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Application of a Telemedical Tool in an Isolated Island and a Disaster Area of the Great East Japan Earthquake

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SUMMARY The present paper has reported a case study of the "Electronic Doctor's Bag" which is a telemedical tool for home-visit medical services using the mobile communications environment in an isolated island and a disaster area hit by the tsunami. Clinical trials performed for 20 patients around a clinic in Miyako Island indicated that the communication functions of the proposed system were highly evaluated by patients as well as medical staffs. However, the system still has room for further improvement in operability, portability and mobile communication environment. The experience at the shelter in Kesennuma City suggested that mobile healthcare tools such as the proposed system will be strongly required when there are no or only paramedical staffs after leaving of emergency medical staffs.

key words: *the Great East Japan Earthquake, telemedicine, isolated island, disaster area, mobile communication*

1. Introduction

On March 11, the giant tsunami in the Great East Japan Earthquake hit the coastal areas of Tohoku district and fully destroyed their environment of life. For several months after the tsunami, the disaster victims who lost their houses were forced to live in shelters such as school gymnasiums with a horrible environment. Currently almost all the victims have moved to temporary houses whose healthcare environment is not always good.

However, the healthcare environment in Tohoku region has already been in a critical state because the uneven distribution of medical doctors has been widened due to an aging and declining population. It can be easily predicted that the disaster will accelerate the deterioration of this serious problem.

On the contrary, this case will become a touchstone for solution of the same problem as all other rural areas in Japan as well as Tohoku region are facing. The use of information and communication technology (ICT) may be a possible solution for such issues.

To prevent crisis in the nation's deficit-ridden health insurance system, the Japanese government is promoting the policy of home medical care. The healthcare insurance reform in 2006 newly established the home care support clinic system which intends to spread the clinics operating house visit services on 24-hour schedules [1].

However, in the case of a small clinic, a doctor may be forced to work in sleepless and hard working environment and the doctor's transportation time to patients' homes reduces the efficiency of medical care. Moreover, the remuneration for medical services decided by the system is not enough to spread the home care support clinics.

In this situation, Tohoku University established a consortium "The Consortium for Medical Information Communications System in the Mobile Environment" on March 4, 2009. The main purpose of this consortium is to provide the ubiquitous communications system not only for home-visit medical services but also for mass health examination, emergency care, and disaster areas. In collaboration with the Sendai Area Knowledge Cluster Initiative supported by the Ministry of Education, Science, Culture and Sports in Japan, the consortium developed a prototype of communications system, named "Electronic Doctor's Bag" in 2009. After evaluation of its function at a few clinics [2], a new version has newly developed in 2010 as shown in Fig. 1.

The purpose of this system is that instead of a doctor, a nurse carries the Electronic Doctor's Bag and visits

Fig. 1 Electronic Doctor's Bag. a) Carrying mode. b) Operation mode.

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a patient's home but an equivalent face-to-face communication between the doctor in his or her clinic and the patient at home can be realized by sending biological information with multiple high-definition images.

This paper will report the results of field tests of the proposed telemedical tool applied in an isolated island and a disaster area of the Great East Japan Earthquake.

2. Methods

2.1 Basic Function of Electronic Doctor's Bag

Figure 2 shows the framework of the Electronic Doctor's Bag. First, personal verification of the patient is done with a vein authentication to avoid mixing-up among patients. Secondly, to verify the patient's state such as complexion, movement and gait, his high resolution video picture is taken, highly compressed and coded for preserving individual security in a real time fashion. This signal is sent to the medical doctor staying in his own clinical office via a mobile communications system of cellular phones and the Internet.

The main targets of the proposed system are general chronic diseases such as circulatory disease, diabetes and the respiratory organ disease. Not only patient's high-definition video image to doctors to provide just like face-to-face examination but also various kinds of biological data are measured with an electrocardiographic (ECG) monitor, a blood-pressure meter, a blood sugar level meter and an ultrasonic diagnostic system. These data are connected directly with the main body of the Bag via USB interface or wireless communication line and also compressed, coded and sent to the doctor as automatically as the nurse does not need any cumbersome procedure. The ubiquitous system can be used in places without the Internet access, including ordinary households or moving vehicles such as ambulance cars.

