Healthcare Challenge with ICT (Information and Communication Technologies)

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Abstract

As Japan is facing a hyper-aged society, Personal Health Records (PHRs), which patients collect and manage their own healthcare information, is currently attracting attention. NEC is advancing R&D to collect "symptom data," "drug adherence data" and "continuously monitored blood pressure data" by directly and objectively accessing the source which are hard to gather sufficiently. With this technology, NEC will contribute to a reduction in the wasteful medical expenses caused by forgetting to take medicines, to the new drug development earlier with quality improvement of clinical trials, and to support higher accurate diagnoses and better medical care.

Keywords

medical, PHR, medical interview, vital data sensing, drug adherence, low load, continuous blood pressure monitoring, diagnosis, clinical trial, clinical study

1. Introduction

As Japan is entering the super-aged society by leading the world, various solutions are about to be started radical technological innovations will be required, particularly in the field of medical care, and the Japanese government is promoting solutions actively as a part of its mid- and long-term "health and medical care strategies."

In such, the "Personal Health Record (PHR)" concept is beginning to attract attention within the society. The PHR may be interpreted in many ways, but we believe that it commonly refers to a mechanism allowing individuals to collect and manage information on their own health and medical care records. Previously medical records consisted exclusively of information collected by medical staff. However, in pursuit of optimum treatment and accelerated medical research it has now become more important to utilize data obtained from the daily life of the patient, thereby enabling more accurate analyses. This is why expectations are being raised for the beneficial input of PHR solutions.

NEC has been focusing on electronic medical record systems for medical facilities. We are currently advancing R&D by taking note of the rising need to utilize information collected via PHRs to support diagnosis and treatment.

In this paper, we will discuss the collection and usage of a patient's "symptom data," "drug dosage data[*1]" and "continuously monitored blood pressure data."

In the past, various information regarding patient's conditions have been collected mostly as follows; the symptom data at interview and from observations by the medical staff the drug dosage data from the memory of the patient and the continuously monitored blood pressure data via presumptions based on clinical results. By using PHR we are expecting that it will be possible to collect the relevant data directly and objectively from the source (i.e. the patients themselves).

As mentioned above, by collecting data that is useful for medical care via PHR, diagnoses of higher accuracy will be achieved and medical care with higher adequacy will be provided. High-quality, optimum medical care will thereby be enabled for the super-ageing society.

[*1] Drug dosage data includes the time and frequency that each patient takes each drug as well as whether the patient takes or does not take each drug.

2. A Technology for the Collection, Extraction and Analysis of Patient Symptom Data

2.1 The Present Status of Collection, Extraction and Analysis of Patient Symptom Data

Information systems for hospitals began with the introduction of the medical accounting system that bills patients and claims for insurance, and subsequently these systems have developed into the introduction of the ordering system that communicates data to the medical accounting system. The ordering system also transmits data to the pharmacy's dispensing machines, and to the inspection department and imaging diagnosis department systems. It also examines the transmitted results according to drug prescription and test orders. The introduction of electronic medical records is now generalized in order to share information between all medical staffs, including the physicians, nurses, pharmacists, radiology therapists and clinical laboratory technicians.

Computerization and sharing of information inside a hospital as described above have made possible the quick linkage of accurate information, reduction of malpractice and patient billing with correct information. However, although such use of IT has brought great improvements to the deskwork and information communication of the hospitals, it is, for the present, still not utilized widely in supporting tests and diagnoses by physicians and nurses.

Here are some examples that currently represent the above issues.

- The patient interview information is entered on paper and is not compiled into a database.
- The physician's findings are mostly recorded by hand-writing in a free format style, which cannot be handled as data for information analyses.
- The information on the test scores, etc. are recorded independently in individual departments and these are managed individually using tools such as Excel, Access and FileMaker.

As is evident from the current situation, the tests and diagnoses are managed by physicians and nurses in systems that are independent of the hospital information systems.

In the following section, we describe a system for collecting and extracting data for supporting tests and diagnoses of physicians and nurses. This system is implemented by integrating the existing electronic medical record system which input and manages patient medical interview information and physical examinations.

