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Technological Developments in Telemedicine: State-of-the-Art Academic Interactions

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The time has come for new developments in remote education

What sort of general impression do surgeons have of “telemedicine”: that it is convenient and useful? Or cumbersome and impractical? Or are they simply not interested or do not know about it? Supposedly, a good number of surgeons have a positive impression of telemedicine, but it is likely that many would choose the latter negative or uninformed descriptions, which reflects how telemedicine is not yet popular in the field of surgery. In contrast, it has been gaining popularity in the fields of radiology and pathology, wherein images are electronically sent out from rural area hospitals that lack particular specialists to leading medical institutions to obtain a professional diagnosis. One example of this procedure that has drawn public attention is when clinical images are sent from the United States to India, which enables an overnight diagnosis, thus taking full advantage of the time difference and providing a solution for the shortage of related specialists in the United States. However, a notable difference between using telemedicine in radiology/pathology and using it in surgery is that the transmitted material is still images and video images, respectively; the latter requires a much larger data transmission volume than the former. This condition made it technologically challenging to use telemedicine in surgery.

Now a new wave of technological developments is influencing the field of telemedicine. It is common knowledge that there have been rapid developments in communications and information technology in recent decades, in the form of computers, email, and mobile phones. These technologies have radically changed our lifestyle, just as endoscopic surgery has revolutionized the whole surgery and has produced a tremendous amount of educational demand for new types of surgery. Telemedicine can be especially useful and helpful in remote teaching applications, by saving time and travel costs. In addition, there are advantages such as allowing a large audience to communicate effectively and enabling frequent interactions. In contrast, in conventional professional teaching, usually only a limited number of people can attend with limited opportunities as restricted by the inconvenience of physical movement. However, these advantages in communication can be applied to the field of surgery only under the condition that the transmission quality of images and sounds is satisfactory and appropriate for the needs of medical professionals, and that it is affordable and can be easily used in hospitals.

In this paper, we review a new type of telemedicine that can better meet the demands of surgeons, focusing on two key technologies: the digital video transport system (DVTS) and the academic internet for research and education.

Advantages

These two new technologies being incorporated into the telemedicine system bring very attractive features, compared with the traditional methods:

1) No loss of image quality during transmission: The quality of the source image created in the original operation theater is perfectly preserved. In comparison, with the conventional technology such as ISDN (Integrated Services Digital Network), images must always be compressed due to the limited transmittable network volume, and this inevitably degrades the image quality and reduces the speed of video movement. One channel in the new system utilizes 30 Mbps, which is 200 times greater than an ISDN channel (0.14Mbps). This huge network volume enables the preservation of clear images in the transmission to remote stations by avoiding compression processes. In addition, the time delay of the transmission is minimized due to the avoidance of complex compression algorithms, which usually create large computation loads and result in considerable time loss.

2) Low cost of initial investment: Another significant drawback of traditional systems is the necessity to obtaining special teleconferencing equipment before beginning the telemedicine procedure, at a minimum cost of around US$10,000. In contrast, this new system only requires quite common and widely available equipment such as digital video cameras and regular personal computers (PCs), which may well be already in many hospitals and even at home. A user can start sending images only by connecting these two devices using an IEEE1394 interface cable and broadband internet access. Simply by adding a video camera and computer to the standard surgical equipment, surgery images can be transmitted to a remote site.

Functions of the two key technologies

The following two technologies, as mentioned above, are essential to the improved functioning of this telemedicine system [1]:

1) Digital Video Transport System (DVTS): The DVTS is a software application used for sending and receiving digital video streams through the internet. It employs differentiated data transmission to send full-resolution video images to

remote stations. This system converts digital video signals directly into Internet Protocol format without any analog conversion, which is the key for ensuring that the images do not lose quality. The DVTS was released in 1999 in Japan, and then was internationally authorized by International Telecommunication Union. Besides it is a powerful and very useful program, it also has the advantage of being downloadable free-of-charge from its homepage (http://www.sfc.wide.ad.jp/DVTS). A Google search for “DVTS” easily locates this site.

