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Telemedicine in the Asia-Pacific Region Transmitted Over a Research and Education Network

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INTRODUCTION

Telemedicine can be classified into two categories: transmission of information between doctors and patients and that between doctors and other doctors. The first category—between doctors and patients—includes remote consultation or surgery that results in assigning a proper diagnosis or applying a treatment[1,2]. The second category—between physicians—can be further divided into (1) the use of teleradiology or telepathology to obtain professional comments or suggestions from specialists and (2) teleconferencing or live demonstrations between remote stations for continuous medical education or interactive discussions[3-6]. The telemedicine discussed in this chapter deals with the latter.

The advantages in telemedicine are well appreciated. They include saving the time and cost of traveling to obtain medical advice and/or personally participating in meetings or seminars[7-8]. Another advantage, which seems to be less well understood, is the scalability of telemedicine; that is, many "actors" can participate simultaneously, and such events can be repeated with ease. When doctors want to visit another hospital to see advanced surgery, for example, only a few can spare the time and expense of such a trip. It would also be difficult to arrange frequent visits. In contrast, telemedicine makes it easy to invite many participants simultaneously and repeatedly. Telemedicine is thus both efficient and useful. The reality, though, is that it is not common practice or popular in the medical community. Why not?

We think there are three main reasons. One is that the image quality was not satisfactory for medical purposes at the remote sites using the early technologies, such as the integrated services digital network (ISDN) and narrowband Internet[9-11]. Image quality is key to making an accurate diagnosis. Should there be a misdiagnosis owing to the deterioration of transmitted images, it would be a serious problem. Moving images are often more educational than still pictures, especially in the surgical arena. Transmitted movies, however, often become sluggish and damaged in the setting of limited bandwidth because video streaming requires much more transmission volume than is needed for still pictures. Thus, it has been a technical challenge to preserve image quality during movie transmission for telemedicine purposes[12-13]. The second issue is the cost[8-14]. Satellites are often used for large congresses to maintain image quality, but it is so expensive that it is not affordable in casual settings or for frequent use. The last (but not least) obstacle is that medical people are often not familiar with advanced technologies. Also, they are unable to identify the engineering staff who are sufficiently knowledgeable to help them, even though they often work in the same hospitals or institutions.

We have used the Internet to solve these problems. The Internet of which we speak, however, is not the common commercial Internet we use at home or in our offices. It is an Internet with large bandwidth and stable conditions, dedicated to research and education[15]. In this chapter, we report our activities in telemedicine and their development in the Asia-Pacific region.

MATERIALS AND METHODS

When developing our system, we used a digital video transport system (DVTS) for image and sound transmission[16]. It is free software that can be installed in one's computer from a download site (http://www.sfc.wide.ad.jp/DVTS/). Image and audio sources from a video camera, medical devices, or microphones were connected to the computer via an IEEE1394 interface. Audio mixers were used to control sound echo problems. The QualImage/Quatre system (Information Services International-Dentsu, Tokyo, Japan) was used as the multipoint connection unit for the DVTS when connections were made with three or more sites simultaneously[17,18]. With this setup, we were able to have interactive discussions between the connected stations via transmitted image steaming.

The network used was not a commercial one but an academic network dedicated to research and education[15]. We chose this type of network because the DVTS requires as much as 30 Mbps to preserve the clear, original quality of images. It would be difficult to maintain a satisfactory quality of service with a regular commercial network. Each country has its own domestic research and education network (REN); these networks, in turn, are connected by international RENs[18]. The networks we used are summarized in Table 1.

	Country/region	Network	URL
Domestic			
	Japan	SINET4	http://www.sinet.ad.jp/index_en.html?lang=english
	Korea	KOREN	http://www.koren.kr/koren/eng/index.html
	China	CERNET	http://www.edu.cn/inglish_1369/index.shtml
	Hong Kong	HARNET	http://www.jucc.edu.hk/jucc/harnet.html
	Taiwan	TWAREN	http://www.twaren.net/english
	Thailand	ThaiREN	http://www.thairen.net.th/NewThaiRen/Thai/index_th.php
	Vietnam	VINAREN	http://english.vinaren.vn
	Malaysia	MYREN	http://www.myren.net.my
	Singapore	SingAREN	http://www.singaren.net.sg
	Philippines	PREGINET	http://www.pregi.net
	Indonesia	INHERENT	http://www.inherent-dikti.net/
	India	ERNET	http://www.ernet.in/index.html
	Australia	AARNET	http://www.aarnet.edu.au
	New Zealand	KAREN	http://wwwkaren.net.nz/home
International			
	Asia-Pacific region	APAN	http://apan.net/
	Europe-Asia	TEIN3	http://www.tein3.net/

