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Digital Pathology for E-Learning and Digital Education – A Review

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Abstract

Recent advances in information technology and telecommunications have made significant improvement in the delivery of education in pathology using a digital format. Digital pathology (DP) images are captured as static images by various scanning, imaging or mobile devices. Whole slide imaging/virtual microscopy (WSI/VM) can be obtained by robotic microscopy on an entire histological glass slide. Anonymized DP images may be stored in remote and/or cloud servers to be used in E-Learning and digital education. Since 1986, clinical services using telepathology (TP) technologies for the transfer of pathology images between distant locations have benefited many patients worldwide, including the University of Alberta. WSI by Real-time telepathology systems provides for a faster diagnosis in intraoperative frozen section and tele-consultations, as well as interactive components in digital education and continuing medical education (CME) for purposes of specialist re-certification or re-validation for the Royal College of Pathologists of Canada and College of American Pathologists. At present, the use of WSI by real-time TP system in DP education seems to be limited due to high bandwidth requirement and high expense, but electronic platforms and their connection to stable operating systems are improving enormously. Social media and mobile devices are increasingly being used in DP education and may provide future platforms for the delivery of DP education. However, full-scale implementations of technologies in DP education may be limited, due to limited resources and infrastructural support, and the lack of integration into the existing laboratory information systems (LIS) or Provincial Health Networks (PHN).

Keywords

Digital Pathology; Telepathology; E-learning; Digital Education

Introduction

During the past two decades, the rapid advancement of information technology (IT) and emerging techniques have rendered many analog technologies and communication tools in education obsolete. Tools for pathology education have made such vastly significant improvements towards digitization and telecommunication that students and professionals in healthcare, patients and even the public of developed countries and under-developed parts of the world continue to benefit. This review summarizes the evolution of digital pathology (DP) and telepathology (TP) in education and the significant challenges for the future in the era of rapid progression of social media usage and advancement of information technology.

Digital Pathology

Digital pathology (DP) can be defined as the electronic capture, management, analysis and distribution of gross or microscopic specimens (Bellis 2013). Digital pathology has been deemed a disruptive technology, which is defined as a technical innovation that improves a product and/or service in a manner that the market does not anticipate. (Pantanowitz 2010)

Static Pathology Images

For more than 150 years and still in practice today, pathologists routinely make the diagnosis using a light microscope on tissue sections layered on glass slides and stained by hematoxylin-eosin staining and/or other special stains. Teaching cases were prepared with recut glass slides or analog color slides (plastic projection slides) using film-based camera mounted on microscopes. The carousal boxes of archival slides were used for clinical rounds and educational seminar presentations and occasionally for medico-legal purposes being accepted in court proceedings for both civil and criminal law systems. Nowadays, such archival collections will have to be scanned and converted to digital images. Microscopic images on glass slides are now captured by digital cameras mounted on light microscopes. On the other hand, the images of gross pathology specimens can be captured by digital cameras, iPAD, and phablets (android tablets and smart phones) and the images downloaded via SD media card, USB interphase or wireless/wifi connections into computers or servers for storage.

Anonymized and digitized static images may be stored in the computers and can be retrieved for review, duplication, editing, or uploading for transmission or sharing with colleagues for rounds / multidisciplinary team meetings.

The digitized static pathology images are important components of digital pathology in E-learning and digital education. Amin and others have reported that digital gross pathology images may be integrated into enterprise-wide electronic picture archiving and communication system (PACS) for storage, rapid retrieval and widespread access. (Amin 2012) Grossing of large pathology specimens (macroscopy) involves specimen orientation, dissection and cutting into thinner slices for formalin fixation and blocking. In our institution, we have been using an iPAD to capture images of these pathology specimen grossing procedures since 2010. The static images are integral parts of our educational tools for pathology residents, assistants, surgical pathology technicians, students and, occasionally, our clinical colleagues for presentation at rounds / multidisciplinary team meetings as well as national and international professional meetings.

