TECHNICAL NOTE

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Image Transfer Using Cellular Phones and Wireless Internet Service

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Objective : Neuroimaging data are of paramount importance in making correct diagnosis. We herein evaluate the clinical usefulness of image transfer using cellular phones to facilitate neurological diagnosis and decision-making.

Methods : Selected images from CT, MRI scans, and plain films obtained from 50 neurosurgical patients were transferred by cellular phones. A cellular phone with a built-in 1,300,000-pixel digital camera was used to capture and send the images. A cellular phone with a 262,000 color thin-film transistor liquid crystal display was used to receive the images. Communication between both cellular phones was operated by the same wireless protocol and the same wireless internet service. We compared the concordance of diagnoses and treatment plans between a house staff who could review full-scale original films and a consultant who could only review transferred images. These finding were later analyzed by a third observer.

Results : The mean time of complete transfer was 2~3 minutes. The quality of all images received was good enough to make precise diagnosis and to select treatment options. Transferred images were helpful in making correct diagnosis and decision making in 49/50 (98%) cases. Discordant result was caused in one patient by improper selection of images by the house staff.

Conclusion : The cellular phone system was useful for image transfer and delivery of patient's information, leading to earlier diagnosis and initiation of treatment. This usefulness was due to sufficient resolution of the built-in camera and the TFT-LCD, the user-friendly features of the devices, and their low cost.

KEY WORDS : Image transfer · Cellular phone · Teleradiology · Telemedicine.

Introduction

Neuroimaging, including magnetic resonance imaging (MRI), computerized tomographic(CT) scan, and plain roentgenogram, is occupying the critical portion of not only diagnosing but also decision-making process in the management of neurosurgically urgent patients. Accordingly, easy availability of imaging informations among physicians can greatly enhance the efficacy of patient management. Telemedicine is a field of medical science which enables a physician to diagnose and treat patients who are in remote places[4,9]. While various devices and softwares for telemedicine have been developed, these are too expensive and technically difficult to be adopted in the medical practice[8-10]. Additionally, the digitalization of the medical imaging such as Picture Archiving and Communication System(PACS) and Hospital Information System(HIS) is designed to be mostly used within the hospital. If the image is to be sent to a physician in other place, computational processing is still needed. Furthermore, the representative technological standards are not settled to date, while additional devices and softwares should be purchased at high cost. Therefore, their applications are frequently limited. We herein introduce an economic and reliable method to transfer medical images using cellular phones and wireless internet service in the neurosurgical practice.

Materials and Methods

The SCH-V420® (Samsung Electronics, Suwon, Republic of Korea) with a 1,300,000-pixel digital camera and a 262,000 color thin-film transistor liquid crystal display (TFT-LCD), was used to capture and send medical images. The images were created with minimum 176×144-pixel and maximum 1,024×1,008-pixel JPEG files. The StarTAC2004® (Motorola, Schaumburg, IL, USA) with a 262,000 color TFT-LCD was used to receive the images. The display size was 30×40mm

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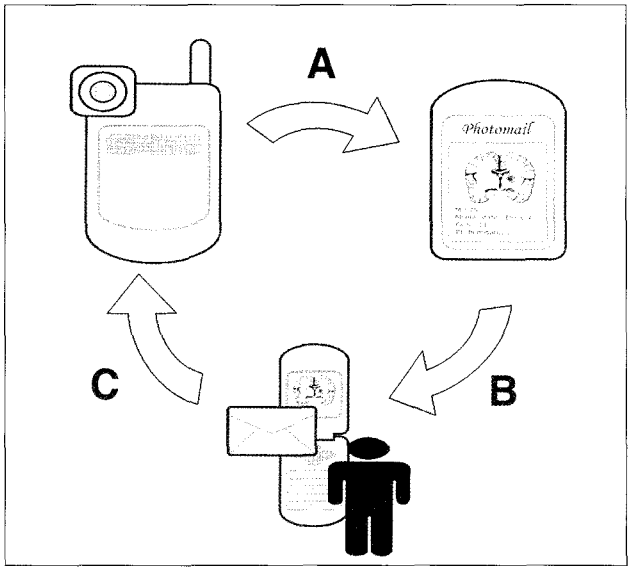

Fig. 1. Schematic diagram demonstrating the process of image transfer using cellular phones. A : Medical image of the patient is photographed by the digital camera of the house staff's cellular phone. B : Then, it is attached to an e-mail message containing the patient's short medical information and transferred to the consultant through the wireless internet service. C : After reviewing the image, consultant can request the house staff to send additional images.

with 128×160 pixel. Communication between both cellular phones was operated by the same wireless protocol (CDMA2000, Qualcomm, San Diego, CA, USA) and the same wireless internet service (NATE, SK Communications, Seoul, Republic of Korea). Once an image of a patient's neuroimaging studies is photographed by the digital camera in the SCH-V420®, it is attached to a cellular phone e-mail message containing the patient's brief medical information by a house staff. The message is transferred to a consultant through the wireless internet service. The transferred image is displayed in the TFT-LCD of the StarTAC2004®. The consultant reviews the image first, then discusses the patient's medical conditions with the house staff by verbal communication. If additional images are required, they can be sent in the same way (Fig. 1). Consequently, the consultant can have not only the imaging information but also detailed the patient's information including bedside examination and other laboratory data. Finally, diagnoses and treatment plans are made through verbal communication between the house staff and the consultant. We compared the concordance of diagnoses and treatment plans between the house staff who could review full-scale original films (A) and the consultant who could only review transferred images (B). These finding were later analyzed by a third observer (C).