Table 1. Research and education networks in the Asia-Pacific region used in this study

To secure patient privacy, we used cipher programs for live demonstrations. C4-VPN (Focus Systems, Tokyo, Japan) was used at the beginning but was replaced after 2006 by IPsec, an internationally authorized security architecture for Internet Protocol. During a session on informed consent, we explained to the patients about the transmission of medical procedures and received their approval before participation. A patient's face was never shown on the monitor, and a moderator was in charge of communications with remote stations so the operators could concentrate on the procedures without creating any disadvantages for the patients[19,20]. The ethics committee of the Department of Medicine, Kyushu University approved our project in 2003.

We devised questionnaires to evaluate the system and the programs. They included questions about image quality, sound quality, and the program in general. The evaluations were performed at Asia-Pacific Advanced Network meetings in New Delhi (India) and Chiang Mai (Thailand) in August 2011 and February 2012, respectively. The medical subjects covered were endoscopy, surgery, transplantation, fetal medicine, and cardiology. The evaluations at all sessions at which the DVTS system was used were according to a four-scale judgment: very bad; bad; good; very good.

RESULTS

Between February 2003 and March 2012, a total of 285 telemedicine programs were undertaken: 189 (66%) teleconferences and 96 (34%) live demonstrations. The fields covered during these sessions were surgery, endoscopy, transplantation, urology, cardiology, fetal medicine, health care, nursing, student education, and others. One hundred seventy one institutions were linked in 29 countries/regions (15 in the Asia-Pacific region, 14 in other areas). The number of connected institutions in total was 977 with average of 3.43 sites participated in each program. The most active country was Japan (with 263 events) followed by Korea (149 events) and then China, Taiwan, Thailand, Singapore, and Vietnam, in that order. The details are as follows and are shown in Table 2.

	JP	KR	CN	HK	TW	TH	VN	MY	SG	PH	ID	IN	AU	NZ	Others
Year first connected	2002	2002	2004	2006	2006	2005	2007	2007	2005	2007	2006	2007	2005	2008	2004
No. of connected institutions	43	21	12	3	8	7	8	5	1	5	2	7	13	2	34
No. of events performed	263	149	60	14	45	43	26	15	31	20	6	15	24	2	39
Teleconference	179	92	34	8	35	26	14	11	23	13	4	9	14	1	30
Live demonstration	84	57	26	6	10	17	12	4	8	7	2	6	10	1	9

JP, Japan; KR, Korea; CN, China; HK, Hong Kong; TW, Taiwan; TH, Thailand; VN, Vietnam; MY, Malaysia; SG, Singapore; PH, Philippines; ID, Indonesia; IN, India; AU, Australia; NZ, New Zealand; Others, beyond the Asia-Pacific region

Table 2. Summary of connections in each country and region

Expansion of Activities

Japan and Korea

Our project started with sessions between Japan and Korea in 2002, and the first successful transmission was in February 2003 between Kyushu University Hospital (Fukuoka, Japan) and Hanyang University (Seoul, Korea). The Seoul National University Bundang Hospital joined in November 2004, Chungbuk National University in January 2008, the Asan Medical Center in April 2009, and Konkuk University in February 2010. There are a total of 21 connected Korean institutions. In Japan, 43 institutions are connected, including Iwate Medical University in July 2005, Kyoto Second Red Cross Hospital and Tokyo Medical and Dental University in June 2007, Fukuoka University in November 2007, Kyoto University in May 2008, University of Occupational Environment and Health in September 2008, Fujita Health University in January 2009, Hokkaido University in November 2009, National Center for Children's Health and Development in July 2010, and Kanazawa University in February 2011.

China, Hong Kong, and Taiwan

We first connected to Tsinghua University in Beijing, China in October 2004. This was followed by Shanghai Jiaotong First People's Hospital in June 2005, National Taiwan University in January 2006, Chinese University of Hong Kong in July 2006, Peking University in December 2006, Peking Union Medical College Hospital in July 2009, University of Hong Kong in August 2010, and Fudang University Zhongshan Hospital in July 2011. A total of 23 institutions are connected.

