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<http://hdl.handle.net/2324/8711>

出版情報 : Hepato-Gastroenterology. 54 (74), pp.373-376, 2007. International Association of Surgeons, Gastroenterologists and Oncologists

バージョン :

権利関係 :



A Remote Educational System in Medicine using Digital Video

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ABSTRACT

Background/Aims: Telemedicine has opened the door to a wide range of learning experience and simultaneous feedback to doctors and students at various remote locations. However, there are limitations such as lack of approved international standards of ethics. The aim of our study was to establish a telemedical education system through the development of high quality images, using the digital transfer system on a high-speed network.

Methodology: Using telemedicine, surgical images can be sent not only to domestic areas but also abroad, and opinions regarding surgical procedures can be exchanged between the operation room and a remote place. The Asia Pacific Information Infrastructure (APII) link, a submarine cable between Busan and Fukuoka, was used to connect Korea with Japan, and Korea Advanced Research Network (KOREN) was used to connect Busan with Seoul. Teleconference and video streaming between Hanyang University Hospital in Seoul and Kyushu

University Hospital in Japan were realized using Digital Video Transfer System (DVTS) over Ipv4 network.

Results: Four endoscopic surgeries were successfully transmitted between Seoul and Kyushu, while concomitant teleconferences were taken place between the two throughout the operations. Enough bandwidth of 60Mbps could be kept for two-line transmissions. The quality of transmitted video image had no frame loss with a rate of 30 images per second. The sound was also clear, and time delay was less than 0.3 sec.

Conclusions: Our experience has demonstrated the feasibility of domestic and international telemedicine. We have established an international medical network with high-quality video transmission over Internet protocol, which is easy to perform, reliable, and economical. Our network system may become a promising tool for worldwide telemedical communication in the future.

KEY WORDS:

Telemedicine;
Network;
Endoscopic
surgery

INTRODUCTION

Advances in Internet technology have greatly contributed to practically every aspect of our life and also on computerization and automation of medicine. Because of these advances, telemedicine has been developed, which is defined as medicine at the remote site and can transmit medical images and a large volume of medical information through a high-speed network (1). Recently, robust research efforts in the field of telemedicine system have yielded some great achievements of telemedical care between domestic hospitals (2). The telemedicine system can also be applied to the education of doctors and medical students. However, the quality of presently transmitted live video images is not optimal for medical purposes, and there are no general and international standards in regard to transmission of high quality image, minimization of transmission lag time and acquisition of a

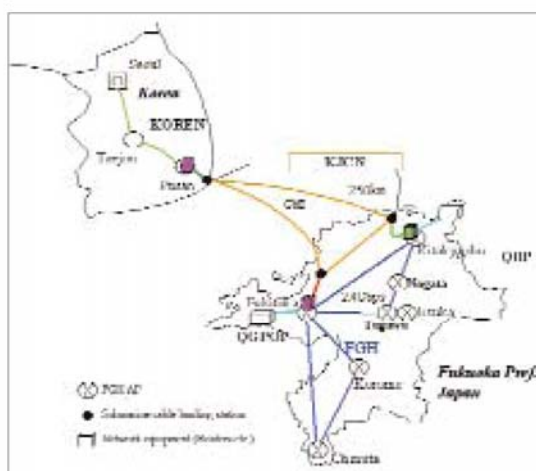


FIGURE 1

Korea-Japan cable network configuration between the Hanyang University Hospital in Seoul and Kyushu University Hospital in Fukuoka, Japan. KOREN was used to connect between Busan and Seoul.

multiplexer channel for voice and other various contents, which are important prerequisites for correct diagnoses and recognition of the human body in detail. In 2001, a broadband fiber-optic cable system between Korea and Japan called APII link, was constructed as part of an international partnership (Figure 1). Before the establishment of APII link, there was no network capable of transmitting pictures of high quality without lost frames between the two countries.

