The Future of Telepathology for the Developing World

Charles L. Hitchcock, MD, PhD

- Physician shortages are acute in developing countries, where disease burden is the greatest and resources for health care are very limited. A lack of pathologists in these countries has lead to delays in diagnosis and misdiagnoses that adversely affect patient care and survival. The introduction of telepathology into countries with limited resources for health care is but one of multiple approaches that can be used to alleviate the problem.

Telepathology is the electronic transmission of digital images that can be used for education and diagnostic consultation. A basic system consists of a microscope with a mounted digital camera linked to a computer. The ability to produce histologic slides, to repair and maintain equipment, and to provide training are also needed for the successful use of this technology.

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Telepathology is a Web-based, open platform, software application which was developed at the University of Basel, Switzerland, for telepathology and which brings together pathologists from around the world to provide telepathology support for diagnostic consultation and provides education to centers with limited resources. The use of virtual-slide technology to provide a digital image of an entire glass slide is another technology for diagnostic consultation and pathology education. This technology requires more costs to support it, which may limit its utility in many areas. Telepathology can generate collections of digital images and virtual slides needed for training indigenous pathologists in their countries to become self-sufficient. Thus, the long-term goal of this technology is to improve patient care and survival.

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THE PROBLEMS

The disparities among low and high income countries are best demonstrated by differences in health care. With only 10% of the world’s disease burden. In sharp contrast, the 11% of the world’s population located in sub-Saharan Africa have 24% of the global health burden, yet they have only 3% of the global health workforce and 1% of the world’s health care dollars. The shortage of physicians and other health care workers in developing countries is a critical component of these differences. This disparity is caused by too few physicians and health care workers being trained, a maldistribution of health care resources within a country, and “brain drain” emigration. For example, the ratio of physicians per 1000 individuals is 0.02 in Tanzania and 0.04 in Chad as compared with 2.14 in Canada and 2.56 in the United States. In an editorial in the *Journal of Clinical Pathology*, Chetty states that there is a global shortage of pathologists of all persuasions. Using *pathologist shortage* and *shortage of pathologist* as criteria, an Internet search quickly identifies a lack of pathologists in small towns in the United States and throughout Canada, Australia, New Zealand, China, and Europe. These reports indicate that this shortage leads to delays in diagnosis, misdiagnoses, and a backlog of postmortem examinations. These shortages and their effect on patients is several orders of magnitude greater in low-income countries of Africa, South and Southeast Asia, and Latin America.

POSSIBLE SOLUTIONS

The lack of qualified physicians and adequate facilities are the highest hurdles to overcome in the delivery of health care throughout Africa, South Asia, and Southeast Asia. Solving these problems requires that multiple approaches be taken to improve both undergraduate medical education and residency training. The number of medical schools is expanding throughout the world, but these schools need to provide adequate numbers of trained faculty, improved facilities, and up-to-date learning resources. The increased need for residents also show that these same improvements are needed in residency programs. Improved pathology training, on all levels, is critical for the accurate diagnosis of a growing number of chronic diseases—such as cardiovascular and respiratory disease, diabetes, and cancer—that are only now being recognized for their potential effect on developing countries. The need to diagnose and treat these chronic diseases represents a movement away from the practice of syndromic medicine to one of evidence-based medicine. As pathologists, we are working to help bridge the disparity gap in training, education, and diagnostic support. One such approach that holds promise is the use of telepathology for support of student/physician training and diagnoses.
Telepathology can be defined as the electronic transmission of digital images of pathology for education, research, diagnosis, or consultation. Since its first proof-of-concept demonstration in 1968, this technology has resulted in close to 600 publications and has been used with ever-growing frequency throughout the world. From a clinical point of view, telepathology has evolved from point-to-point transmission of live or near-live video images, to the capture of digital images of selected microscopic fields for storage and later transmission, to robotic control of the microscope with rapid point-to-point transmission, to development of software that facilitates Web-based consultations and interactions, to the generation of virtual slides that represent the entire slide for easy Web site access or for storage.7–9

