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Simple and low-cost tele-nuclear medicine conference system with the e-mail protocol

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Purpose: Because of the recent innovative growth in computer technology, digital imaging, and the Internet, we can take advantage of these facilities for education and clinical work in nuclear medicine. We developed a tele-nuclear medicine conference system with electronic mail (e-mail) on the Internet. ***Methods:*** Twenty-one physicians (20 radiologists, 1 neurologist), 6 technologists and 2 medical students in six university hospitals (Japan 5, Canada 1), 5 local hospitals in Japan participated in this project. We used digital still cameras (330 k pixels) equipped with a floppy disk drive and 10 × optical zoom to digitize images with JPEG compression (640 × 480 matrix). The images were attached to e-mail messages (containing a brief description of each case). The mail was sent simultaneously to all members on the mailing list. Scintigram and SPECT images as well as other radiological images were sent by e-mail. Reply mails about each case were sent to all members via the mailing list. ***Results:*** During a period of 6 months, 18 cases (tumor/infection: 7, bone: 6, cardiovascular: 1, neurology; 3, endocrine: 1) with 144 e-mails (average 5.6/case) were submitted to the conference. The average period of discussion was 15.6 days. The number of attached images was 1 to 9 (average, 4.2/e-mails). JPEG compression rate was 1/10 to 1/20. The quality of the images was good enough for discussion. Some cases required additional images for further discussion. ***Conclusion:*** Our tele-nuclear medicine conference with an electronic mailing list and digital camera was simple and low-cost. The conference system was useful for education and clinical work.

Key words: Internet, e-mail, mailing list, tele-nuclear medicine

INTRODUCTION

TELEMEDICINE can be defined as the "delivery of health care and sharing of medical knowledge over a distance using telecommunication systems."[1] Historically, the telephone was the first medium for long distance medical consultation. In 1880 Alexander Graham Bell, the telephone inventor, summoned his assistant by telephone for help when he had an accident in his laboratory.[1] Interactive television was used for consultations in the field of psychiatry and radiology in the 1950–1960s,[1,2] but those systems were inadequate, inconvenient, and expensive, and communication band width was limited.[1] Telemedicine as well as the Internet have recently come to be widely used in nuclear medicine because of the innovative growth in computer technology.[3]

In the last decade, not only university hospitals but also local hospitals, which have nuclear medicine divisions, have replaced the single head gamma camera with a dual head system. Recent advances in this technology

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Table 1 List of participated institutions and populations

No.	Institution	Country	Prefecture/Province	City/District	Number of Members			
					Ra	Neu	RaT	MeS
1	Fujita Health Univ. Hp.	Japan	Aichi	Toyoake	6		4	2
2	Nagoya City Univ. Hp.	Japan	Aichi	Nagoya	1			
3	Aichi Medical Univ. Hp.	Japan	Aichi	Aichi	1			
4	Tokoname City Hp.	Japan	Aichi	Tokoname	1		1	
5	Komaki City Hp.	Japan	Aichi	Komaki	1		1	
6	Daido Hp.	Japan	Aichi	Nagoya		1		
7	Mie Univ. Hp.	Japan	Mie	Tsu	1			
8	Ise City Hp.	Japan	Mie	Ise	1			
9	Gifu Univ. Hp.	Japan	Gifu	Gifu	5			
10	Hokushin General Hp.	Japan	Nagano	Nakano	2			
11	Mount Sinai Hp. (Univ. of Toronto)	Canada	Ontario	Toronto	1			
					20 (21 Doc)	1	6	2

Univ. = University, Hp. = Hospital, Ra = Radiologist, Neu = Neurologist, RaT = Radiological Technologist, MeS = Medical Student, Doc = Medical Doctor