2.2 New Features of Electronic Doctor's Bag

The system has following new features in comparison with the previous version [3].

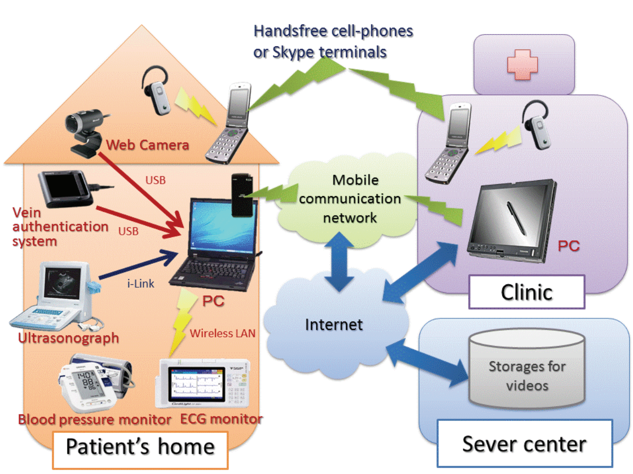

Fig. 2 Framework of the Electronic Doctor's Bag.

1) The PC for transmission
A high performance laptop computer was used. For mobile Internet access, E-mobile 3G (D31HD; Upstream: 5.8 Mbps, Downstream: 21 Mbps) and Willcom CORE 3G (HX006ZT; Upstream: 5.7 Mbps, Downstream: 7.2 Mbps) were used However, it is assumed that any clinic can have sufficiently high Internet access such as an ADSL or a fiber-optic network. The whole system measures 475 × 355 × 185 mm and weighs 8 kg.
2) 12-lead electrocardiographic monitor (Fukuda Denshi; ESP-300DX/SP)
A wireless LAN was used for sending data to the PC after monitoring to enhance operability.
3) Ultrasonographic monitor
A High resolution-type portable ultrasonographic unit (Honda Electronics; HS-2100) was used and its video output signal was acquired with the video capture box to be sent to the PC. Moreover, an ultra-compact ultrasonographic unit (GE; Vscan) was used in an off line fashion.
4) Web camera
A digital video camera (1080 p) used in the previous version had high performance such as a function to avoid blurring of images due to hand movement. However, the camera was heavy and not easy to handle. A Web camera (Microsoft; LifeCam Cinema; 720 p) with lower weight and cost has been adopted to improve operability.
5) Conversation tool
Not only at the clinic but also at patients' homes, video terminals for Skype (ASUS; AiGuru SV1T) were used to hold a conversation among the patient, his or her family, the nurse and the doctor with a low-definition video image (monochrome, 640 × 480 pixels) as well as a high-definition image (color, 1080 p) provided by the Bag.
6) Personal authentication
A vein authentication tool (Sony; FVA-U1) was used to identify patients, nurses and doctors. Such a biometric tool is useful for avoiding mixing-up among patients and preventing unauthorized persons from accessing patients' individual information.
g) Data server
A data server is placed in Tokyo and working to preserve the data sent from the PC in patients' homes. This has enabled the plural doctors to refer and share the patients' present data as well as the past one. The size of the server is 430 GB and ensures records of over 3,000 hours with the present resolution of the video signal captured by the system. It is easy to extend the size of the server.
7) Data access of the PC as a receiver
In the previous version, a gateway named "Digital Gate" made by Sony Co. was needed to receive the

encrypted data. In the current version, any PC that can access the Internet has been able to receive the data if the PC is installed with the certification software to certify the right of access to the information. This process has enabled the plural doctors to receive the data of the same patient simultaneously in anywhere all over the world by accessing the server in the Internet without loss of security. This function will be able to promote establishment of a cooperation network among doctors.