Results

CT scans, MRI scans and plain films of brain and spine obtained from 50 patients in our neurosurgery department were transferred and diagnostically analyzed. One to 4 images per patient were transferred. Thirty-six patients showed structural abnormalities in their brain, and 14 patients in their spines. The mean time of complete transfer was 2~3 minutes with no transmission errors occurring. The cost to transfer each image was 200 won excluding the expenses of subscribing and purchasing cellular phones. The quality of all images, despite the small size of the display, was good enough to make precise diagnoses and to select treatment options (Fig. 2).

Fig. 2. Display of an image in a thin-film transistor liquid crystal display of the consultant's cellular phone. Regardless of the small size, the resolution of the transferred image is good enough to make diagnosis of occlusion of right middle cerebral artery.

House staff vs counsultant

The diagnoses of the house staff were concordant in 48 cases, and discordant 2 cases were modified by the consultant seeing transferred images (Table 1). The discordant 2 cases included a case of T11 compression fracture and a case of C2 teardrop fracture. In the case of T11 compression fracture, the house staff noticed the fracture in the anterior column of T11 with maintaining stability. However, the consultant revisioned the diagnosis as an unstable fracture by a transferred image, because a pedicle fracture was visualized in this image. In the case of C2 teardrop fracture, the house staff could not confirm the diagnosis, but the consultant could confirm the diagnosis by a transferred image. The treatment decision-making scenarios of the house staff seeing original films and the consultant seeing transferred images were similar in 47 cases and different in 3 cases (Table 1). In a patient with tuberculous spondylitis, the house staff suggested conservative management, but with transferred images and accompanied medical information, the

Table 1. Concordance of dianosis and treatment plans using transferred images by cellular phones

Concordance	House staff (original film) vs. consultant (transferred image)	Consultant (transferred image) vs. third observer (original film)
Diagnosis	48/50 (96%)	49/50 (98%)
Treatment plan	47/50 (94%)	50/50 (100%)

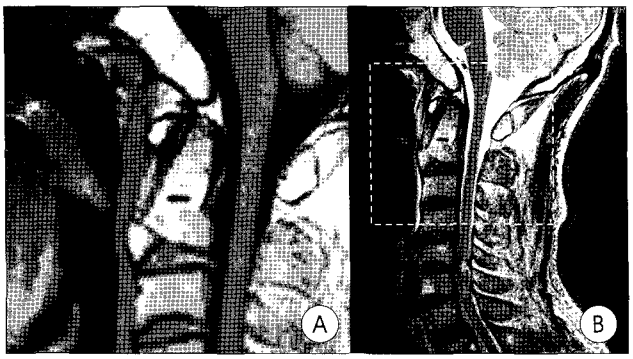

Fig. 3. Demonstration of selection bias of transferred image. The house staff photographed and sent only C2 portion of the whole cervical spine (white dotted box in B), the consultant missed severe cervical stenosis and spondylosis below C4.

consultant decided to perform decompressive laminectomy. In a patient with a severe intraventricular hemorrhage and acute hydrocephalus, the house staff suggested extraventricular drainage, but conservative care was recommended by the consultant after reviewing a transferred image and the patient's neurologic status. In a patient with severe contusional hemorrhage, the house staff suggested placement of an intracerebral drainage catheter, yet conservative care was recommended by the consultant after reviewing a transferred image and the patient's medical conditions.

Consultant vs third observer

The diagnosis of the attending staff seeing transferred images and that of the third observer seeing original films were similar in 49 cases and different in 1 case (Table 1). The discordant case was the same case as the aforementioned second case. The patient visited emergency department with numbness and weakness in both arms. The house staff noticed a questionable C2 fracture and spondylosis in the MRI, yet sent only an image of the C2 fracture because it appeared to be more important to himself (Fig. 3). The consultant confirmed the C2 teardrop fracture by the transferred image, however, he was unable to see severe cervical stenosis and spondylosis in his lower cervical spine. The third observer could confirm the severe cervical stenosis and high signal intensity in his cervical spine MRI which was not included in the initially transferred image. We regard this as very important possible errror in this system. The decisions in treatment of the consultant seeing the transferred images were similar to those of the third observer seeing the original films in all cases (Table 1).