2.2 Medical Interview Input

Currently in the general hospitals, information on new patient medical interviews is entered on paper media, which is then circulated among nurses and physicians. However, the information collected in this way is often written by hand-writing and in a free format style so that it does not hold a systematically structured format. To deal with this, we have developed an interview information input system that uses tablet terminals so that patients can directly input information. This medical interview input system uses a Q&A type selection format to enable simple input operations by the patients (**Fig. 1**).

The input system also accepts the simultaneous registration of patient profiles such as overseas travel history, allergies, drug history, past history, social history and family history (**Fig. 2**).

Patient profile information is also provided from the electronic medical record system, but a quick conversion into electronic data is difficult in actual hospital operations because medical interview information in paper format has to be input

Fig. 1 Medical interview/symptoms input display.

Fig. 2 Medical interview/patient profile input display.

into the electronic medical record system. In order to correctly supply the patient's symptom data and his/her profile information for tests and diagnoses without omissions, it is necessary that such information should be archived as data in the hospital information system immediately; at the moment it is input by the patient.

2.3 Attribution of Medical Keywords

The system described below provides a data-base called the Medical Keyword Database for use in managing the medical interview information input by patients. For example, in the medical interview input procedure described in the previous section, a detailed question such as "How is your physical condition?" might be addressed to a patient who displays a "pallid look," and the answer might be "hard to breath" or "I have been told I have a heart or lung disease." The medical keyword "Malaise - Yes" is then registered in the database in the KEY-VALUE section. As medical keywords are attributed to all of the answers to the interview questions, it becomes easy to search all of the data held in the hospital based on symptoms. Some such medical keywords are listed in **Table 1** below.

Such registered medical keywords are also utilized in the patient information search to be described later.

2.4 Collection of Electronic Medical Record Information

Since information on drugs prescriptions, test results and disease names is essential for clinical studies, this system acquires the information generated by the electronic medical record system and registers it in the KEY-VALUE format, in the same way as registering the medical keywords for physical symptoms into the KEY-VALUE database (**Table 2**).

Table 1 Examples of medical keywords.

KEY	VALUE
Ca antagonist prescription	Yes
Snoring	No
Snoring	Yes
Degree of Snoring	Heavy
Malaise	Yes
Malaise	No

Table 2 Examples of disease name, test result and drug prescription information.

KEY	VALUE
Disease	Rheumatoid arthritis
Test Result: CRP	4.5
Prescription	Azulfidine EN

Table 3 Example of disabilities of arm, shoulder and hand (DASH) table.

KEY	VALUE
Score: DASH	25

Fig. 3 Patient search display.

All of the information on the drug prescriptions, test results and disease names is arranged similarly and is utilized in general-purpose search operations.

The recorded information of each department can be handled in the same way as the test results by setting the keywords just as for the test results information (**Table 3**).

Recording the electronic medical chart information and the per-department information in a unified format as describe above can provide a suitable database for a secondary search of the hospital information.

2.5 Patient Information Search UI

In the previous section, we have described a practical usage of the keyword search with this system. For use in searching the keyword in the database compiled in this system, we prepare the user Interface (UI) as shown in **Fig. 3**.

This page can use the symptom, disease name, test results, drug prescription and scores recorded in the database as the search targets.

Especially, a symptom can be selected from a display classified in three steps (**Fig. 4** and **Fig. 5**).

The targeted search information is generated from the medical keywords described above and is fashioned to facilitate symptom selection by the users.

After setting the search parameters, executing the search operation enables display of the list of applicable patients on the screen as well as the extraction of CSV files as shown in **Fig. 6**.