Thailand

Mahidol University Siriraj Hospital was the first institution connected in Thailand, which was accomplished in June 2005. King Chulalongkorn Memorial Hospital followed in January 2007, Rajavithi Hospital in January 2010, and Pramongkutklao University Hospital in June 2010. A total of seven institutions are connected.

Vietnam

The National Hospital of Pediatrics, Hanoi, was the first Vietnamese hospital connected, in January 2007. It was followed by Backmai Hospital (Hanoi) in August 2007, #108 Hospital (Hanoi) and Cho Ray Hospital (Ho Chi Minh) in March 2009, and Viet Duc Hospital (Hanoi) in August 2010. The total number of connected sites is eight.

Other Asian Countries

Singapore joined us at an early stage of our activity, in November 2005. It turned out that the National University of Singapore was the first and is only site connected in that country.

The Philippines was one of the most active countries among other Asian countries. The University of the Philippines Diliman was connected in March 2007, and the University of the Philippines Manila followed in February 2010. There are now five connected institutions.

The University of Malaya Medical Center is the main hospital in Malaysia, and it was connected in August 2010, following an earlier 2007 connection to Malaysian Research and Education Center. Five institutions have connections.

The first connection in India was at the Tata Memorial Hospital in Mumbai, which occurred in January 2007. The Asian Institute of Gastroenterology, Hyderabad, and the Institute of Liver and Biliary Sciences, New Delhi, were connected in May 2011 and December 2011, respectively. India has seven connected sites.

Indonesia has two connected institutions. The Institute of Technology Bandung was connected in July 2006 and the University of Indonesia in January 2007.

Australia and New Zealand

Flinders University, Adelaide, was the first Australian university to join our program in November 2005, followed by Royal Brisbane Hospital in August

2008. The number of connected institutions is 13. In New Zealand, two sites were connected with Auckland University linked in August 2008.

Beyond the Asia-Pacific Region: Americas, Europe, and Africa

A connection was first established in the United States at the University of Hawaii in January 2004, followed by Stanford University in January 2007, Florida International University in August 2007, University of California Irvine in January 2008, and Seattle Science Foundation in April 2008. There are nine institutional connections. In Central and Latin America, the University of Sao Paulo Ribeirao Preto in Brazil, the National University Autonoma of Mexico in Mexico, and the Red Universitaria Nacional (REUNA) in Chile were connected, respectively, in July 2009, October 2009, and November 2010.

In Europe, the University Medical Center Hamburg-Eppendorf in Germany and University Bordeaux 2 in France were connected in August 2007. Rome Tre University was the first to establish a link in Italy, which occurred in December 2007. Other European connections included those at Czech Technical University of Prague and Masaryk Hospital Ustinad Labem in the Czech Republic in September 2008; St. Olvs University Hospital in Norway in June 2009; and in Spain the Hospital Clinic I Provincial De Barcelona (September 2008) and the World Institute for Digestive Endoscopy Research in Barcelona (August 2011). Thus, a total of 18 institutions in eight European countries, including Belgium and Lithuania, are members of our network.

The first connection in Africa was made in Egypt at Cairo University in May 2009, followed by the Theodor Bilharz Research Institute in June 2010 and another at the Mohamed V Souissi University in Morocco. A successful connection was made at the University of Cape Town in May 2011, which became our first site in South Africa.

• *Surgery:* The total number of surgical programs undertaken was 98, with 50 teleconferences and 48 live surgical operations, including general surgery, thoracoscopic surgery, neurosurgery, transplantation, urology, and robotic surgery (Fig. 1).

Figure 1. Live demonstration of surgery. Two simultaneous operations were sent from Fukuoka, Japan (right, top) and Seoul, Korea (left, bottom) to Bangkok, Thailand (left, top) and Shanghai, China (right, bottom). Any of these images can be enlarged to full screen upon request.

• *Endoscopy:* Endoscopy was addressed by teleconference in 66 instances and as live performances in 30 instances, for a total of 96 programs. Endoscopy for gastroenterological purposes was the main subject, with various new procedures being addressed, including narrow-band imaging, ultrasonography, double--balloon endoscopy, endoscopic submucosal resection, magnifying endoscopy, and biliary stenting, among others (Figs. 2, 3)[21-23].

