Evaluation of Image Qualities on the International Standard Video-conferencing

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International standard-based video-conferencing systems are widely used in telemedicine activities worldwide. Through our experiences with these systems, it is apparent that the image quality is high enough to conduct educational and conferential sessions. However, because the terminals are intended for common use, we evaluated their qualities. After having an international standard system evaluated by a general practitioner using medical images, we prepared non-medical graphic images to examine the characteristics of the video-conferencing equipment. ROC (Receiver Operation Characteristic) analysis was employed for the evaluation. We concluded that the international standard video-conferencing systems are of sufficient quality for medical presentations, and that their interactivity and the use of proper software will aid the understanding of images in specific medical areas.

Key words : International standard, Video-conferencing, Medical images

INTRODUCTION

We evaluated the quality of images on the international standard video-conferencing systems for medical education and conferences. Many video-conferencing networks for education are used in Japan today [1]. For example, a medical education network using video-conferencing via satellite is regularly used at medical schools of national universities in Japan [2]. Despite their good quality, the devices are large, telecommunication lines are expensive and, as a result, most general hospitals cannot adopt such systems for use by their own staff.

In 1995, the G7 countries initiated a five-year project on telemedicine [1]. One of the objectives was to establish global infrastructure for telemedicine among the countries. We have carried out medical education programs using satellite lines [3] and terrestrial telephone lines between Japan and Canada. We have held regularly multipoint clinical case presentations between these two countries. The project employed ISDN (Integrated Services Digital Network) lines, because the Internet could not offer the quality of transmission required for video-conferencing between countries except for the experimental lines.

Video-conferencing offers several advantages. For example, simultaneous multi-point connection is possible, real-time conversation and collaboration are possible, and the display is expandable. However, line speed is necessary for this work. As for the device, connection with 6B (384 Kbps), 4B (256 Kbps), 2B (128 Kbps) are possible when using ISDN. Switching connection is simple.

First, a 6B connection was considered. It contains three 2B lines (128 Kbps each), and an inverse multiplexer (IMUX) gathers the lines. There is no guarantee to match delay times of the international lines. Therefore, IMUX may fail to gather them into a 6B line. Furthermore, it is expensive

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Table 1 Component of ITU-T H.32x
Each element is shown. Shown in italic is minimum and necessary function. T.120 offers the environment that works jointly between different equipment.

	H.320	H.323
Enacted year	1990	1996
Use line/network	N-ISDN	Ethernet Internet
Image	***H.261*** H.263	***H.261*** H.263
Voice	***G.711*** G.722 G.728	***G.711*** G.722 G.728 G.723.1 G.729
Multiple, Synchronization	H.221	H.225
System control	H.230 H.242	H.245
Multi point conference	H.231 H.243	H.323
Data	T.120	T.120
Security	H.233 H.234	H.235

for international sessions. We decided to use 2B lines for international sessions. To support the exchange of precise medical images on a 2B line, we have employed ITU-T (International Telecommunication Union - Telecommunication sector) T.120 correspondence which offers a virtual data line (Table 1).

Through our experiences, it appears that the standard video-conferencing system was of sufficiently high quality to carry out medical education, conferences and other research [4-11]. Nevertheless, these qualities had to be evaluated, because these systems were not specifically designed foe medical consultations.

The images that we used in this study were not limited to the medical matters, because we hoped for a pure evaluation of the device that would not depend on the observer's area of expertise.

According to the result, we should be able to decide whether to employ a system on specific medical subjects.

MATERIALS AND METHODS

Strategy

A series of ROC analyses [12-14] was performed to measure the image qualities of international standard video-conferencing systems. ROC analysis is a subjective evaluation method that relies on one's vision. The clinical evaluation of the image quality of the digital image is possible by ROC analysis. To obtain the ROC curve, the false positive rate〔P(S/n)〕is plotted on the transverse axis. The true positive rate〔P(S/s)〕is plotted in the spindle. Hence, an ROC curve drawn by plotting specificity on the horizontal axis and sensitivity on the vertical axis exhibits a median curve between a perfect curve and a random curve. As a test that shows high rates in both insensitivity and specificity is a high-quality test, an ROC curve drawn at the upper left position indicates a high evaluation mark. In other words, a higher evaluation is given when the area of the bottom of the curve (AZ value = area under fitted curve) is closer to one.