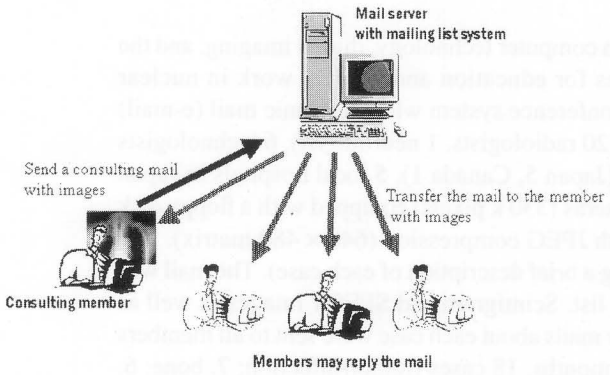
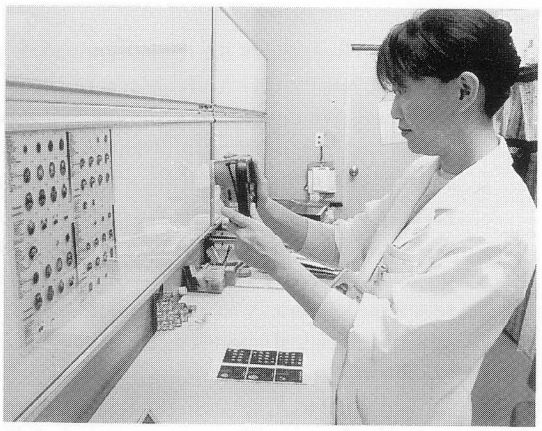


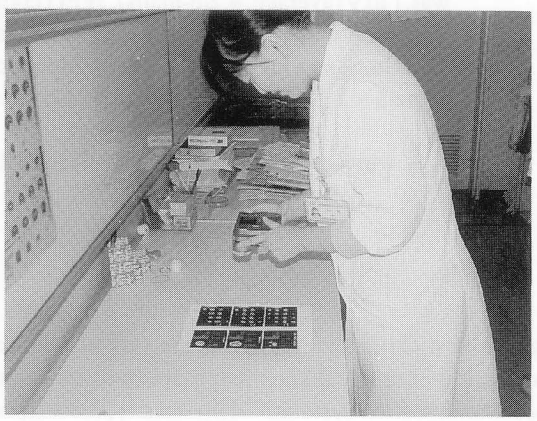
Fig. 1 The tele-nuclear medicine conference system used in this project. First, a consulting e-mail with attached images is sent simultaneously to all members on the mailing list. Reply mail from some members are also sent to all members via the mailing list.

including improved collimator designs, attenuation-scatter correction, and sophisticated reconstruction algorithms have resulted in vast improvement in image quality.[4–6] In addition, several new radiotracers such as brain perfusion[7] and receptor ligand[8] have become commercially available, but it has been difficult at local hospitals for general radiologists to interpret specialized nuclear medicine studies because of the lack of the current knowledge or expertise. On the other hand, it is quite difficult for "stand alone" Japanese radiologists in local hospitals to frequently attend nuclear medicine conferences for consultation and education purposes.

In view of these circumstances, we developed a tele-nuclear medicine conference system with electronic mail (e-mail) on the Internet. In the present study, we evaluated the usefulness and limitations of this conference system for education and routine clinical work.



A



B

Fig. 2 Images are easily acquired from the film (A) and color hard copy (B) with digital still camera by using floppy disk system with 10 × optical zoom to digitize images with JPEG compression.

MATERIALS AND METHODS

Institutions

Twenty-one physicians (20 radiologists, 1 neurologist), 6 technologists and 2 medical students in 6 university hospitals and 5 local hospitals in Japan participated in this project (Table 1). Nine hospitals were located in the same district "Tokai" in Japan; 6 in Aichi Prefecture, 2 in Mie Prefecture, 1 in Gifu Prefecture, and 1 hospital was in Nagano Prefecture in the "Koshinetsu" region. In addition, 1 hospital in Toronto, Canada also participated in this project. All hospitals had a nuclear medicine division