Figure 2. A. *China–Japan teleconference for early gastric cancer, connecting Fukuoka, Japan (left, top), Tokyo, Japan (right, top), Shanghai, China (left, bottom), and Beijing, China (right, bottom).*

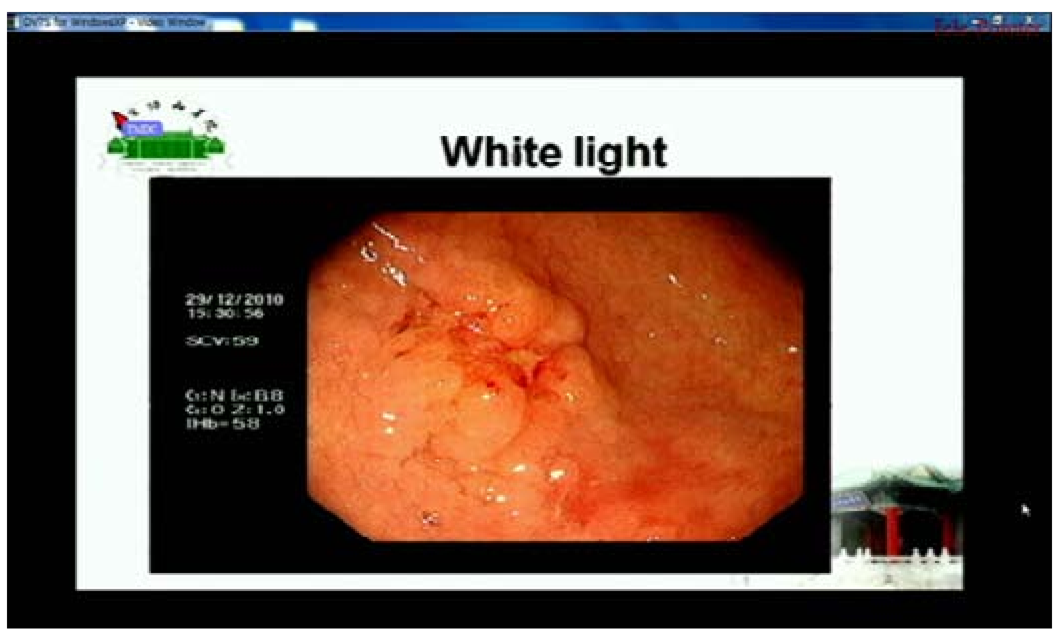


Figure 2. B. *Transmitted endoscopic image shared among four stations.*

Figure 2. C. *Transmitted pathological image is discussed for a final diagnosis.*

Figure 3. Teleconference beyond the Asia-Pacific region. An endoscopic center in Barcelona (Spain) (left, top) joined a case conference with Seoul (Korea) (right, top) and a Chiang Mai venue (Thailand) (left, bottom), with other hospitals in Taipei (Taiwan), Hong Kong (China), and New Delhi and Hyderabad in (India).

• *Cardiology:* Cardiology programs started in June 2008, and this was a new experience for us and our network. Sapporo Tokushukai Hospital in Japan offered live demonstrations to Seoul (Korea) and Beijing (China) in June and July 2008, respectively. National Taiwan University gave another demonstration to a conference venue in Chiang Mai (Thailand), National University of Singapore (Singapore), and Osaka University (Japan) in February 2012. Thus, five programs were performed, including one teleconference and four live demonstrations.