For the detailed situations of patients, since the electronic medical record system already has a corresponding function,

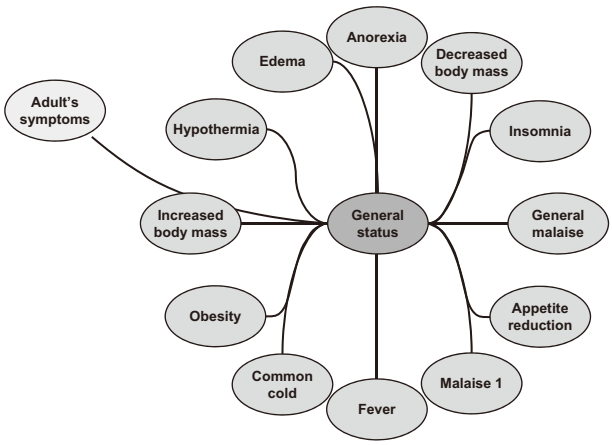

Fig. 4 Symptom classification/selection.

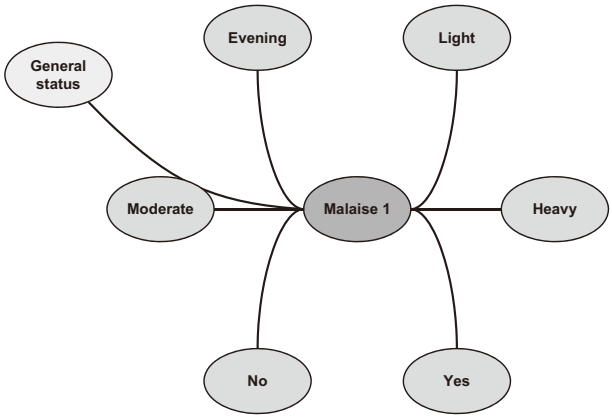

Fig. 5 Detailed symptom selection

患者数: 8名 患者データ参照 Csv出力

hospital	patient	gender	birthday
430003	3997D049E078557A1EE77F745C4DF14E	男	1945/03/21
430003	4B6C427AFE34827ADE6DDA2083DFE8DC	男	1947/12/11
430003	95C1C21CEB4EF46F5E0205A4894C78EA	男	1955/01/04
430003	968EA9C813EE6208C80936185ABA7288	女	1942/03/18
430003	A288769E61C9AC3514008511F2A1D46F	男	1945/02/19
430003	F261E4D8F06B5E09A349071847DC0403	男	1965/11/11
430003	F6C18FA90708916D55D6661389A2C034	男	1954/07/29
430003	F87519C410C33C8D9087ACE4AFD2CEB5	男	1942/08/10

※Patient Nos. are encrypted.

Fig. 6 Patient search results.

the present system provides the electronic medical record linkage on the extraction result display for referencing patient data. The system is compatible with the CSV output for the medical statistics processing function. This function outputs a file together with the data in the KEY-VALUE format so that the file can be input to statistical software for various usages.

2.6 Effects and Issues Raised by the Patient Symptom Data Collection/Extraction/Analysis System

The mechanism described above has been used in arranging the medical interview information and various tally data into a systematically structured format, and it has been implemented as the basis for utilizing information in support of treatment and diagnosis. As this information is the result of daily collections by frontline physicians, the cost and the time taken for the collection have posed major issues. We aim to make the new system more capable of reducing these costs and to thereby significantly advance medical science.

The new system still has some issues, especially in acquiring accurate information regarding drug dosage (especially for prescribed drugs). The future technological development is required to incorporate these in the system. The development of new devices and the application of innovative solutions must be adopted more actively.

3. A Technology for Home Sensing of Medical Information

The groundwork for the collection, recording and utilization of information related to diagnoses and treatment in hospitals has been developed based on electronic medical record systems and clinical examination systems.

At medical facilities, therapeutic action is taken after observing the progress of the disease, diagnosing and defining the disease and other information by performing various clinical examinations and deciding on a treatment program. In many cases, therapeutic drugs are prescribed and the patients take the drugs until the next hospital visit for treatment.

What is vital in the therapy is to take the drugs correctly as prescribed and to find out how the symptoms change accordingly. At present, information on drug dosage and symptom changes that occur at home is obtained by relying on interviews with patients and the daily treatment records per disease as reported by the patients themselves, such as for blood pressure and asthma, etc.