The purpose of this research was to attempt a domestic and international remote medical education using the Digital Video Transfer System (DVTS) over a high-speed network and to establish a new vision of telemedicine through high-quality image processing technology.

METHODOLOGY

1. Establishment of Network

An advanced network for telemedicine required a digital camcorder to catch the global view of the personnel and the environment of the operating room, an analog camera mounted on the astral lamp to have the picture of the operating table, and an image splitter installed in the operating room. The operating room was connected to a seminar room to serve as a place for live discussion about the operation, and a network was connected to Kyushu University Hospital, Fukuoka, Japan. This project was established as a joint project of Hyunhae/Genkai project and made use of APII link and KOREN (Korea Advanced Research Network), both of which were constructed with the assistance of the Korean National Computerization Agency subsidiary to the Ministry of Information-Communication.

APII link cable was laid in the bottom of the sea for 300km distance between Busan and Fukuoka, and 300km distance between Busan and Hanyang University in Seoul was connected by KOREN (Figure 1). The first video conference between Hanyang University Hospital and Kyushu University Hospital took place on February 12, 2003 (3).

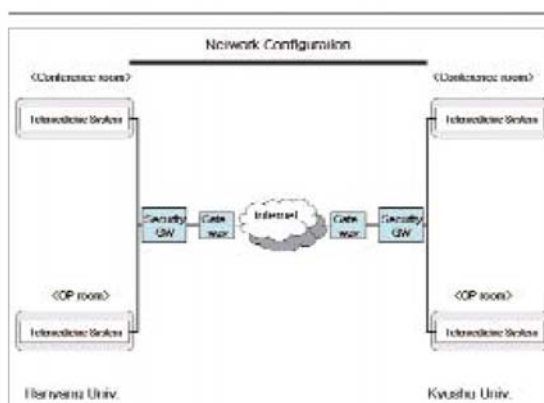


FIGURE 2 Schematic network configuration between the Hanyang University Hospital in Seoul and Kyushu University Hospital in Fukuoka, Japan.

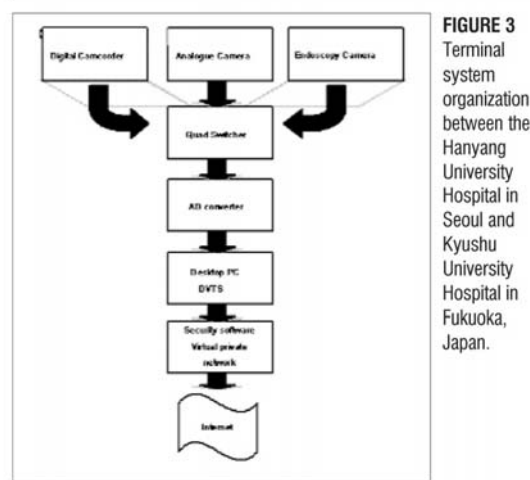


FIGURE 3 Terminal system organization between the Hanyang University Hospital in Seoul and Kyushu University Hospital in Fukuoka, Japan.

2. Design of System

Our telemedicine system is based on both way communications. Unlike a more traditional communication system that allows only an exchange of simple information, our system is not only able to exchange images, but also offers the possibility of smooth verbal communication between the medical teams of both countries. Other special features of our system include the construction of a user environment of Korean-Japanese automatic translation system during the video conference to provide a synchronic translation into the language of the opposite country and the introduction of a security software (focus system corporation, C4VPN Ver 3.0) to preserve patient's privacy during remote transmission of the operation.

3. Video System for Telemedicine

In order to improve the video image quality, we constructed a fully digital video system which comprised with only a digital video camera and a personal computer (PC) equipped with an IEEE1394 interface. Contents have been developed at the Network Research Institute, Hanyang University College of Engineering and been used in videoconference between a hospital and the Network Research institute, a hospital and a seminar room, or between hospitals. Optical fibers of APII link used in this research to connect Busan to Fukuoka offer 2 Gbps band width for data transmission.