First, physicians evaluated images of X-ray, endoscope and pathology through a video-conferencing system. Though properly designed ratings are ideal for the evaluation, we thought that the ratings would contain biases that would lead to incorrect conclusions. Since we could not control the specialty of the physicians, the ratings were composite of the physician's skill and the intrinsic quality of the system. We set up an experimental system to evaluate the quality of the images on the international standard video-conferencing systems.

Video-conferencing equipment

To exchange precise medical images, international standard video-conferencing terminals (VCON Cruiser384) (ITU-T H.320 / H.323) with ITU-T T.120 correspondence and a data channel were selected. The video resolution is restricted to 352 pixels by 288 lines (Common Intermediate Format: CIF) on video-conferencing (H.261). We can share any digital images on PC terminals (Pentium II 350 MHz) with T.120.

To have multipoint sessions, a Multipoint Control Unit (MCU, Video Server 2007) with T.120 correspondence was prepared. We have been using the system regularly for international and domestic clinical seminars for medical students.

Sending medical images

We can send medical images through the video-conferencing system using the following three methods.

1. Through a video channel

The video is available on the video-conferencing systems when an input a composite video signal, such as an NTSC (National Television System Committee). We could obtain various signals using an ordinary video camera, a video presentation stand, a microscope camera or a down converter connected to PC video output. It was easy for senders to move and magnify images immediately. They could handle cameras as usual. The image signals were compressed with H.261. We could not improve the spatial resolution and motion of images simultaneously because of the line capacity.

2. Through a data channel

2-1. Whiteboard

The 'whiteboard' is a standard application on T.120 correspondence. It enables users to share pointers and drawn figures including medical photo images. It takes a long time, a minute or more, to send one complex color image to a remote terminal.

2-2. Application sharing / collaboration

An industrial standard widely available with international standard video-conferencing systems on PCs was used. Users could look over or manipulate any PC application at a distance. However, only 256 colors can be sent by this method due to the restriction of the software which is compatible with this video-conferencing system at present. The number of colors is restricted to 256. This method is not suitable for sending X-ray images or color photos.

Evaluation of medical images by physicians

1. Dates, locations, readers, and medical images

A demonstration of video-conferencing for general practitioners was given at a conference hall in Gifu city on October 10, 1995 [15]. Three terminals each located at the hall, Tokai University and Nagoya University were connected to the MCU at Tokai University. Medical still images of endoscopy, chest X-ray and pathology were sent from Tokai University. We prepared pairs of X-ray and endoscopy images. Each pair had images with or without a lesion for ROC analysis. A pair of pathology images with resembling diseases was also prepared. The capacity of the hall was an audience of 800. Pictures were projected to the main screen of the hall. Another demonstration was given at a lobby in front of the hall on October 11 [15]. The video-conferencing systems were connected directly to the terminal in Tokai University. A screen was set up about 3 meters away from the audiences. An additional three pairs of medical images were sent from Tokai University.

We measured the luminance of the white and black portion on the screen with an exposure meter (Minolta Spotmeter F). The luminous intensities of the white and black portions on the screen were 29 cd/m^2 and 3.0 cd/m^2, respectively, on the first day, 230 cd/m^2 and 120 cd/m^2 on the second day.

2. Rating procedure

After introducing video-conferencing in telemedicine, an operator at Tokai University sent the pairs of medical images via a video channel that had been down-converted from the other PC. We employed Nichimen Image AXS, a DICOM viewer, to present the medical images. Then the operator used 'whiteboard (T.126)' on Microsoft NetMeeting 2.11 to present bitmap images through the data channel. The operator magnified images when asked by the physicians. The physicians rated images immediately after presentation of the pictures.

3. Questionnaires to the physicians

Each receiver physician rated the findings on the images using the following five categories:

1. Normal (no signal)
2. Rather normal
3. Cannot decide
4. Rather abnormal
5. Abnormal (signal)

For pathological images, the first category indicates disease A and the fifth category indicates disease B. Receivers replied after hearing general guidance by a pathologist.

4. Analytical method

The ROC analysis was employed for the evaluations. We used ROCKIT, a software created by the University of Chicago [16].

Experimental system using artificial images

1. Devices and readers

Video-conferencing terminals were prepared in the seminar rooms of Tokai University School of Medicine. A receiver terminal and an operator terminal were connected with a LAN. The luminous intensity of the white portion on the screen was adjusted to 100 cd/m^2. An operator terminal was set up at a position where it could not be seen from the receivers.