Discussion

Advent of high technology diagnostic equipment of modern medical system improved the management of emergent patients. However, medical diagnosis requires experienced physicians' decision-making in every critical settings for the patients. Although these necessities are generally recognized, not all attending physicians can stay 24 hours in the hospital. This emphasized the importance of efficient communication between a house staff and a consultant in anytime to make correct diagnosis and therapeutic decision. A cellular phone can be a strong communication link overcoming the barrier of space and time. Even though consultation can be accomplished verbally without seeing medical images, medical images are often essential for proper diagnosis in neurosurgical practice[4]. Medical images such as CT scans, MRI scans and plain films likely play the most important role in the neurosurgical practice rather than in other medical fields[4]. Listening to a house staff's report on a patient's medical images often causes misunderstanding and misinterpretation[7]. Several studies, including the present study, demonstrate that image transfer using cellular phones is feasible[1-3,6,7]. The quality of the display screen on the cellular phone is high enough to adequately display CT, MRI scans, and plain films. Although the size of the screen is not big enough to display large sized images, such as chest roentgenograms or whole spine scout films, fortunately, a slice of MRI or CT scans is small enough to be displayed on the screen. If a larger image is needed, a lesion site of the whole image can be zoomed in. At the present time, transmission speed is not fast enough to transfer a full series of MRI or CT scans, but usually 1 or 2 images are necessary in neurosurgical decision-making process in most cases. What is promising is that the mobile systems are still being developed to provide faster communication rate and larger screen.

Commercial use of cellular phone systems began several decades ago, yet high quality image transfer using cellular phones became feasible only recently. This possibility has been accomplished by the development of high quality displays, high resolution cameras, image compression technologies and high speed transmission protocols. In the early stages of cellular phone development, 2 lines of black and white LCD were used. Currently, TFT-LCD with more than 13 lines and 262,000 colors is in use. The built-in digital camera in a cellular phone is designed to have a 2,000,000 pixel resolution and the ability to zoom in the object. In addition, JPEG image transmission has been shown to compress images to 10% of the original file size without a noticeable change in the quality of the images[8], which reduces image transmission time by 90%[8]. By using JPEG, a series of radiological images that would normally take 60 minutes to transmit would take only 6 minutes to transmit using a 10-to-1 compression[8]. Well-known CDMA (Code Division Multiple Access) is a digital cellular technology that uses spread-spectrum techniques. CDMA consistently provides a better capacity for voice and data communications than other commercial mobile technologies, allowing the subscriber to

connect at any given time. CDMA2000 delivers peak data speeds of 24,000,000 bps (bits per second) and supports applications such as MP3 transfers and video conferencing[5]. The first third generation networks to be commercially deployed were launched in Republic of Korea in October, 2000 using CDMA2000 technology[5]. Currently, the Republic of Korea is highly competitive in the field of telecommunication technologies[5]. According to the Ministry of Information and Communication of Republic of Korea, the number of Republic of Korea's mobile telecom subscribers surpassed the 37-million mark in May, 2005 and 77.45% of the population of Republic of Korea has a cellular phone. The actual supplying rate excluding children and old people is 93%, currently being the best in the world. Because this entire country is connected by cellular phone systems, the convenience of this existing network infrastructure makes it an attractive choice for the simplest form of medical image transfer.

This system is not a fully equipped telemedicine system. However, perfect telemedicine systems require expensive fiber optic lines that connect centrally located hubs. Because these lines are so expensive to lease, it is not financially feasible to extend the network into a physician's home[8]. Furthermore, it does not have convenience of portability. Although this cellular phone system cannot replace the advanced functions of telemedicine such as videoconferencing and medical records transmission, it is still very useful to deliver medical images with lower cost.

In our experience, however, potential errors of this system exist. First, a house staff's personal selection of images can influence a consultant's decision. When the house staff, usually trainee, selects the image to be transferred, the true lesion can be missed out due to lack of knowledge and experience. These possible errors which can be caused between a house staff and a consultant can be overcome by additional verbal communications. Second, this is not an official medical system and does not have legal protocols. It is difficult to determine individual responsibility, when transfer failure and misreading due to low resolution or image distortion occur. A physician using this system should understand this system's limitations and have high alertness to manage the possible errors of communications and interpretations.

Conclusion

The cellular phone system is useful for image transfer and delivery of patient's information, leading to earlier diagnosis and initiation of treatment. Transferred images were helpful in making correct diagnosis, and decision making in 49/50 (98%) cases. This cellular phone system is useful because of sufficient resolution, ease of handling, and its low cost. However a physician using this system should be aware of potential errors due to a house staff's personal erroneous selection of images, and lack of legal protocols.

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Commentary

This paper describes the method to transfer medical images via the cellular phone over CDMA mobile network. It demonstrates the effectiveness of proposed method for making correct diagnosis and decision when physician is not within the hospital. It is unique to conduct cross validation among house staff, consultant and third observer in comparison with another radiological transmission system over CDMA network (Kim DK et al., Instant wireless transmission of radiological images using a personal digital assistant phone for emergency teleconsultation, Journal of Telemedicine and Telecare, 2005; 11 (S 2): 58-61, 2005). However, it has an ambiguous sentence. In discussion, the authors mention that cellular phone system is useful to deliver medical images with lower cost. In general, the data transmission price for cellular communication is not a low cost. It is particularly low cost when the mobile service provider offers a special price for special marketing. Moreover, the manuscript will be strong if the authors include the performance comparison in terms of "with verbal communication" and "without verbal communication".

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