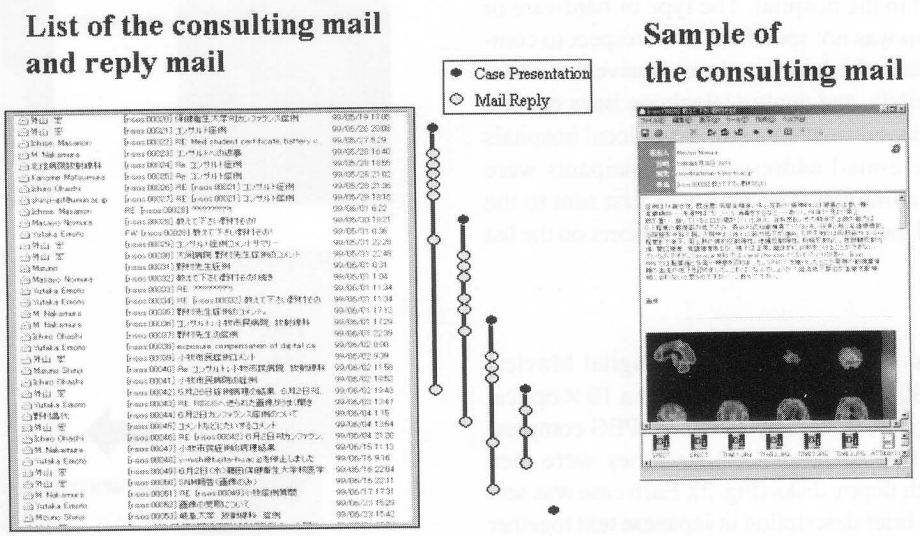


Fig. 3 Discussion held via e-mail. Left; List of the consulting mail (closed circle) and reply mail (open circles). Right; Sample of the consulting mail (top) with attached image and image files (bottom).

Table 2 List of submitted cases to the tele-nuclear medicine conference

No.	Classification	Diagnosis	Modality and no. of attached images	(total no.)	comments no.
1	tumor/infection	renal cell ca.	MIBG sci. 2, CT 3, MRI 4	(9)	6
2	tumor/infection	sternal abscess	bone sci. 2, gallium sci. 3, CT 2	(7)	7
3-1	tumor/infection	skull metastasis (lung ca.)	bone sci. 3, CT 3, MRI 3	(9)	2
3-2			bone sci. 1, CT 2, chest X-ray 1	(4)	
4-1	tumor/infection	malig. lymphoma (skull)	gallium sci. 2, CT 3, MRI 1, angio 1	(7)	3
4-2			gallium sci. 3, CT 3, MRI 1, angio 1	(8)	
4-3			bone sci. 6	(6)	
4-4			angio 4	(4)	
4-5			CT 6, spine X-ray 2	(8)	
5	tumor/infection	soft tissue tumor	Tl-201 sci. 1, bone sci. 1, CT 1, angio 1	(4)	2
6	tumor/infection	malig. melanoma	lymph sci. 4, CT 1, gallium sci. 1	(6)	5
7	tumor/infection	malig. lymphoma (spleen)	gallium sci. 2, CT 1, MRI 2	(5)	4
8-1	cardiovascular	tetralogy of Fallot	lung perfusion sci. 3, CT 2	(5)	3
8-2			CT 1	(1)	
9	bone	bone metastasis	bone sci. 2, CT 1	(3)	1
10	bone	bone metastasis	bone sci. 1	(1)	6
11	bone	splenic infarction	bone sci. 1, CT 1	(2)	3
12	bone	insufficiency fracture	bone sci. 2, pelvis X-ray 1	(3)	2
13	bone	fibrous dysplasia	bone sci. 1, CT 1, MRI 2, bone X-ray 1	(5)	2
14	bone	benign bone tumor	bone sci. 3, bone X-ray 1	(4)	3
15	endocrine	adrenal gland tumor	Adosterol sci. 2, bone sci. 1, CT 1, MRI 1	(5)	1
16	brain	ALS	brain SPECT 2, MRI 4	(6)	12
17	brain	AVM	brain SPECT 1, CT 1, MRI 1, angio 1	(4)	2
18	brain	CNS lupus	brain SPECT 1	(1)	2

No.: number, ca.: carcinoma, malig.: malignant, sci.: scintigram, angio: angiogram, CT: computed tomography, MRI: magnetic resonance imaging, ALS: amyotrophic lateral sclerosis, AVM: arteriovenous malformation, CNS: central nervous system, *Subdivision (−2 to −5) shows images attached to additional E-mail

and SPECT devices.

Internet Systems

We used communication between individuals by e-mail through local Internet service providers (ISP).[3] Communications were made between computers (PC and Macintosh) with e-mail software, modems or local area network (LAN) in the hospital. The type of hardware or operating system was not specified. With respect to communication lines to the Internet, the exclusive line at the university hospitals, and analog telephone lines or integrated service digital networks (ISDN) at local hospitals were used. The e-mail addresses of participants were added to the mailing list. The mail was first sent to the mailing list, and then distributed to all members on the list (Fig. 1).