2) Research and Education Network (REN): Most of the general public are not aware that there are two types of internet in the world: one is for commercial use and the other is for academic use, and the two are rather different entities. The former is for general use and is the one that most people know of, and the latter is restricted to academic use by universities or research institutes. The differences between the two types of internet are briefly summarized in Table 1. An academic network is usually government-funded and is much better than the commercial network in terms of speed, capacity, and technology. These two types of networks can be compared with a highway in which there is much less traffic congestion and construction detours thus allowing large vehicles to travel at high speeds and in safe conditions, and a regular road in which the reverse conditions are true. Although many network engineers use academic networks on a daily basis for internet research and for various applications such as weather forecasting, agriculture, astronomy, and disaster management, medical doctors are likely not even aware of the existence of this kind of network and the fact that thousands of universities and academic institutions are already connected to this worldwide network. If the REN connection is already reaching hospitals, the end users there who wish to engage in telemedicine do not have to pay extra for its setup.

The REN is now accessible in almost all developed countries and is rapidly expanding into developing countries as well [1]. Table 2 shows some examples of RENs around the world. Internet2 in the United States connects 200 major universities, and the member list is available on its homepage. All national universities are connected in Japan, and the same is the case in China with its 1000 universities. There are also international RENs that connect these domestic networks and enable worldwide communication. REANT2 is the European version, connecting over 30 countries and 3000 universities, while APAN is the Asia-Pacific network and RedCLARA is the South American counterpart.

Potential communication and activities

This new form of telemedicine brings various possibilities for academic interaction in surgery. There are two main types of telemedicine communication: live surgery, and teleconferences using PC presentations or recorded videos. Live surgery is attractive to surgeons, with its real-time transmission and the excitement of watching the actual surgery while it is taking place; meanwhile, teleconferencing allows audiences more in-depth discussions, with the possibility of reciprocal presentation of videos, while remaining in a more relaxed environment. After a large academic network was established between Japan and Korea in 2002, this new form of telemedicine was launched [2]. The first surgical teleconference using DVTS over a REN was performed between these two countries in February 2003, and it expanded rapidly to other countries due to its attractive advantages [3]. China was first connected in October 2004, Thailand in January 2005, Singapore in November 2005, Vietnam in June 2006, Indonesia in July 2006, and the Philippines, Malaysia, and India in January 2007 [4]. Its expansion continued outside Asia around the Pacific rim to Australia, New Zealand, and the mainland US in July 2004, August 2008, and January 2007, respectively [5]. The first connection to Europe was established in August 2007 to Germany and France, followed by Italy, Belgium, the Czech Republic, Spain, and Norway after December 2007 [1]. In May 2009, Cairo University in Egypt was linked, as the first such connection in Africa. As of June 2009, 103 centers in 22 countries have implemented our system and 178 teleconference events have been performed. The network continues to expand and more than 100 hospitals are now showing interest in joining and are in talks or making preparations to implement our system.

Our telemedicine system can easily be set up for casual settings because the system is simple and adds practically no running costs, while it can also be used for a large formal congress because the transmitted surgical images can be shown in high quality on a big screen in a large venue. The image quality is as good as that of television, but bidirectional live interactions are another great benefit of our system. Satellite connections have been commonly used for surgery professional meetings, but the extreme expense and tight scheduling are prohibitive. The Internet offers greater flexibility with much less use of resources.

A multi-station connection allows greater interaction when compared with the one-to-one connection, because multiple stations can communicate multi-directionally, thus creating a more constructive discussion that includes more specialists and other participants. Another technical breakthrough has made multi-party teleconferences possible. The system, called QualImage/Quatre (Information Services International-Dentsu, Ltd., Tokyo, Japan), digitally merges multi-station images into one image without any analog conversion, and sends the merged image back to the original stations. Now up to eight remote stations can be connected for an interactive discussion (Figure 1).

The topics of these telemedicine interactions are now not limited to general surgery, but have expanded to various fields such as neurosurgery, respiratory surgery, robotic surgery, urology, transplantation, gastrointestinal endoscopy, cardiology, healthcare, medical informatics, nursing, and education for medical students [6]. Evaluation questionnaires have revealed that these participants are satisfied with the quality and process in this new communication style, and that the efficacy of distance education was also improved [7,8].

Future directions

Technological development matched with the demands in surgical education has led to the development of an extremely practical and useful tool for academic communication. Although there is no doubt that this begins a new era of remote communication for surgeons, there are some issues to be considered and resolved for the further improvement of this system.