2. Landolt C rings

The images used to evaluate the channels were bitmap pictures of Landolt C rings, which are usually used for measuring acuity of vision [17]. The gaps of the rings were adjusted to 3 pixels by 3 lines. The ISO standard prescribes the ratio of the gap to the diameter of the ring to be 1:5, whereas we prepared rings of 19 pixels in diameter that looked like circles. Each pixel on the gap was randomly filled to obtain a connected (O-shaped) or an unconnected (C-shaped) ring. We defined 'connected' as pixels with sides adjoined, and 'unconnected' as pixels with corners adjoined (Fig. 1). We selected 50 connected rings and 50 unconnected rings, and randomly placed them in a matrix of 10 by 10. Because it was very easy for subjects to make a good guess whether a ring was an O-shaped or a C-shaped one, we added a random noise pattern to each matrix empirically (Fig. 2).

3. Transferring images

3-1. Through a video channel

Images on a PC were down-converted into the NTSC signal for video input of the video-conferencing terminal. The pictures shown by the image presentation software were transmitted to the reader terminal through the LAN. The pictures were compressed with ITU-T H.261. The resolution was fixed on 352 pixels by 288 lines (CIF).

3-2. Through a data channel

Application sharing function (Microsoft NetMeeting) on the terminals was used. To magnify images at a distance, the collaboration function for the application was used.

4. Rating procedure

A receiver rated four sets of Landolt C rings sequentially.

1. Using a video channel without magnifying
2. Using a data channel without magnifying
3. Using a video channel with magnifying
4. Using a data channel with magnifying

5. Rating

Each receiver reported the levels of connection of the rings with five categories:

1. Connected
2. Rather connected
3. Cannot decide
4. Rather unconnected
5. Unconnected

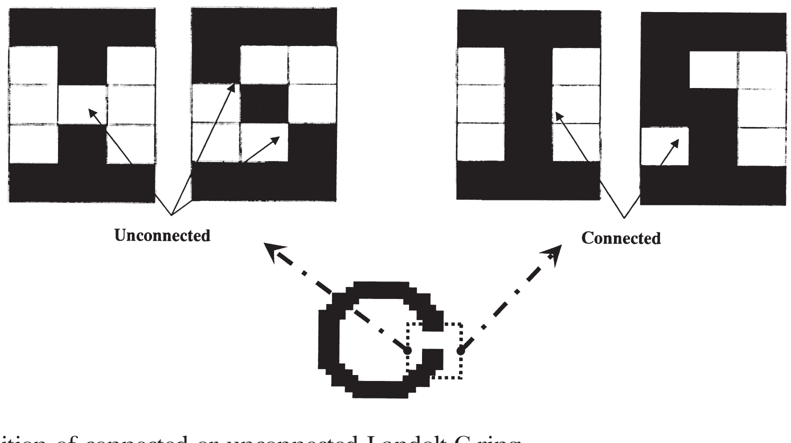


Fig. 1 Definition of connected or unconnected Landolt C ring
We defined 'connected' as pixel's sides adjoining each other, and the other cases were defined 'unconnected'.

