LIVE SURGERY BROADCAST FROM JAPAN TO SOUTH AFRICA: HIGH-QUALITY IMAGE TRANSMISSION OVER A HIGH-SPEED ACADEMIC NETWORK

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Abstract

Quality preservation during the transmission of medical moving images is challenging owing to image compression in the limited bandwidth of the Internet. Satellite transmission does not solve this problem because of the high cost involved, hindering the advancement of practical telemedicine. We developed a new, affordable and usable system, and applied it to the live transmission of surgery from Japan to South Africa. The digital video transport system (DVTS), which is free software that transforms digital video signals directly to Internet Protocol, and academic networks dedicated to research and education purposes were used with bandwidth of 30 Mbps. The cipher program IPsec was used to protect patient privacy. Laparoscopic rectal surgery was transmitted live from Kyushu University Hospital in Japan, to the University of Cape Town in South Africa, as well as Cho Ray Hospital in Vietnam, over a period of 2 hours. Interactive discussion was held among the three sites with the transmission of clear, high-resolution, and smooth surgical images. This project is an important milestone achieved in South Africa indicating its feasibility for developing nations with National Research and Education Networks and provides a base for its domestic and international expansion.

Keywords: Research and education network; digital video transport system; live surgery; medical education; videoconference; South Africa.

Introduction

Moving images are much more useful than still pictures in medical education when showing various procedures such as surgery. Preservation of image quality is important in telemedicine and medical tele-education, but the transmission of clear moving images is more technically demanding than that of still pictures. Conventional videoconferencing systems often provide sluggish and blurred images at remote sites.1,3 Even though satellite transmission ensures excellent image quality to multiple locations, its expense is prohibitive when used for smaller regular interactions. Hence the need for alternate inexpensive high quality solutions to increase the appeal of telemedicine and medical tele-education using live video transmissions was awaited.
We developed a remote system for medical education in 2003 that is satisfactory in terms of quality and cost, and we have expanded this activity through Asia and beyond in the last 10 years. In South Africa networks have been too immature to use our system and telemedicine activities have only used commercial videoconferencing systems on narrowband connections.

Although large-capacity Internet lines were gradually constructed from Europe, the Middle East and South Asia along the eastern and western coasts of Africa, there were few international remote medical education programs which took full advantage of these improved bandwidths. The situation changed when South Africa hosted the Fédération Internationale de Football Association (FIFA) World Cup in 2010, at which time medical staff and engineering researchers started collaborations in harmony. Similar academic networks are now seen in other developing world such as RedClara in Central and Latin America.

This report is a brief case study of the first successful live surgical transmission from Japan to South Africa using our telemedicine system and a fast academic network dedicated to research and education.

**Material and Methods**

The operating room of Kyushu University, Fukuoka, Japan, was connected to a conference room at the University of Cape Town, South Africa, and to Cho Ray Hospital, Ho Chi Minh, Vietnam, as the third station. A digital video transport system (DVTS) was used to transmit images and sound during live surgery. DVTS software was downloaded, free-of-charge, from http://www.sfc.wide.ad.jp/DVTS and was installed on a personal computer (PC) as reported previously.

Figure 1 is a diagram of the audio and visual connectivity at the transmission site. For transmission, three image sources were prepared: a PC for presentation, an operating instrument for surgical view, and a video camera for showing the operating theatre and its staff. These image sources (A) were switched by a video mixer (B) and input into a video convertor (C) to mix audio and video images. The signal was then transferred to a DVTS-installed PC (D) via an IEEE1394 port and sent out through an encrypted network connection (Data Encryption Standard), called IPsec, to protect patient privacy and maintain data security. The QualImage/Quatre system (Information Services International-Dentsu, Tokyo, Japan) server, located on the engineering campus of Kyushu University, was used to merge images from the three remote stations and to send images back to each station. For receiving, another PC (F) was prepared with a large display device (G).

Figure 2 shows the network topology used in this study. We secured 30 Mbps bandwidth throughout the connection from Kyushu University Hospital to University of Cape Town, via the Research and Education Networks (RENs) listed in Table 1.

The University of Cape Town is a member institution of SANReN, which covers the interconnectivity of universities in South Africa, and 1 Gbps bandwidth was prepared. SANReN has an exchange point with UbuntuNET Alliance in Johannesburg, and provided a 10 - Gbps connection between Johannesburg and London, United Kingdom. The traffic arriving at London was transferred to the research and education network for the whole of Europe, GEANT, whose bandwidth was between 40 and 100 Gbps.
Figure 2. Academic networks used in this study.

From Europe to Japan, there were two routes, one West-bound and the other East-bound. In this demonstration, the West-bound route was chosen because it secured a larger bandwidth than the East-bound route, and the network operation team set this route as the primary route.

In this setting, all traffic was transferred to Internet2, the research and education network for the United States; the trans-Atlantic bandwidth was at least 40 Gbps. In the United States, there is the access point of SINET, the Japanese research and education network. Kyushu University Hospital is a member of SINET, and we used a 10-Gbps line from the United States to our institution. In the East-bound route, the Trans-Eurasia Information network (TEIN), funded by the European Union, provides the backbone service from Europe to Singapore with 2.5 Gbps. Because Hong Kong is an exchange point of TEIN and provides a 155-Mbps service to Vietnam, this east-bound circuit was used to connect to Cho Ray Hospital, a member of VINAREN, the Vietnam research and education network.