Hardware

We used digital still cameras (SONY Digital Mavica, MVC-FD71, 330 k pixels) equipped with a 10 × optical zoom lens to digitize images by means of JPEG compression protocol (640 × 480 matrix), and they were then stored on 3.5 inch floppy disks (Fig. 2). Each case was sent by e-mail with a brief description in Japanese text together with attached image files (Figs. 1 and 3). The mail was sent to all members on the mailing list at once via the common address ("RISOS") in addition to sending other radiological images and nuclear medicine images. Reply mail (Japanese or English) from members who sent comments was sent to all members via the mailing list.

Operation Guideline

Each case was submitted with the patient's age, gender, classification of the case (e.g., tumor, cardiovascular disease), brief history and discussion or consultation points. The patient's name and identification number were withheld to ensure privacy. Attached images were limited to a maximum of 6 images for each case, to avoid overloading the network system. Sending comments about each case was at the member's own free will. If the first submitted text or images of the case were insufficient, additional information or images were sent during the discussion (Table 2). If the final diagnosis was confirmed, the result was reported later. All procedures conducted in this project were voluntary and none of the participants received a financial reward.

RESULTS

Over a period of 6 months (May 26–November 1, 1999), 18 cases (tumor/infection: 7, bone diseases: 6, cardiovascular disease: 1, neurological diseases: 3, endocrine disorder: 1) were submitted to the conference (Table 2). The total number of e-mail messages was 144 with an average of 5.6 e-mail/case. The average period of discussion was 15.6 days (in fact, 9.1 days, except for one case which took

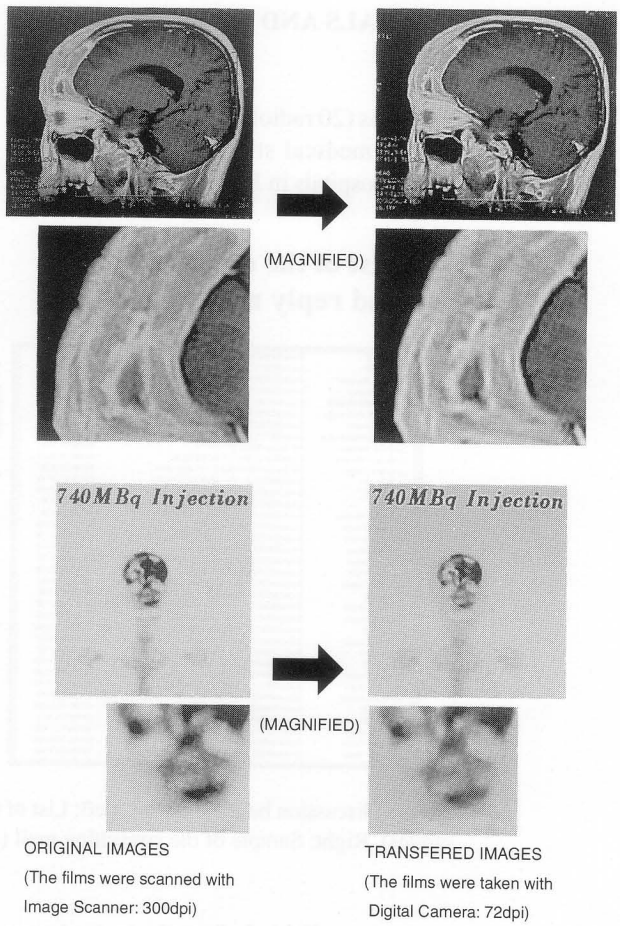


Fig. 4 Representative original images (left) and transferred images with digital still camera (right) of MRI (top) and bone scan (bottom) in Case 4. The quality of the transferred images are good enough for discussion.

139 days). The total number of e-mail messages with attached images was 38. The average number of attached images was 4.2, and minimum number of attached images was 1, and the maximum number of attached images was 9 (Table 2). The JPEG compression rate was 1/10 to 1/20.

Image quality was adequate for the purpose of general case discussion (Fig. 4). Some cases required additional images to be sent for further discussion (Table 2). Several cases presented required sending biopsy or autopsy results before the final diagnosis could be established. All images submitted were readable and of good quality for discussion. The majority of the important nuclear medicine images could be sent at once, because they were fewer in number than CT and MRI images. Most of the cases or comments were submitted by the staff radiologists or experts in this conference.