8) Display function of the PC as a receiver
Both of the video image of the ultrasonographic monitor and the video image of the Web camera can be displayed simultaneously on the PC for receiving the data. This function has enabled the doctor to watch the echo image, ascertaining the position and the posture of the probe operated by the nurse.

2.3 Application in an Isolated Island

In general, the healthcare environment of isolated islands is not good due to geographical conditions. In an isolated island, it is likely that residents have a bad access to hospitals and that a doctor and an insufficient number of healthcare professionals are forced to perform a heavy medical practice, coping with a sense of isolation under less up-to-date medical information.

The Electronic Doctor's Bag is suitable for improvement of the healthcare environment of isolated islands. This system will be able to save the cost and time for transportation if the nurse visits patients' home with the Bag instead of the doctor.

To ascertain the above thought, the experiment was performed at total 20 patients' homes around "Umyaasu N Clinic" (Director: Dr. Futoshi Takei) in Miyako island, Okinawa Prefecture for 20 days from October 20th, 2010 to November 10, 2010.

The following items were preliminarily evaluated for a nurse with a simulated patient before carrying out the main experiments using actual patients.

1) To check the mobile communication environment of the patients' home.
2) To understand how to carry and deal with the equipment.
3) To learn the procedure of preparation, operation, data transmission and communication with the doctor.
4) To understand the purpose of the operational protocols related to ordinary healthcare treatments.
5) To learn how to get an informed consent from the patients and their family.
6) To learn remote indication and instruction from the doctor.
7) To check the adequacy of conversation among the patient, the nurse and the doctor through remote communication devices.
8) To check the adequacy of healthcare treatments according to kinds of diseases under remote instruction from the doctor.
9) To learn how to record the procedure of the experiment.

After the preliminary evaluation, patients satisfying the following conditions were used to apply the proposed system.

- The patients who have been receiving the home visit medical services or who do not easily go to the clinic.
- The patients who have indication for ECG, blood pressure or ultrasonographic examination.
- The patients who can be diagnosed with the transmitted video or still images.
- The patients who have chronic diseases such as cardiovascular diseases, diabetics or cerebral stroke, etc.

In the experiment with actual patients, the following items were evaluated.

10) For the doctor

a) To check if the doctor can clearly read ECG, blood pressure and ultrasonographic data, comparing with the original data measured at the patient's home.
b) To check the followings on the basis of the transmitted video image.
   - The state of attaching the electrodes of the ECG monitor.
   - The state of attaching the cuff of the blood pressure monitor.
   - The position and attitude of the probe of the ultrasonographic monitor.
   - The effect of motion of the camera operated by the nurse on visibility of the video image.
c) To check the followings on the basis of the transmitted sounds.
   - Quality and delay of sounds.
   - Ability of conversation among attendants.
   - Ability of instruction from the doctor to the nurse.

11) For the nurse and the patient
In addition to the above items for the doctor, the followings were evaluated.
   - To check if the camera can be set at an appropriate position to take the state of the patient as soon as possible.
   - To check if the camera can be successfully moved according to the instruction from the doctor.
   - To check if the nurse can operate the PC of the Bag even at the patient's home.
   - To check if the patient and his or her family feel uneasy due to unfamiliar equipment and strange operation.

The above all items were evaluated with questionnaires asked to the doctor, the nurse and patients.

2.4 Application in a Disaster Area

Moreover, the proposed system was also applied in a disaster area hit by the tsunami of the Great East Japan Earthquake. On June 18, 2011 at the shelter of the gymnasium of Hashikami Junior High School in Kesennuma City, Miyagi prefecture, Japan, the Bag was used for health consultation of 17 people of the victims. The place was a temporary healthcare room that had been a preparation room for sporting equipment. The doctor, Dr. Tomoyuki Yambe, was at the laboratory of the Department of Medical Engineering and Cardiology, Institute of development, Aging and Cancer, Tohoku University, Sendai City, Japan.