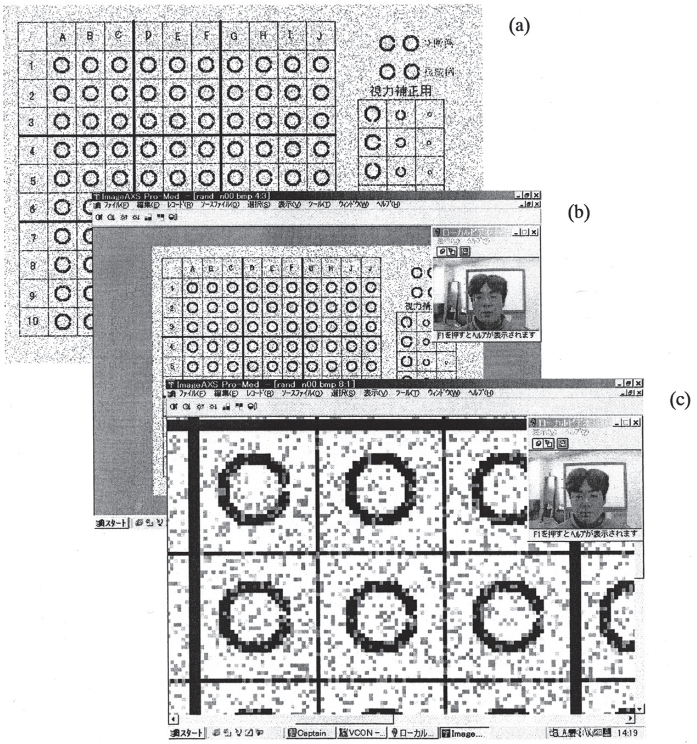


Fig. 2 Landolt C rings
a: An original image. A random noise pattern was added to a matrix of connected and unconnected Landolt C rings.
b: A sample on the reader videoconferencing terminal.
c: A sample magnified image on the reader videoconferencing terminal.

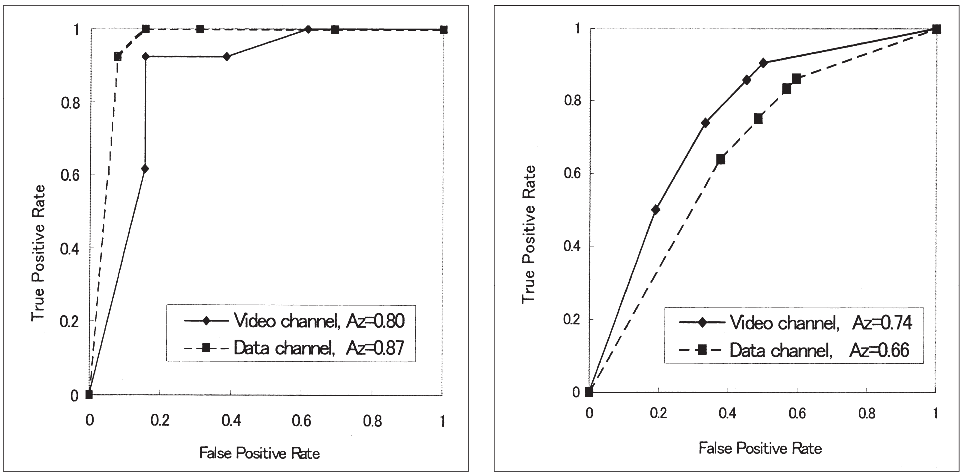
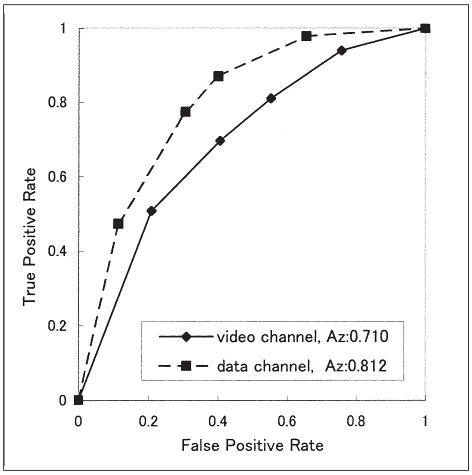


Fig. 3 ROC curves to compare the guidelines of the video channel and the data channel (medical images)
The rates of right answer on the X-ray images (chest X-ray images with or without abscess) was higher with the data channel, however, the difference was not statistically significant (NS: paired t-test)(left). The rates of right answer with the pathology images (diabetic glomerulosclerosis and lupus nephritis) was higher with the video channel seemed higher, however, the difference was not statistically significant (NS: paired t-test)(right).



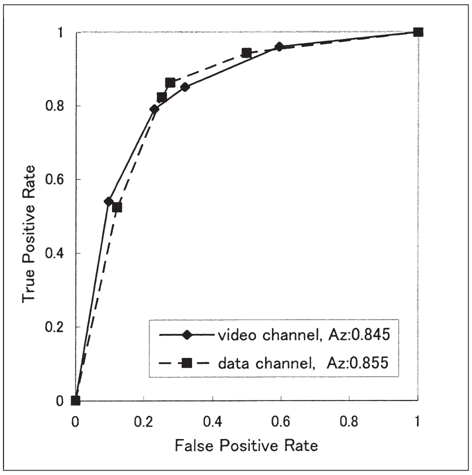


Fig. 4 ROC curves to compare the guidelines of the video channel and the data channel using Landolt C rings
The rates of right answer on the data channel was higher without magnification ($p < 0.05$: paired t-test)(left). With magnification, there were no significant differences between the two channels (NS: paired t-test)(right).