Several problems were encountered during the project, which were rectified by the following solutions. In PCs running the Windows operating system, some images sent as attached files could not be recognized as image files due to the lack of a proper filename extension and

thus could not be opened automatically. This problem was corrected by sending each image with a full file name set as file name.jpg. At first, connection to e-mail was interrupted due to the attachment of several images to the same message when using analog phone lines. This problem was later corrected by attaching a maximum of 6 image files and using ISDN and major ISPs, but the limited number of images exchanged between participants created another problem: missing information, particularly on originally consecutive CT and MRI images (Cases 3 and 4). Additional images, which were sent during the discussion, were supplemented. The Japanese physician in Canada was unable to use Japanese e-mail software because of the English Operating system at the time. Therefore, Japanese E-mail which was transformed to image data with a Graphics Interchange Format (GIF) file was sent without using the mailing list.

DISCUSSION

Advantages

The Internet is a telecommunications structure linking together millions of computers on all continents of the world.[9] Due to the standardization of communication protocols on the Internet, any computer, regardless of the type of hardware or operating system could connect to the Internet. In addition, the cost of accessing the Internet for individuals has fallen to the present rate of US$20 or less per month for unlimited access.[9] In this regard, our system was widely available in all hospitals, because several institutions were able to participate even with a personal analog telephone line or ISDN without an exclusive line. Furthermore, there is no need for special equipment except for a digital camera (US$740) and personal computer.

For tele-radiology, all images must be in digital form before transmission is possible. Conventional hard copy images from any mode can be digitized by laser scanners or charge coupled device (CCD) scanners.[1] If digital images are in a standard DICOM (Digital Image Communication in Medicine) format, they can be directly linked to a teleradiology system,[1] but the file size of typical digitized medical images is too large. The digital data should therefore be compressed prior to transmission for both practical and economic reasons.[1] Our image acquisition method, in which images were obtained by means of a digital camera and stored on floppy disks, was simple and easy. Images were automatically compressed to 1/10 to 1/20 with JPEG compression. Although compression results in some loss of the original data set, several studies have shown that compression ratios of 1/20 or higher can be achieved, without sacrificing diagnostic image content.[10] The quality of the images in our project was actually good enough for discussion. All procedures including the following step of attaching image files to e-mail directly through the floppy disk drive were practical in daily clinical work. Health-care professionals will gain experience and expertise through the interaction with experts, and higher accuracy should be achieved.[1,2] Useful comments from subspecialists and discussion between distant institutions were actually significant in daily clinical work. Several institutions have designed world-wide web (WWW) sites to upload nuclear medicine teaching files.[3,11] We can access those sites freely at a number of institutions.[3] Not only radiology and nuclear medicine specialists but also radiology residents, radiological technologists and medical students participated in our project. Most of the cases or comments were submitted to this conference by experts, but typical or rare cases were made significant in education by examining the images, i.e., "observer" through the discussion on the Internet. Generally speaking, small size nuclear medicine images are well suited for creating digital data.[1,3] In addition, nuclear medicine images were found to be more suitable than other CT and MRI images, because most of the scintigrams with fewer images could be sent in a single e-mail.

Limitations, Problems and Plans

We were sending comments in Japanese as image files as opposed to e-mails in Japanese to a collaborating physician in Canada because Japanese e-mails could not be displayed on his English operating system, but those problems have been solved by recent operating system upgrades that allow the use of several languages.

Because of the long transmission times with dial-up telephone line faced by some participants in local hospitals (actually, at home), interruption of connection occurred frequently. We tried to send only as few selected images as possible with JPEG compression, but we had to send several images, i.e., beyond the set limit, in some cases several times, especially with consecutive CT and MRI images. Improvement of transmission media with wider bandwidths should allow much faster and more detailed consultations for any types of imaging methods to remote experts.[1,2] At present, as WWW, newsgroups and discussion forums are used,[3] we are planning to use a multi-media conference system and a website encrypted with a user name and password. The present system as well as the future website system requires strict security and privacy assurance.[2] Such a tele-conference system could be used as an important tool for educational purposes, such as a teaching file database, after establishing general Internet ethics guidelines for sharing and cooperation.

CONCLUSIONS

Our tele-nuclear medicine conference with an electronic mailing list and digital camera is simple, low-cost, and widely available. The system has allowed discussion at a distance. This conference system is useful for education and clinical work. Nuclear medicine should be admirably

suited to tele-medicine because of the fewer and smaller but informative images.

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