The basic components of a telepathology system are a microscope with a mounted digital camera linked to a computer. Basic systems provide an image that can be stored and forwarded via e-mail or the Internet to an expert for consultation. The cost and complexity of a basic simple system increases with the addition of a robotic microscope and point-to-point transmission but allows the observer to control slide movement, focus, and use objective selection (Figure 1, A and B). Virtual-slide technology, the most expensive of the options for telepathology, forms a single image of a glass slide. These instruments combine an objective (×10 to ×40) with automated stage and digital camera with the computer power to rapidly obtain a series of images that are automatically stitched together in software and compressed to form a single image file of the slide. Each of these systems is currently used for all aspects of telepathology, but each varies in its applicability in providing pathology support for countries in the developing world or in areas with limited resources.

Each type of system is currently being used for telepathology in the United States and Canada, but are they applicable for the needs of the developing world? In the experience of Benediktsson and colleagues,4 we first have to determine the resources available before we bring telepathology and other new technologies to bear in a developing country. Knowing that good telepathology begins with a good hematoxylin-eosin–stained slide, centralization of anatomic pathology services and education affords economies of scale and standardization of techniques and technology.10

The infrastructure available should be the major consideration in the establishment of a telepathology resource, followed by the choice of a telepathology system. Servicing and maintaining telepathology equipment—camera, microscope, and computer—is often difficult, costly, and time-consuming where resources are few. Regardless of the system used, consultation and educational efforts will ultimately fail if the equipment cannot be adequately maintained.

At the local level, equipment cost, inadequate infrastructure, and lack of trained pathologists have contributed to the problem of insufficient attention being given to telepathology in the developing world. A lack of standardized equipment, image format, and minimal training of pathologists have resulted in only a few pathologists from high-income countries considering telepathology as a solution to the problem at hand, and they would rather use an overnight courier service.

Simple systems are not as susceptible to variations in environmental conditions as those using sensitive electronics by itself or in a virtual slide scanner. Simple systems don’t require higher rates of transmission speed associated with robotic control of a microscope nor the broadband requirements needed for virtual slide viewing. A microscope with a digital camera can generate one or more images (ie, a digital photograph) that can be transmitted via e-mail or the Internet. Such a simple system is the most commonly used method in telepathology today. This method is regularly used for transmission of consultation cases to the Armed Forces Institute of Pathology (Washington, DC),11 and it has been used for the past 20 years in support of remote areas of Norway.12 Faculty at the University of Basel (Basel, Switzerland) developed a Web-based, open platform, software application, iPath, for use with various types of equipment to support all aspects of telepathology. It has been used to provide telepathology consultation and education to the Solomon Islands and other sites.10 The iPath platform has been combined with a basic telepathology system to provide telepathology support for Lao University of Health Science in Vientiane, Laos.6 This approach to telepathology is reported to be hampered by inadequate image sampling of the slide and poor image quality that
can lead to discordant diagnoses.\textsuperscript{11,13} However, in my experience, diagnostic concordance increases when both of these problems are reduced by adequate training and constant feedback.

The Ohio State University Medical Center (Columbus) uses a robotic telepathology system with a rapid refresh rate and a rapid point-to-point transmission, which provide the observer with the ability to control all aspects of the microscope and to rapidly view microscopic fields of the entire slide (Trestle Corp, Newport Beach, California). The result is excellent diagnostic concordance, 97\% or greater, for fine-needle aspirates, frozen sections, and hematoxylin-eosin–stained slides from another breast cancer center 11 miles from the hospital\textsuperscript{14} (Figure 2). We have the ability for multiple observers to simultaneously view the same slide, but the real-time nature of the system precludes asynchronous review of the material. This same system was deployed around the world in support of the telepathology efforts of the US Army.\textsuperscript{15,16} Real-time telepathology is an excellent choice if the sending and receiving stations are in similar time zones. In the case of the US Army, it was required to have an on-call pathologist read the slide. Much like the NightHawk (NightHawk Radiology, Montara, California) teleradiologists, real-time telepathology can also be accomplished at home using a virtual private network connection to the receiving computer network.\textsuperscript{17} Results similar to ours have been recently reported for locally developed robotic systems in Taiwan\textsuperscript{18} and mainland China.\textsuperscript{19} Lack of appropriate environmental control systems and/or insufficient transmission speed are potential reasons not to select this type of telepathology system.