Whole Slide Imaging/Virtual Microscopy

The development of whole slide imaging (WSI) has made it possible to capture images of the entire pathology slide. The creation of digital slides at high resolution and multiple magnifications and focal planes is intended to simulate light microscopy, also referred to as "virtual microscopy (VM)". The robotic microscopic scanner automatically scans glass slides and employs software to combine individual scanned fields into a composite digital image. (Pantanowitz 2012) The viewing software with user-friendly interfaces makes it possible for the operator to navigate to various regions of the virtual slide or change magnifications. The WSI can be used for primary pathological diagnosis, to capture static images for reporting, archiving or computer-aided analysis and educational activities.

The traditional pathology glass slides for teaching purposes are limited by the number of viewing pathologists or pathologists in training to be shared in a multi-headed microscope, restricted access to the trainees and limited numbers of slides to be recut and the stain quality deterioration over time. In contrast, the WSI slides are more interactive than static images, easier to share with multiple users anywhere and at any time. Training materials can be standardized and images may be made available by hyperlinks to the file servers. (Pantanowitz, 2012) WSI has been used for a plethora of educational activities, including graduate schools, trainees in different medical specialties and allied health, in E-learning and tele-education. Successes have been reported in graduate educations for medical, (Foster 2010, Monaco, 2011) dental, (Weaker 2009) and veterinary schools. (Dee 2007) E-learning and virtual workshops with virtual atlases to promote web-based learning are made available by several societies including the United States and Canadian Academy of Pathology (USCAP), and International Academy of Cytopathology (IAC). (Khalbuss 2011) WSI is also being used for performance improvement programs and proficiency testing by the College of American Pathologists (CAP) and is an integral part of the board examination of the Royal College of Pathologists of Canada (RCPC). WSI is also an important module for purposes of specialist re-certification or re-validation for the Royal College of Pathologists of Canada and College of American Pathologists. (Sergi 2008) The diagnostic scores of the pathologists undergoing the Performance Improvement Program in Surgical Pathology (PIP) online do not appear compromised by the converting to WSI. (Sharma 2011)

Telepathology

Telepathology (TP) is the practice of pathology at a distance using telecommunications technology to facilitate the transfer of image-rich pathology data between distant locations for the purposes of diagnosis, education, and research. It is a singular synchronous two-way communication between the host and recipient. Telepathology, a name coined by Dr. Ron Weinstein (Weinstein 1986), has also been variously named: teleconsultation, telemicroscopy, remote robotic microscopy, teleconferencing, and web conferencing. Weinstein first reported TP and the network of pathology diagnostic services on breast tissues by remote workstation-controlled light microscope attached to a high-resolution video camera and a telecommunication linkage. (Weinstein 1987) TP with similar analog technologies has been used for remote frozen section services in northern Norway since 1990. (Nordrum 1995) With the advent of digital technologies, and the FDA approval for use of digital pathology for primary diagnosis, today, beyond the use in surgical pathology, TP is also being employed in telecytopathology, ultrastructural telepathology, and telehematology. (Pantanowitz 2010)

Telepathology Systems

The three major telepathology systems currently used are static, real-time, and WSI/virtual microscopy. In the static digital telepathology system, pre-captured still digital images are stored on a server. In an example of TP session in Canada, on tele-conference time, the presenter (the pathology specialist) and participating audience from across Canada log-onto the remote server, the user-friendly interface appears and the static DP slides are downloaded automatically, and the conference begins. The disadvantages of static TP are that the telepathologist presenter controls everything including acquiring the images, while the audience are passive participants. In tele-consultation, the consultant pathologist has no remote control of the glass slide and has limited fields of view to examine. However, static TP systems are welcome in the parts of the world with limited resources, shortages of trained personnel and lack of continuing education programs. It is considered to be a simple, cost-effective, reliable and efficient means to provide diagnostic and educational support to pathologists in the developing world. (Sohani 2012)