3. Results

3.1 Application in an Isolated Island

Mobile communication quality

Around "Umyaasu N Clinic", Willcom Core 3G was not stable and about 60 kbp upstream at most. On the other hand, E-mobile 3G was sufficient for communication because it attained about 250 kbps upstream and 3.8 Mbps downstream. The most severe problem was that almost all patients' houses were built of concrete against typhoons, and thus it was difficult for radio waves to penetrate through the wall into the room where the Bag worked.

Evaluation of the adequacy of the proposed system

Figure 3 shows a scene of measuring blood pressure at the clinic using a simulated patient. It was ascertained that the almost all preliminary items 1)–9) shown in 2.3 were successfully evaluated by the nurse.

In the actual clinical trials, the nurse visited total 20 patients with cerebral infarction, cerebral hemorrhage, chronic endocranium, Alzheimer's dementia, aphasia, Parkinson's disease, depression, cardiac noise, expansion type cardiomyopathy, hypertension, hyperlipidemia, hypercholesterol, metabolic syndrome, diabetes, glucose tolerance obstacle, SAS, bloody bowel discharge tumor, hyperuricemia, bone fracture, arthropathy, gonarthrosis, congenital scoliosis, back pain, uneasy walk, pigmentary degeneration of the retina, etc. Most of them were accompanied by complications. It was also confirmed that the almost all items 10) and 11) for the experiment using the actual patients were successfully evaluated except some parts shown below.

Fig. 3 Measurement of blood pressure with the Electronic Doctor's Bag at "Umyaasu N Clinic" using a simulated patient.

The function of almost automatic transmission of biological data, i.e., ECG and blood pressure, was highly evaluated by the nurses. However, they assessed that the procedure of setting of the video camera and connection among the main body, the peripheral devices and the electrical power units should be improved to be done in a much simpler way. In particular, it could be found that setting and operation of the video camera may prevent the nurse from taking care of the patient and performing other usual medical tasks.

It could be verified that the transmitted high-definition video image from the Bag was very useful for the patient's state from the view point of the doctors. On the other hand, the doctor and the nurse indicated that the Skype terminals were also useful for conversation in a similar face-to-face fashion due to bidirectional communication but not suitable for diagnosis and precise instruction from the doctor to the nurse.

Moreover, the patients and their family told comments, which were described in questionnaires, as follows:

- I really impressed by the fact that I can face and talk with the doctor using the TV phone.
- I think this system will be very good unless the Skype works intermittently.
- I am happy to take the health check while sitting in my own home.

3.2 Application in a Disaster Area

Figure 4 shows the photos taken at the temporary healthcare room of the shelter of the gymnasium of Hashikami Junior High School in Kesennuma. At that time, about three months had passed from the Earthquake but the shelter was full of victims as shown in Fig. 4(a). Figure 4(b) represents a scene of the tele-consultation of a patient with the doctor in Sendai about 100 km far from Kesennuma. As shown in Fig. 4(c), another patient holds a conversation with the doctor through the Skype terminals. In this case, the communication line was not the mobile communication but the temporary Internet cable provided by a communication company without any charge. Figure 4(d) shows a scene of the ultrasonographic diagnosis using the Vscan.

This ultrasonographic machine is so compact that the measurement was very easy even if the patient was lying on a mat spread out on the straw bed, which is a Japanese traditional type of room floor. Their surfaces were almost the same level. Unfortunately, the Vscan does not have an electrical outlet port of the video signal, and then the nurse was forced to take the display screen of the Vscan with the camera of the Bag to send to the doctor. Of course, the res-

Fig. 4 Application of the proposed system at the shelter using a gymnasium in Kesennuma. a) Whole view of the shelter, b) Remote consultation assisted by a nurse, c) Conversation between a patient and a doctor far from there with Skype terminals, d) Use of an ultra-compact ultrasonographic unit.

olution of transmitted video image was reduced due to indirect shooting and the stability of the video frame was poor because the nurse took the video with the camera supported by only her hand without any tripod stand.

On the other hand, it could be verified that the high resolution color video transmission to the doctor was valid for consultation with a male patient complaining about pain at his hand because the doctor could judge his condition correctly.