The first consideration is that the REN is not yet connected between all interested hospitals. The connectivity of a hospital must first be determined, and if it is not connected, establishing a new link from this hospital to the access point of the academic network is usually the responsibility of that hospital. The second is that the quality of the digital videos is standard (720 X 480 pixels) and not high definition (HD, 1920 X 1080 pixels). It is now technologically possible to transmit HD quality uncompressed to remote stations over a REN, but it still costs a lot of money and has not attained practicality [9]. Now that many forms of HD surgical equipment are commercially available, another technological breakthrough for telemedicine should not be far behind.

For this project to be widely initiated and well maintained, however, the most important requirement is to organize good teamwork between medical and engineering professionals. Although the DVTS has many advantages, it works properly only when a large and stable broadband network is secured all along the transmission route, the establishment of which requires professional knowledge and skills. Medical doctors alone would not likely know how to establish access to a REN and control the large volume of internet data. Furthermore, the DVTS is not a simple piece of equipment like the traditional and commercially available Polycom videoconferencing system (PictureTel Corporation, Danvers, MA, USA), and so audio-visual engineers are also needed to manage sound quality and image projections, otherwise its high quality streaming capacity could be diminished by unpleasant noise or frequent image freezes. Luckily enough, many universities and academic hospitals have on-staff engineers or clinical technicians who are in charge of internal networks and advanced surgical equipment, so these employees could be consulted for help and collaboration. The technological benefits of good image quality and no additional costs are completely dependent on the establishment of a good human resource network with varied roles and on the leadership of medical doctors in promoting the project.

On-site education with information sharing from senior to junior surgeons is of course the best education method, and this will likely never change. But it is rare to have every type of specialist in any one hospital, and academic interactions between hospitals are of extreme importance especially in rural areas and in bridging geographic borders. Now the development of truly practical remote medical interactions over a worldwide network is at hand, and hopefully this system will work synergistically with on-site education, with the ultimate goal of better healthcare for the public.

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Figure legend:

Figure 1. Live surgery demonstration between seven participatory stations. An endoscopic surgery was video-transmitted from Seoul, Korea, to the main audience venue in Xian, China, connecting to Singapore, Tokyo, Manila in the Philippines, Sydney in Australia, and Bordeaux in France.

Figure1
Click here to download high resolution image

Table 1. Comparison between Commercial and Academic Networks

	Commercial Network	Academic Network
Setup	Service Providers	Governments
Maintenance	Service Providers	Researchers
Costs	Price list	Free for end users
Bandwidth	Price list	Maximum
Content	No restriction	Only for research & education
Performance	Not bad, not good	Best tuned
Technology	Less advanced	Most advanced
Support	Service Agreement	24hr X 7days

Table2

Table 2. Examples of research and education networks (RENs)

Country or region	Name of REN	Homepage
Japan	SINET3, JGN2plus, WIDE	http://www.sinet.ad.jp/english/
Korea	KOREN, KREONET	http://www.koren21.net/eng/index.php
China	CERNET, CSTNET, NSFCNET	http://www.edu.cn/HomePage/english/index.shtml
Australia	AARNET	http://www.aarnet.edu.au/
USA	Internet2	http://www.internet2.edu/
Canada	CA*net4	http://www.canarie.ca/about/index.html
Mexico	CUDI	http://www.cudi.edu.mx/
Brazil	RNP	http://www.rnp.br/en/index.php
Italy	GARR	http://www.garr.it/garr-b-home-engl.shtml
Spain	RedIRIS	http://www.rediris.es/index.php.en
Germany	DFN	http://www.dfn.de/en/enhome/
France	RENATER	http://www.renater.fr/
Netherlands	SURFnet	http://www.surfnet.nl/en/Pages/default.aspx
Czech Republic	CESNET	http://www.ces.net/
Norway	UNINETT	http://www.uninett.no/index.en.html
England	JANET	http://www.ja.net/
Egypt	EUN	http://www.eun.eg/
Asia-Pacific	APAN	http://apan.net/
Europe	GEANT2	http://www.geant2.net/
South America	RedCLARA	http://www.redclara.net/