Telepathology that uses virtual-slide technology is receiving growing acceptance. As a diagnostic or consultative tool, the hope has been that it would be incorporated into the normal work flow of a pathology service. This has happened at the reference laboratory level—US Labs (Irvine, California)\textsuperscript{20} and the Armed Forces Institute of Pathology being examples—but has yet to become a routinely used tool from day to day. The potential for this technology has led General Electric (GE Healthcare, Chalfont St. Giles, United Kingdom) to provide $40,000 to the University of Pittsburgh (Pittsburgh, Pennsylvania) in partnership to develop a fast-scanning, virtual slide generator. A similar fourth-generation virtual slide scanner has been developed at the University of Arizona (Tucson).\textsuperscript{21} Recent reports indicate that routine clinical application of this technology may be limited by factors that go beyond diagnostic accuracy.\textsuperscript{22} System factors include cost, data transmission speed, and screen refresh rates, whereas user-related factors include a pathologist’s level of confidence with interpreting digital images, inadequate communication between the pathologist and clinician, and the need for increased time to thoroughly examine an image to make a diagnosis. As such, it is not ready for deployment as the sole tool for consultative telepathology in the developing world. However, virtual-slides technology can play a key role in medical education and research.

Virtual-slide technology has been widely accepted by medical educators as a tool for replacing glass slides\textsuperscript{23,24} (Figure 3). In this setting it has a major role in undergraduate medical education, graduate medical education, and continuing medical education (CME), as well as in proficiency testing. It has been used to assess interobserver variability to increase standardized diagnostic criteria.\textsuperscript{25} Virtual slide images are now a critical part of the certifying examinations developed by the American Board of Pathology. The Ohio State University Medical Center is...
currently collaborating with members of the Colposcopy and Cervical Pathology Society of South India (Chennai) to establish a virtual-slide database of World Health Organization–acquired cervical biopsies. The aim is to standardize diagnostic criteria for cervical lesions and to establish a distributive telepathology consultative service for assessment of cervical biopsies obtained from women in rural Tamil Nadu. Similar approaches can be taken to provide Web-based virtual-slide resources for training pathologists in the developing world. Two things are essential to keep in mind. First, there has to be sufficient bandwidth for viewing of these slides. Working in collaboration with Marin Nola, MD, PhD (deceased), of the University of Zagreb in Croatia, pathologists from around the country were asked to access a Web site at The Ohio State University Medical Center that contains virtual slides for assessment of diagnostic competency. This study’s unpublished results demonstrated that the lack of appropriate bandwidth led to timing out of the connections. This is overcome by the use of virtual slides on DVDs or portable hard drives that can subsequently be downloaded directly onto a computer. This has been the approach taken by Scott Jewell, PhD, of the Cancer and Leukemia Group B Pathology Coordinating Office at The Ohio State University Department of Pathology (Columbus).20 Cases used should be relevant to the pathologists’ practice. Thus, disease-specific or region-specific virtual-slide databases need to be developed for educational purposes.

The use of telepathology in the developing world must adhere to the Chinese proverb: “Give a person a fish, and you feed them for a day. Teach a person how to fish, and you feed them for a lifetime.”

The facts are clear. There is an acknowledged worldwide shortage of trained pathologists, which is even greater than the shortage of primary care physicians. Chronic disease will have a growing effect on global health. The response to these diseases requires that pathologists be present to ensure timely and accurate diagnoses. Pathologists in high-income countries need to expand their willingness to take an active role in solving this problem. Technology, in the form of telepathology, can’t be thrown into the process without an accurate assessment of the need and resources available for its effectiveness. However, it has the potential to play a key role in providing diagnostic consultation support as well as in training local pathologists and students, enabling them to train the following generation of local physicians.

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References