As there is a term of drug adherence, patients under treatments are required to understand the treatment program and to participate positively in correct drug dosage and treatment. Nevertheless, a very large number of patients actually experienced forgetting to take their prescription drugs or have had difficulty with accurately recording and reporting their symptoms.

We believe that, if we are able to monitor the pattern of drug dosage of a patient at home and also to collect vital data such as blood pressure without imposing a load on the patient, it will thus be possible to significantly reduce the labor of recording daily treatment. It will also be possible to greatly improve a patient's commitment to follow prescribed dosages (medical adherence) and to gather valuable information for diagnoses and treatment in support of an effective cure.

At NEC, while optimally using sensing technologies and "Internet of Things (IoT)" scenarios we are conducting R&D into the mechanisms of collecting data on drug dosage and other vital home based signs without burdening patients too much.

3.1 Drug Dosing Alerts/Detection Technologies

We have recently developed a system for providing alerts and detecting drug dosage in order to support a disciplined approach to drug adherence.

What is important with drug adherence is to let the patient; 1) take the prescribed drug at the designated time (drug dosing alert) and; 2) record the drug dose and time of day so that the record can be checked by the physician and pharmacist as well as the patient (drug dosage detection). To make these tasks possible, we designed the system so that it can issue an alert advising on dosage at the designated timings and detect the drug dose taken by the patient.

The mainstream drug packaging is to use the PTP (Press-Through Package) sheet made by attaching aluminum to a plastic base. However, it is very hard to incorporate the drug dosing alert and detection functions in the PTP sheet due to the need for ease of use and the cost. We therefore developed a dedicated drug container in which these functions are incorporated.

The premise for the development was to let it function correctly throughout the effective period of the drug. Considering that drug users include many aged persons, the container should be available for use without the need for special settings by patients. We therefore designed it so that the alert and management functions start automatically at the first time the patient takes out the first dose.

The container has a composition as shown in **Fig. 7**.

The drug dosage is advised by causing the LED to flash at the designated timing in order to alert the drug user. The LED stops flashing when the drug is taken out of the container. If the drug is a pill, the patient unlocks the mechanism that prevents the accidental ingestion by an infant. The patient then moves a pill to the drug outlet and pushes the ejector button to take it out of the container. The container has a mechanism for detecting the outlet of a pill so that, when a pill is ejected, the date and time of the ejection is recorded in the memory of the control module. The ejection will not be recorded when the pill is not taken out of the container, even if the ejection button is pressed.

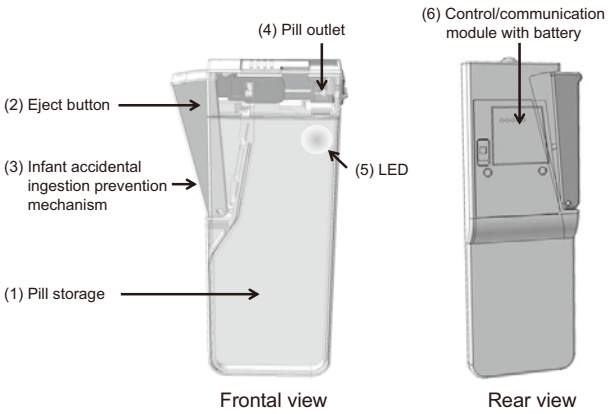

Fig. 7 Drug container with drug dosing alert/management functions.

The recorded pill ejection date/time information can be sent to a smartphone or similar device via Bluetooth. The time and situation of drug dosage can be checked by the patient, physician and/or pharmacist using an application running on a smartphone. The operations of these functions are guaranteed from the shipment from the pharmacy plant to the distribution and completion of drug dosage by the patient. A single CR2032 button battery is used in the low-power consumption design of the control and communication module.

NEC will deploy the drug container with drug dosing alert/management functions for various drugs in order to prevent disease recurrences due to forgetting to take a prescribed drug, and eventually to contribute to the solution of the important social issue of medical expenses reduction.