The geography of Canada with cities separated by vast distances suggests that telepathology may have a particularly promising future in this country. The University Health Network (UHN) is a multi-site academic institution in Toronto, comprising several downtown hospitals and remote hospitals in Northern Ontario. WSI has been effectively utilized for telepathology in primary frozen section diagnosis and secondary/tertiary teleconsultation. (Evans 2009, Pantanowitz 2011) In the Province of Quebec, implementation of the Eastern Quebec telepathology project provides uniform frozen section diagnosis and teleconsultation services across a huge geographic region comprising 21 sites. (Tetu 2012) Real-time and WSI/virtual microscopy in TP systems offer higher diagnostic accuracy and faster turn-around time and are most suitable for clinical applications. The disadvantages of real-time robotic TP system include the need for high bandwidth, highly experienced personnel; that equipment is still expensive and slow, both host and recipient require integrated software and video conferencing equipments. (Pantanowitz 2010) The image-rich sessions perform best on local area networks, and performance may suffer and data security is also one of the challenges if these are employed using the Internet proper as a backbone. However, WSI/VM telepathology is emerging as the technology of choice for TP education, despite similar disadvantages as real-time TP. Several commercial systems are now available at reasonable price. Recent advances in storage technology allow for the large digital files of WSI to be stored in local or cloud servers, which storing and simultaneously retrieving are made possible.

Social Media and Mobile Device Use

The advances in computing power and the exponential growth of internet search for learning resources have permitted the establishment of powerful new web-based technologies and technologies for web publication and digital education. Digital atlases, virtual slide teaching sets and WSI/VM have been created for e-learning and digital education. (Fung 2012, Nguyen 2014) An example of a robust website recommended for pathologists is *PathologyOutlines.com* which was created by wiki technology. A "wiki" is defined as a webpage in which the contents can be edited by users in realtime using a web-browser. (Rasmussen 2013) Wiki software is of particular interest to medical education because of its emphasis on large-scale collaboration and publication of articles. (Park 2012) Skype is a popular and free software application that allows personal computers and mobile devices to be used for video communication over the Internet. Videos can be uploaded to YouTube, a popular video sharing website, and downloaded for educational use. (Solez, 2011) Telepathology using smart phones and tablets with Skype and MSN for live, synchronous online communication are feasible for clinical and educational uses. (Armfield 2012, Bellina 2009, Klock 2008) The use of an iPAD tablet or similar android device to download DP slides from a Web server for E-learning has been found to provide satisfactory solution in low-resource countries. (Fontelo 2012) In a review of social media use in medical education, (Cheston 2013) the incorporation of social media tools promoted learner engagement, feedback and collaboration and professional development. The most commonly cited challenges were technical issues, variable learner participation and privacy/security concerns.

Challenges of Digital Pathology Education

Digital pathology is a rapid evolving niche in the world of pathology. In a recent Scientific American review of DP, (May 2010) the editors have pointed out that a remake of pathology is overdue; that emerging techniques allow computerized images to be manipulated, and that digital pathology will allow for more precise diagnoses. Lately, however, the adoption of digital pathology has been slower than the adoption of digital images in radiology, although both disciplines require imaging modality to collect primary data. This is related to the fact that radiology images are primarily acquired as digital data and different picture archiving systems. (Pantanowitz 2011) In a recent survey of pathology residents and staff in Canada, the results showed that telepathology was used in less than half of the institutions, mainly for teaching, followed by operating room consultations. Majority of the pathologists and residents use digital images in their practice and believe there is a need for TP in their practice. (Bellis 2013)

The limitations in implementation of DP in education include: 1. Infrastructure and resources supports. The cost of acquisition and maintenance of DP equipments, networking equipment and personnel expenses are very high. 2. Integration into existing laboratory information system (LIS) or Provincial Health Network (PHN) portals such as the Netcare in Alberta rather than a stand-alone DP education system may attract investments from government or the private sector. 3. Acceptance of digital pathology images in the diagnosis, with FDA or Canadian authority approval. 4. Engagement of all pathologists in practice or in training.

Conclusions

In conclusion, the rapid advancement of information technology and emerging techniques has allowed the gradual acceptance of digital pathology and telepathology. The use of DP and TP in clinical services is well recognized in multi-site medical centres as well as in geographically diverse health-sites. Their uses in education are somewhat limited, due to limited funding of infrastructures and technologies and limited bandwidth for transmission.

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