The ethics committee of Kyushu University Faculty of Medicine approved the project and written informed consent was obtained from the patient.

Results

Laparoscopic surgery for rectal disease was transmitted for two hours on September 21, 2011. The surgical view and theatre view were shown by switching images accordingly. A moderator beside the operator mainly talked to the remote participants, explaining the surgical procedures, introducing various instruments used, and finally showing a resected

Table 1. Academic networks used in this study.

<table>
<thead>
<tr>
<th>Network name</th>
<th>Description</th>
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<tbody>
<tr>
<td>SANReN - South African National Research Network</td>
<td>Domestic research and education network in South Africa</td>
</tr>
<tr>
<td>TENET - The Tertiary Education and Research Network</td>
<td>Research and education network in South Africa to coordinate the international activities</td>
</tr>
<tr>
<td>UbuntuNet Alliance - Ubuntu is an African word meaning “humanity to others”</td>
<td>The Regional Research and Education Network for Eastern and Southern Africa</td>
</tr>
<tr>
<td>GÉANT - Géant means “giant” in French</td>
<td>European research and education network</td>
</tr>
<tr>
<td>Internet2</td>
<td>Research and education network in the US</td>
</tr>
<tr>
<td>TEIN - Trans-Eurasian Information Network</td>
<td>South, South –East, and East Asian network connecting to Europe</td>
</tr>
<tr>
<td>VINAREN - Vietnam National Research and Education Network</td>
<td>Research and education network in Vietnam</td>
</tr>
<tr>
<td>SINET - Science Information NETwork</td>
<td>Japanese research and education network</td>
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specimen, and there was interactive discussion among the three stations (Figure 3).

Figure 3. Screen shot of live surgery demonstration transmitted between Kyushu University, Japan (top left), University of Cape Town, South Africa (top right), and Cho Ray Hospital, Vietnam (bottom left).

A slide presentation summarizing the surgery was also made from Kyushu University Hospital. The image was smooth and clear at all three stations and sound quality was good for communication. A short clip of the recorded video is available for review.11

Discussion

There is no doubt that telecommunication is useful for remote medical education. The time and cost associated with physical movement can be saved, and the program can be easily repeated for a large audience at remote sites. Synchronous medical tele-education is both economical and effective for teaching.

Video conferencing has thus become increasingly popular and various types of equipment are commercially available. Simple image transmission and video transmission with static presenters is being increasingly used in the telemedicine for multidisciplinary cancer networks and for medical tele-education. Live video transmission with switching of sources and conversion of analogue to digital signals has largely been confined to specialised units and large congresses which utilise commercial technical support for single events which require large budgets. An alternative to reduce costs is to use data compression techniques. These inevitably degrade the image quality and when used with a narrow-band network often result in transmission delay, sound asynchronisation and pixelated images. This has made physicians reluctant to use low bandwidth teleconferencing for high quality video transmissions.3

The emergence of DVTS for high-quality video transmission and the development of an academic network to provide sufficient bandwidth for DVTS in late 20th century dramatically changed the situation.12,13 Once accepted in Japan and Korea for the first time in 2003, this system rapidly expanded through Asia and beyond.14-18 Activity was accelerated by good end user evaluations of quality.19,20 Desktop or laptop videoconferencing obviates the need to buy dedicated videoconferencing equipment at each site. Access to bridge or one MCU allows multi-point desktop videoconferencing at very low cost. In the wave of global expansion, some of our collaborating hospitals in northern Africa were connected with the Mediterranean academic network in 2010; however, a sufficiently large-capacity network did not reach southern Africa until recently.8

TENET (Tertiary Education and Research Network of South Africa) was created as a non-profit organization in 2000 and began providing networking and Internet services to 40 universities, research institutions and associated support institutions in 2001. TENET then provided operational services to SANReN (South African National Research Network), which was formed as part of a comprehensive plan of the Department of Science and Technology to ensure South African researchers had high-speed services. TENET is also a founding member of the UbuntuNet Alliance, and operates UbuntuNet’s hub and connection to GEANT in London on behalf of the Alliance, thus providing a very-high-speed research network that boosts South Africa’s national cyberinfrastructure.21,22 It is interesting that the Japan–Korea network was drastically upgraded when these countries co-hosted the FIFA World Cup in 2002, which initiated our activity in Asia, and a similar event happened in South Africa. These networks became harmonious and were practically implemented at the time that regions hosted the FIFA World Cup. Mars et al. at the University of KwaZulu-Natal made the first trial using the DVTS system over the academic networks in South Africa in 2011 (personal communication).

Although we made a successful live transmission
of surgery between countries as far as 14,000 km part, there are problems to overcome. One relates to the campus network at the University of Cape Town, where a sufficient network in the affiliated hospital is not yet available. Refinement of the local network is planned. Another is the necessity to integrate and educate engineers controlling South African University Academic Network bandwidth with Medical Faculty IT personnel. This will improve the handling of a huge-volume network, whose use on a regular basis is still relatively new to Medical Faculties in the country.

This first successful experience, however, encourages us to further develop this type of telecommunication for medical tele-education and telemedicine in South Africa. One direction is to expand the present system domestically among leading university hospitals in South Africa where the academic network is already available. Another is to expand the activity internationally, especially to other African countries and to Europe with academic networks in the same or a near time zone. We strongly believe that remote medical education, now in real practice, can provide health providers with updated information without delay, ultimately giving patients a better and timely service in every corner of the globe.

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Conflict of Interest: The authors declare no conflict of interest.

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