Table 2 Differences between the areas under the ROC curves; the video channel and the data channel (Landolt C rings / bivariate test)

	two-tailed paired t-test		95% confidence interval (LB, UB)
	t value	p value	
Without Magnification	−3.713	0.005 SIG	(−0.16575, −0.04025) SIG
With Magnification	−0.965	0.360 NS	(−0.03247, 0.01305) NS

(SIG indicates statistical significance at p=0.05; NS indicates not statistically significant.)

Table 3 Jackknife analysis on the differences between the areas under the ROC curves; the video channel and the data channel (Landolt C rings)

	SS	DF	MS	F ratio	P value
Without Magnification	10.784	1	10.784	14.580	0.003 SIG (p<0.01)
With Magnification	0.190	1	0.190	0.592	0.457 NS

(SIG indicates statistical significance at p=0.01; NS indicates not statistically significant.)

6. Analysis method

The ROC analysis was employed for the evaluations. Additionally, the Jackknife method was employed. This method uses broadly applicable tools designed to help the researcher to perform statistical tests or to estimate confidence intervals on parameters of interest, and has been applied to the ROC analysis by several authors [18, 19]. We used ROCKIT and Labmrmc, software from the University of Chicago.

RESULTS

Medical images

Forty-three general practitioners (no resident) rated the three pairs of images on October 10. Thirteen practitioners (no resident) rated the other three pairs of images on October 11. We drew ROC curves to compare the quality of the data channel with that of the video channel (Fig. 3). The rates of right answers were high in the four pairs of them, and no difference was detected (paired t-test).

A correct response rate on the X-ray images through the data channel was higher on the second day. The correct response rate with the pathology images through the video channel was higher on the first day. However, there were no statistically significant differences (paired t-test). We speculate that the results relate to the diagnosis processes of physicians. Physicians often gaze on the details of X-ray films, whereas they frequently move the stage of the microscope and rotate the revolver to magnify objects when they are seeking lesions.

Artificial images (Landolt C rings)

Ten readers participated in the examination using graphic images. We constructed ROC curves to compare the quality of the two channels, and Az values (areas under the ROC curves) were calculated (Fig. 4). The rates of right answers with the data channels were higher in the cases without magnification ($p < 0.05$). With magnification, there were no significant differences between the channels (Table 2). The Jackknife method was performed to confirm the reliability of the statistic testings, and we obtained the same results (Table 3).

DISCUSSION

International standard-based video-conferencing system

International standard-based video-conferencing systems through ISDN (ITU-T H.320) are widely available and used for medical educational programs [20]. The H.320 protocol provides high efficiency with a narrow ISDN line (2B: 128 Kbps) as compared with video-conferencing on the Internet (H.323).

The video characteristics are defined in H.261. The format of the video is called CIF and it is useful for international sessions because it accepts both the NTSC and PAL television signals. The resolution is fixed to 352 pixels and 288 lines, which seems inadequate for showing medical images. Nevertheless the terminal are often used for telemedicine.

The narrow bandwidth forces the user to weigh the advantages of image quality versus smooth motion. The video-conferencing systems that we used in this study can be adjusted whenever necessary.

Data channel

The standard (T.120) of the data channel on H.320 has become available recently. Every terminal in this study had T.120 correspondence. We used 'whiteboard' (T.126) to share medical images. We can send and share precise images with it. It has been used for daily medical tele-education programs between three Tokai University Hospitals.

The bandwidth of the data channel was 24 Kbps when using the MCU. We could not use a high compression method with the 'whiteboard' and it takes several minutes to send a medical image with complex patterns to the other terminals.

Application sharing and collaboration are useful when making or giving presentations. A study reported that medical images could be sent in this way. In our study, the number of colors to be sent was restricted to 256, and it was not tolerable for us to share medical images with the 'application sharing'.

We have been able to use the 'fast T.120' when the terminals have the function. The bandwidth of the data channel is 68.8 Kbps with the NCU. Unfortunately, it is only a de facto standard.

Comparison of the video and the data channels

Although physical characteristics, such as resolution or MTF (Modulation Transfer Function), are completely objective when evaluating video-conferencing equipment, we employed ROC analysis. It includes subjective items, and we believe that it matches our objective to evaluate the diagnostic quality of the medical images.