A bi-directional digital video system based on IPv4 address system over the network was used for teleconferencing and streaming of video between Hanyang University Hospital and Kyushu University in Fukuoka (Figure 2).

RESULTS

Several live transmissions of operations were successfully carried out as preliminary experiments, including the transmission from the operating room to a seminar room and to Japan. A surgical workshop on a new surgical technique for practicing surgeons in the

country, including live broadcasting and videoconferencing, was also successfully performed with our system. Before the digital video was sent to Kyushu University Hospital, a series of alterations were made by several instruments or software, including an image splitter, a digital converter, DVTS and security software (**Figure 3**). At the same time, the video image of the participants in the seminar room was transmitted back to both the operating room and Kyushu University Hospital through another connection. During the operation, the operating surgeons and observers were able to discuss about the surgical process. In a brief survey after the session, the participants had the opinion that the quality of the transmitted video image was not different from the original image and was far superior to the general analog video image. The operations transmitted live were laparoscopic cholecystectomy and laparoscopic radical prostatectomy, and the anatomic structures could be well recognized and the whole process of operations was well understood during the operations (**Figure 4**). Thus, the transfer of video on Internet protocol using DVTS, was successfully achieved. Patient's case history and preoperative X-ray images could also be sent in still images. The transmission was smooth and devoid of any lagging, while it attained a rate of 30Mbps, and the voice was clear with almost no flutter or cross fire throughout the process. The delay time between the networks on both ends was less than 0.3 sec.

DISCUSSION

Multimedia communication technology using Internet and advances in the fields of information-communication has made great contributions to many aspects of life. In the medical fields, they accelerated computerization and automation, establishing the basis for telemedicine, which made it possible to transmit medical images and various forms of medical information to a remote place through high-speed network. The merits of telemedicine are as follows. First, it is possible to have a medical practice and give medical advice even from a remote site without spatial limitation. Second, availability of diagnostic tests at a remote hospital eliminates the necessity to be equipped with expensive machines, and inter-institutional share of a patient's records is possible. Third, teleconferencing enables doctors to share medical knowledge at a low cost, and telemedical education of medical students is possible. However, establishment of a medical network system requires several prerequisite conditions of which quality of the image is the most important. An example of the importance of the image quality may be found in the endoscopy of the upper digestive tract where by early gastric cancer may be diagnosed; if an early gastric cancer was missed due to poor image quality, resultant impact could lead to serious consequences on patient survival. Other problems such as transmission rate and noise remain to be resolved (4). Several modes of transmission have been tried in order to resolve these problems and realize medical networking. First, ISDN (Inte-



FIGURE 4 (A) Screen image of laparoscopic prostatectomy. It shows a clear image of surgical view. (B) Operation room at the Hanyang University Hospital. It shows a surgical team during laparoscopic prostatectomy. (C) Conference room at the Hanyang University Hospital. Many medical staffs discuss about the surgery with Kyushu University Hospital staff through DVTS. (D) Conference room at Kyushu University Hospital in Japan. Medical staffs also discuss about the surgical view from Korea.

grated Services Digital Network) is a service network that uses the existing telephone line for analog voice signals to provide every communication service, including voice and data as an integrated service. A telephone line can simultaneously offer 2 circuits of 64Kbps (voice) and 1 circuit of 16Kbps (data). Before ISDN, separate network lines were necessary to provide different kinds of communication service, because modes of transmission for voice, character, image and data are different. However, with ISDN different kinds of information are converted into digital signals and transmitted through a single channel. Despite this advantage, the maximal rate of transmission for ISDN is 384Kbps, which is inadequate for image quality high enough for making accurate diagnosis. For this reason, only a few researches on the use of ISDN for transmitting endoscopic images have been available (5). Second, ADSL (Asymmetric Digital Subscriber Line) is a system that links telephone office and home one-on-one, with which downward data transmission from the telephone office to the user, is possible at a high speed of minimum 1.5Mb, however, the upward signal transmission from the user to the telephone office is slow. The advantage of ADSL is that, not only is high speed data transmission possible without interrupting the use of the telephone, but also a single telephone line can handle both conventional telephone communication and data communication. Unlike ISDN, after voice and high speed data are sent by different frequencies to an existing two-wire analog telephone line, voice from low frequency bandwidth is used by the telephone and high frequency bandwidth

