy, virtual microscopy technology has not gained much popularity, even in wealthy nations. However, smaller laboratories can collaborate with a reference laboratory that has a WSI system in a hub-and-spoke model to overcome some of the challenges faced. Addressing regulatory and validation requirements, especially in developing countries, is crucial, as is dealing with technical and financial concerns. Nonetheless, virtual microscopy provides pathologists with a unique opportunity to shape its development, standardization, and application by playing a vital role in creating guidelines, developing resource-specific digital pathology labs, and sharing standardized educational modules to educate the next generation of virtual pathologists.[3]

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