The different responses from physicians on medical images between the video and the data channels were acceptable. Magnifying images may compensate for low spatial resolution in such cases as pathology images. However, it would be difficult to develop the study to further clarify this issue.

We could not control the skills of the physicians for the study. Although general physicians had not examined pathology images for quite some time, they might quickly recall the basic points of viewing pathology images that they had learned in medical schools. For this reason, we made graphic images which were not dependent on the skills of the readers. We thought that we could test the difference between the video and the data channel using non-medical graphic images with sufficient number of readers and images.

Though there were to absolute reference values for ROC curves, we employed the method described in the guidelines that were derived from medical decision making [21]. Odds ratios of 4 or 3 are equivalent to the Az (area under the fitted ROC curve) of 0.88 or 0.83. We used the criteria for evaluating quality of the video-conferencing systems in this study.

Interpretation of the results

1. Ratings of the medical images by general practitioners

To detect the lesion from mycoplasma pneumonia on the X-ray image was easy, and good responses were received on both the video and the data channels. To detect an abscess was difficult because the contrast of the images on the screen was poor on October 11. Judging from the good results on the digital images, spatial resolution seemed to be the main factor on X-ray images.

The results with the pathological images appear paradoxical. Better results were obtained from the video channel although the images had poorer resolution than that on the data channel. This indicates that high resolution is not necessary in particular medical areas. The pathologists, who used the terminal, regularly pointed out that motion quality is important on pathological images. We must select good video cameras for pathology.

We interpreted the paradoxical responses as follows. First, the images were presented on the video channel. A pathology specialist gave the general practitioners a general explanation of the images. After that, clear images were presented through a data channel. This was perplexing to the general practitioners, because we chose the images that were difficult to assess. Therefore, we conclude that there was no difference between the two channels. However, further empirical investigations will be required for the conclusion. Now, we are proceeding with an experiment in cooperation with the Shimizu City Hospital to evaluate tele-pathological consultation using international standard video-conferencing systems. Pathologists prefer video images from a microscope video camera during consultations rather than precise digital still images [22].

To detect the lesion with endoscopy was easy. There were no significant differences between the video and the data channels.

The analysis showed that magnifying images on demand might compensate for low spatial resolution on specific medical images. This suggests that interactive image sharing between physicians through video-conferencing increases the accuracy of diagnoses.

2. Ratings on the Landolt C rings images

A total of 1,000 Landolt C ring images were evaluated on the video channel and the data channel respectively. First, we confirmed that the images had a good quality through a data channel. When the images were presented through a video channel without magnification, a poor result was obtained. Because the outlines of Landolt C ring images lacked sharpness, the readers found it difficult to distinguish connections from images to which noises were added. When the images were expanded, we could obtain good results that were almost equal to the data channels.

We concluded that magnifying images interactively could compensate for low spatial resolution of artificial images with the video channel.

CONCLUSION

The international standard video-conferencing systems that we used are economical and are readily available in developed countries and areas. Although we can purchase and use practical tele-medicine systems, telepathology equipment for example, they are not interoperable with different systems. This considerably restricts the extension of application.

We employ common international standard video-conferencing systems and MCU with ITU-T T.120 correspondence (a data channel) to have daily educational seminars between three Tokai University Hospitals in Japan. The devices are also used to carry out monthly international conferences with Canada. We find that they are good applications for the system. We are trying to use the same terminals for clinical consultation on pathology, psychiatry and respiratory diseases.

We can send precise medical images through various methods including the Internet.

We can easily digitize medical images, pack them into a document and send it worldwide. However, real-time image transmission and interactive conversation is necessary for tele-pathology, tele-psychiatry, and other specific tele-medical applications. The regular Internet does not guarantee the quality of service. Recently, various new digital networks, such as Gigabit-Net [23], have been developed in Japan. High-speed communications are possible using them. However there are regions where they cannot be used. Therefore, we concluded the most suitable medium for tele-education and telemedicine on the network is domestic and international ISDN.

We predict that within a few years, we will be able to use highly efficient, high-quality digital networks among developed countries [24]. The video-conferencing systems used in the study are compatible with H.323. Therefore, we can easily move the system into the next generation Internet when it becomes available.

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