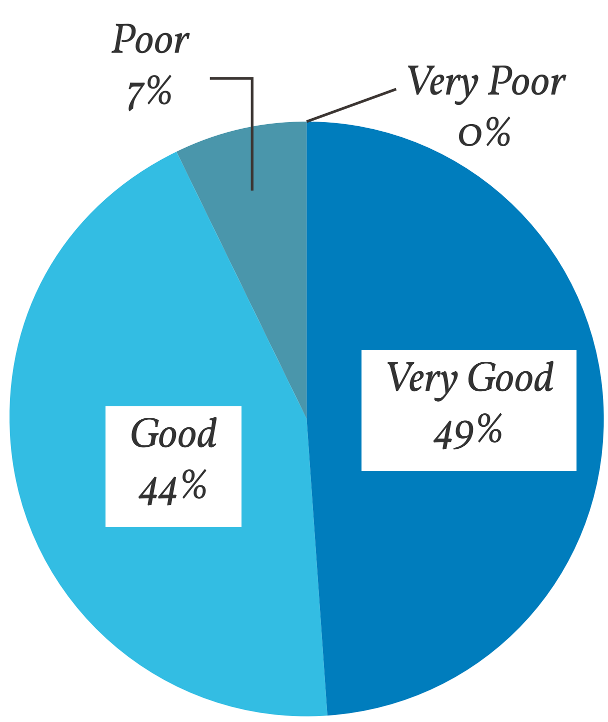
• *Educational programs for medical students and nurses:* Six remote lectures were undertaken for medical students with four settings of live surgery demonstrations. One conference that addressed cases was organized by medical students based on their particular interests. Conferences for nurses were transmitted to remote sites for the purpose of sharing presentations and discussions on 16 occasions. They included 10 programs on surgery and 4 on endoscopy (Fig. 4).

Figure 4. Teleconference for nurses. The local workshop on endoscopic surgery was shared with three remote sites in Japan.

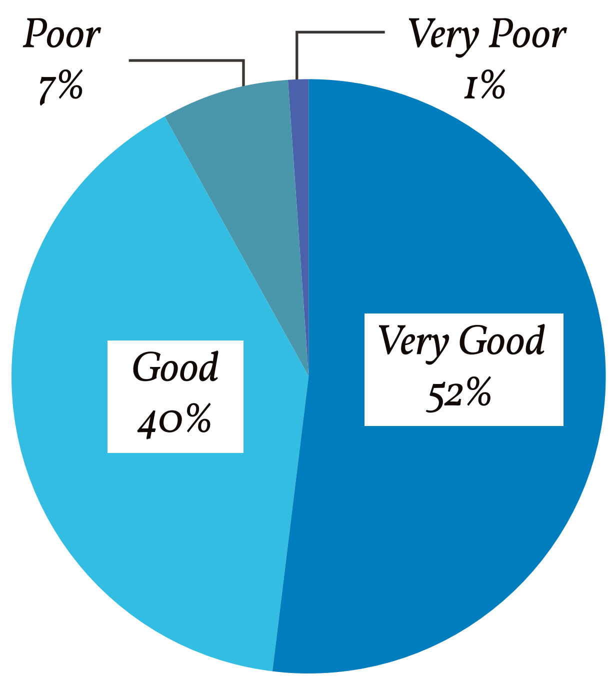
Questionnaires

The evaluation questionnaires were collected from 75 responders for six sessions. The responders' evaluations, based on four possible judgments of the presentation, were as follows (Fig. 5).

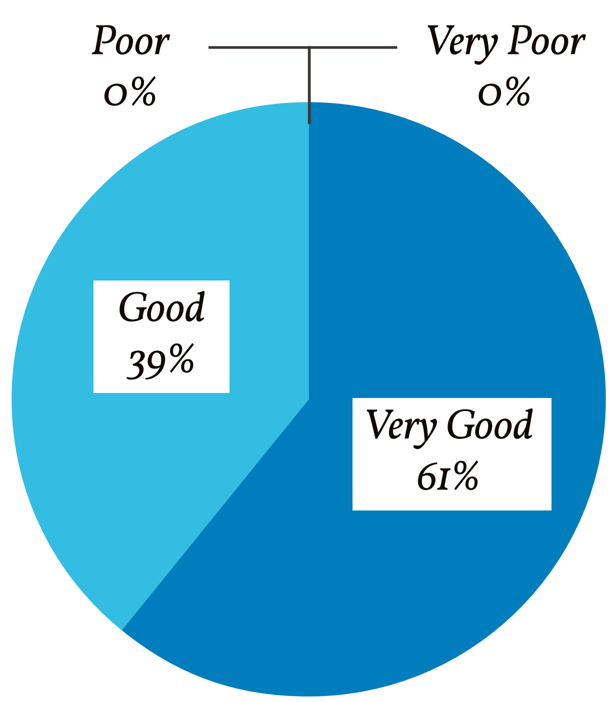
• Quality of moving images: 37 (49%) very good, 33 (44%) good, 5 (7%) poor, (0%) very poor



• Sound: 39 (52%) very good, 30 (40%) good, 5 (7%) poor, 1 (1%) very poor



• Program evaluation: 46 (61%) very good, 29 (39%) good, (0%) poor or very poor



DISCUSSION

We have established a practical telemedicine system with a domestic research and education network (REN) and a digital video transport system (DVTS), the combination of which provides clear images and comfortable conditions at remote stations[24,25]. The fact that so many hospitals in various countries have participated in more than 200 remote meetings suggests that telemedicine is useful and that there is a need for remote communication in the medical community[26-32].