4. Discussion

4.1 Application in an Isolated Island

It was not until we went to Miyako Island and actually performed the experiment that we found average private houses so bad in mobile communication environment. Miyako Island is an isolated island but a popular sightseeing place, and then we had considered that its mobile communication environment was better rather than rural and remote areas in the mainland. However, the ability of radio wave reception will be improved if a radio repeater is set around a window. On the other hand, in the case of extremely rural and remote areas such as mountain villages where mobile phones are out of service, the proposed system is, of course, invalid. The similar problem will happen if the proposed system is used in an ambulance car that may go to a poor reception area of radio wave.

In the literature [3], the authors pointed out the superiority of the proposed system to the other types of telehealthcare systems [4]–[9]. That is to say, the proposed portable high-definition video transmission system based on mobile communication is unique in comparison with other similar systems [7]–[9].

The results obtained from the clinical trials performed in Miyako Island indicates that only a low-definition TV meeting system or a TV phone like Skype terminals is not sufficient for precise medical diagnosis while the proposed system is useful due to both functions of high-resolution video image transmission and bidirectional audio and visual communication with cheap cost. However, it should be noted that the communication based on Skype has often been criticized for its weak security because of usage of P2P technology [10].

As shown in the patients' and their family's comments described in the questionnaire, they did not feel uneasy. This may be because the nurse was always with the patient and his or her family and she explained the procedure of the remote diagnosis. This fact suggests that home visit-type telemedical services will be easily accepted to at least patients.

4.2 Application in a Disaster Area

The results mentioned here were obtained from a temporary and transient situation such as the shelter about three months after the disaster. However, the situation changed rapidly than one might imagine in spite of the same disaster area. In the first several weeks, the healthcare situation was most sever and many doctors and paramedical staffs were strongly needed as well as emergency materials such as drags, foods, fuels, electricity and communication tools.

In this meaning, the proposed system will become useful a few or several months later when emergency medical teams had already gone but the healthcare environment around shelters or temporary houses remains poor. As already described above, the shelter we visited had a sufficiently fast fixed Internet access line at that time, and thus the mobile communication cards were not necessary. However, it is not realistic that all temporary houses in the disaster areas have the fixed line because the communication fee must be paid by oneself. In this case, similar healthcare units should be equipped at a house built as a community center in the temporary houses, or some healthcare cars equipped with clinical instruments and mobile communication lines should visit there with paramedical staffs instead of a doctor.

Currently, smartphones and tablet PCs have spread drastically into many people. In addition, the speed of mobile communications lines is getting higher, for example, the next generation WiMAX (IEEE802.16 m) will be 350 Mbps in the best effort. This stream enables us to guess that in the future, patients as well as doctors will think of mobile healthcare as a matter of course. The key to the promotion of the mobile healthcare may be to develop various kinds of light, compact and portable medical devices linked wirelessly to smartphones or tablet PCs, and more simple, precise and cheap personal authentication units are required. It is also important to develop groupware to collaborate among doctors and paramedical staffs with a high security level after some related legal deregulation.

Judging from this tendency, the system developed here can be regarded as a transitional prototype of a mobile healthcare tool in order to predict its idealized model in the near future.

5. Conclusions

The present paper has reported a case study of the "Electronic Doctor's Bag" which is a telemedical tool for home-visit medical services using the mobile communications environment in an isolated island, Miyako Island, and a disaster area, Kesennuma City hit by the tsunami.

Clinical trials of the proposed system were performed for total 20 patients around a clinic in Miyako Island. As a result, it was shown that both functions of high-resolution video image transmission and bidirectional audio and visual communication equipped in the proposed system were highly evaluated by patients as well as medical staffs. However, the system still has room for further improvement in operability and portability. In addition, we should cope with the poor radio wave environment inside private houses built of concrete.

At the shelter in Kesennuma, the proposed system was used for healthcare consultation for the victims with the doctor in Sendai. The experience suggested that mobile healthcare tools such as the proposed system will be strongly required when there are no or only paramedical staffs after leaving of emergency medical staffs.

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