data are received by an ADSL modem to be used by the PC after transformation into digital information. Although ADSL offers 8-12Mbps high speed, it is still not appropriate for use in telemedicine, because of the reduction in video stream data despite of good network use.

Low speed and noise produced by the present network stream appear frequently also with ADSL and are great obstacles to telemedicine. In the network linked abroad, these obstacles can produce dropped video frames or distortion of images and can result in more serious problems, such as loss of data, image hang-up and complete arrest of the image streaming (6,7). Under certain circumstances, a transmission speed of 40Mbps should be secured to transmit an endoscopic image clear enough for correct diagnosis (8).

On the other hand, various video compression techniques have been developed to reduce transmission load in the network (9). MPEG (Moving Picture Expert Group) is a standard format for video compression and has several versions. MPEG1 is standardized for recording media such as CD-ROM, and MPEG2 is a version upgraded from MPEG1 to allow it to be used in communication and broadcasting as well. MPEG4 is an encoding format that compresses video and audio with a high efficiency at a low speed of about 64Kbps. Usual formats, such as MPEG1 or MPEG4, have bandwidth of less than 1Mbps, and have image quality inadequate for medical purposes (10). All of these formats have been tried, however, none has been validated as clinically valuable and adopted as an international standard.

In this research project, a new and very appealing internet-based DVTS was tested and found to have many apparent advantages as follows. First of all, in telemedicine transmitted images must preserve precisely the quality of the original ones, and DVTS was found to have the advantage of displaying transmitted video quality practically indiscernible from the original video and of keeping voice data clear all through the transmission. Second, transfer time delay was minimized, because DVTS does not require a complex process of compression algorithm or modulation-demodulation. Third, this system can be constructed

simply on PC equipped with only a digital video camera and an IEEE1394 interface environment. IEEE1394 interface has a very high transmission speed and can transfer in 3 different speeds of 100, 200 and 400Mbps, depending on different modes. Because there is no limitation in transmitting digital audio or video image at such speed, multimedia peripheral devices, such as scanner, digital camera and digital video camera, can be connected, and two-way communication is also excellent. APII link uses optical fibers for data transmission and offers 2Gbps bandwidth to connect Fukuoka, Japan and Busan, Korea. Our project succeeded in securing a unique resource of 100Mbps for two video streams, while protecting the horizontal transfer data of another project competing for the same resource, thus realizing for the first time between the two countries, the transmission of high quality medical video using two digital video DVTS streams. In contrast to the above, however, DVTS has the major disadvantage of requiring a broadband network that provides 30Mbps per channel, therefore, it is still in the experimental stage.

Recently, diagnosis and treatment through endoscopy are replacing conventional surgery in many fields. In gastrointestinal medicine, for example, endoscopists are performing multitudes of endoscopic procedures in most countries around the world. If high quality on-line operation becomes possible, it is expected to be unnecessary for an endoscopist to visit a country abroad or another hospital to learn new techniques and for hospitals to perform same surgeries as other hospitals do, thus leading to specialization of hospitals. This in turn will force specialists to engage in collaboration in and outside the country, thereby accelerating the development of endoscopic procedures.

In conclusion, under the present circumstances where there is no internationally standardized and clinically proven telemedicine system available, DVTS is expected to eliminate obstacles which interfere with standardization of high quality video and telemedicine. Therefore, although still in experimental stage, DVTS would be a very useful network tool in the future for not only domestic but also international telemedicine.

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