3.2 Low-stress Continuous Blood Pressure Sensing Technology

3.2.1 The Need for Continuous Blood Pressure Monitoring and Its Current Issues

The escalation in medical expenses that has resulted from the ageing of society has been increasing the importance of detecting diseases at an early stage in order to prevent them from becoming severe. In particular, the management of mild stage disorders is important in adult diseases because many patients suffer from them and these diseases could be a cause of more severe ones, if they are left uncured. One of the major adult diseases, hyper blood pressure is a disease of the largest scale, with 9.06 million outpatients in Japan and the number of potential patients in Japan is said to be as high as about 40 million. The data of highly frequent blood pressure monitoring data in the early morning, during work and at night (during sleep) is utilized as an important index of cerebral vascular diseases (cerebral infarction, subarachnoid hemorrhage, etc.) These diseases are the most frequent causes of certification of long-term care needs.

However, the current ambulatory blood pressure monitoring (ABPM) system imposes a very high measuring stress and its daily use causes a risk of obstructing activities and the sleep of the person wearing it. To deal with this, in collaboration with Dr. Tochikubo of the Medical School, Yokohama City University, we have developed new blood pressure monitoring solutions aimed at reducing the effort required of the wearer. The

following subsections describe the technology for system size reduction for wearing stress reduction and the approach to a unique blood pressure monitoring algorithm aimed at reducing cuff (i.e. armband) wearing stress in the effort required during measurement.

3.2.2 Issues of Current ABPM

Fig. 8 shows the comparison between the current ABPM system and the newly developed system. The current ABPM system is composed of three modules including the cuff, tube and data logger. The system is attached by the medical staff at the medical facility and the patient lives with the system attached to an arm for 24 hours, during which time the blood pressure is monitored automatically about every 30 minutes. The patient then returns the system to the medical facility, and the physician reads the blood pressure data from the data logger and gives a diagnosis and a prescription based on the continuous data collected at early morning, during work and at night (during sleep). However, the current ABPM system is actually not used often because wearing it for a long period is not comfortable for the patients. As a result, reduction of the stress of monitoring by decreasing the system size/weight and the securing stress during measurement have become issues that require solution.

3.2.3 Low-stress Blood Pressure Monitoring Technology

(1) Development of compact, accurate pulse wave information acquisition I/F

The most widely used blood pressure monitoring method is the oscillometric method that identifies blood pressure values based on the relationship between changes in vascular oscillation produced by pressurizing an artery with a cuff to stop blood flow temporarily. It is said that to stop the blood flow, the cuff needs to have a certain width (12 to 13 cm if the patient has the average arm circumference of Japanese people) and air needs to be fed at a constant rate. The pump capacity and battery power required to feed air into the cuff are the constraints that make the system size reduction and system integration difficult.

We therefore developed a technology for increasing the cuff pressurization efficiency using an innovative stress relaxation mechanism that features a high human body affinity. This enables pulse waveform acquisition with an accuracy sufficient for blood pressure prediction using a low volume cuff; of about half that of the conventional cuff (**Fig. 9**). The reduction of the cuff volume led to the integration and size/weight reduction of the system and improvement of wearability.

(2) Development of algorithm for securing stress reduction

Since the traditional oscillometric method cannot identify the blood pressure unless the blood flow is stopped completely, it has been necessary to secure the monitored region with a pressure higher than the maximum blood pressure. To deal with this, we have developed a blood pressure prediction algorithm for calculating the blood pressure with a pressure below that of the maximum blood pressure.

This algorithm converts the parameters such as the pulse wave distortion and phase change into numerical values and analyzes their correlation with the blood pressure information using a unique signal analysis technique. The securing pressure of this method is much lower than the traditional oscillometric method and can obtain the blood pressure data at low loads throughout the day. We are currently improving this method to reduce the securing pressure to much lower than the present one.

The low-stress continuous blood monitoring technology described above will enable continuous blood pressure monitoring by wearing the user-friendly cuff so that the early detection of the signs of cerebral vascular diseases will be available, and it will thereby contribute to the extension of a healthy life span. In the future, we intend to advance the analysis technique even further and to perform R&D for supporting healthcare at home with ICT.