The advantages of REN have been reported previously[33]. Briefly, it provides academic people with a large, stable Internet atmosphere that enables clear image transmission with multidirectional communications—in contrast to commercial networks, which have limited and crowded transmission pathways. RENs are basically government funded and are now established in many developed and developing countries. In the Asia-Pacific region, RENs are available not only in Japan, Korea, China, Singapore, Australia, and New Zealand but also in Thailand, Vietnam, the Philippines, Indonesia, and India. Links have recently been established in Nepal, Bhutan, Cambodia, and Myanmar as well.

International networks have been established that connect these domestic networks, such as the Asia-Pacific Advanced Network (APAN) and the Trans--Eurasia Information Network (TEIN3). Academic networks also exist worldwide outside the Asia-Pacific region, such as GEANT2, which connects more than 3500 institutions across 34 countries in Europe. Another international network, located in South and Central America, is called RedClara, which covers Brazil, Argentina, Chile, Uruguay, Colombia, Peru, and Costa Rica, among others[18].

The advantages of DVTS have been discussed previously, with the main points being that it is free-of-charge and does not require special, costly instruments[18]. With DVTS, digital video signals are transformed directly to an Internet protocol by a personal computer in which the program has been installed. The video qualities are perfectly preserved with smooth motion and image quality. When we started this project in 2002, the ISDN and H.323 protocol with standard definition were popular, but the quality difference with DVTS became evident, which explains why our activities expanded so quickly and so widely. The cost is especially important for the system's expansion in Asia, where there are many developing countries with limited economies.

Although REN and DVTS have been our fundamental tools and are highly beneficial and useful, there are some limitations. REN ensures quality of service in data transmission, but the connected institutions are limited to those in academia. Although numerous universities and hospitals are already connected (e.g. , 600 in Japan, 2000 in China), many more want to join the network. Because REN is government funded, and governments have their own policies about the connecting sites, private or small nonacademic hospitals, perhaps in rural areas, may not be considered although they are sometimes the ones that most need updated information. The main limitation of DVTS is the number of connecting stations because Quatre/QualImage, a multipoint connection unit for DVTS, has the basic ability to connect only four stations and up to only seven stations with special arrangements if the quality of the transmission is to be preserved at all of the connected sites. In fact, for some of the more popular programs, other hospitals have wanted to join, but there has been no room for them on the network.

It is not surprising that technologies have been developed to solve these limitations[34,35]. A major improvement is the emergence of the H.323 protocol with high-definition quality. This protocol seems to offer significant improvement over the poor transmission of moving images with standard-definition models[36]. The transmitted video images are much better than the earlier ones. Another new technology is the H.264 compression algorithm, which also has improved the quality of the transmitted video image. Because these protocols do not require a large, stable network, they can work with commercial networks—with the result that many more stations can be connected simultaneously. However, these new technologies also some drawbacks (in addition to cost), and therefore each station must select the best system for its own institution and for each event, which may depend on the conditions at other connecting stations and on the contents to be transmitted.

There is no doubt that better technologies will be developed and that the conditions of telemedicine will continue to be revised and improved. With this in mind, our future direction depends on the following points. The first is to combine REN and commercial networks so any institution interested in telemedicine can join programs transmitted with acceptable quality, some of which of course depends on the institution's own instrumental conditions and human resources. The second is the need to have engineers on the team. The need for technical support is unquestioned, and efforts should be made to allocate adequate technical staff and strengthen the partnership between the engineering and medical staffs. The presence of a dedicated engineer would be ideal. The third and probably the most important point is solid establishment of application teams and development of attractive, continuous programs in the medical community. The system itself is a tool, and its application is the goal of our activity. We sincerely hope that telemedicine will expand over the information network, ultimately providing better health care worldwide.

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