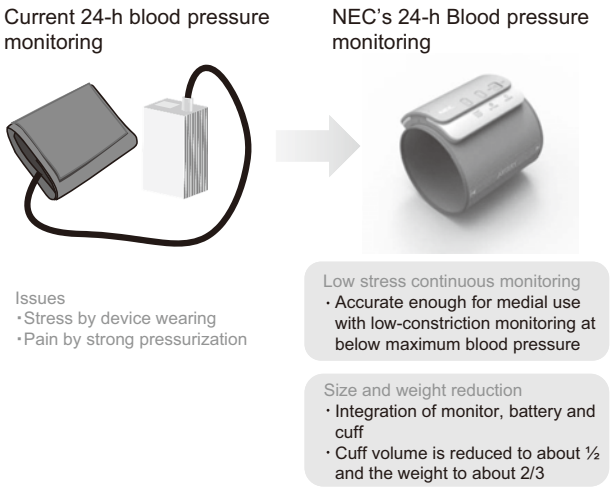

Fig. 8 Comparison between the current ABPM and the newly developed system.

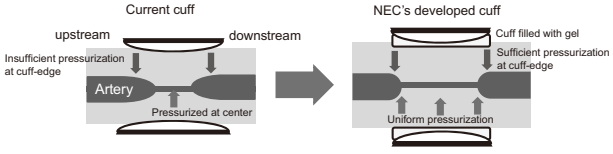

Fig. 9 Diagram of cuff-edge pressurizing effect improvement and of the size reduction thanks to the stress relaxation structure.

3.3 Drug Dosage and Vital Sign Sensing Services in Clinical Trials

3.3.1 Clinical Trials for the Collection of Drug Dosage Data and Vital Signs Measurement Data such as Blood Pressure – Present status and issues

In the clinical trials of new drugs, the subjects should take the drugs according to the dose and method prescribed in the trial program and measure vital data such as blood pressure so that the effectiveness and patient safety of the administration of the new drug can be judged accurately.

The quality and efficiency of clinical trials in the hospitals are improving because the drug administration and blood pressure monitoring of subjects are performed by medical specialists using ICT. On the other hand, with the clinical trials at home, one should record the drug dosages and blood pressures by oneself, enter the results in a journal and submit it later when visiting the hospital. This procedure involves various issues including the effort required of the subject for entering the data in a journal, forgetting to take the prescribed dose or record the blood pressure monitored by the subject and the erroneous entry of data in the journal. Therefore, a reduction in the effort required of the patient, prevention of forgetting and a decrease in the number of entry mistakes can lead to improvements in the quality of the clinical trials.

3.3.2 Outline of Drug Dosage and Vital Signs Sensing Service

By making use of NEC's medical equipment for clinical trials and the results of the R&D of the drug dosage detection, drug dosing alerts and low-load continuous blood pressure sensing technologies described above, we are planning to start a cloud service business. This will collect the drug dosages and vital sign data of each subject from the patient's home, online and real time and archives them so that the raw data is always accessible (**Fig. 10**).

(1) Collection of trial data in the home

Medical devices (blood pressure monitors, weighing scales, etc.) equipped with communication functions are to be prepared as a means of collecting trial data from the patient in the home. Dosage and other vital information is currently collected based on reports from the patient, but the R&D of the dosage detection/alert and low-load continuous blood pressure solutions described above are presenting the potential of collecting the required information with less effort required of the subject.

(2) Online real-time collection of device data

Next, a smartphone turned into a dedicated terminal for the trial (hereinafter called the dedicated terminal) is to be prepared as the means for receiving data from the devices above and communicating it to the server. When a subject takes a drug or measures a vital sign using the applicable device, the data is automatically transmitted to the dedicated terminal via Bluetooth. If the dosage or vital measurement is not performed at a designated timing, the dedicated terminal transmits an alert to the subject to prevent forgetting.

The subject can easily reference his or her own dosage and measurement history by accessing the server from the dedicated terminal so that self-management of the trial by the subject is enhanced.

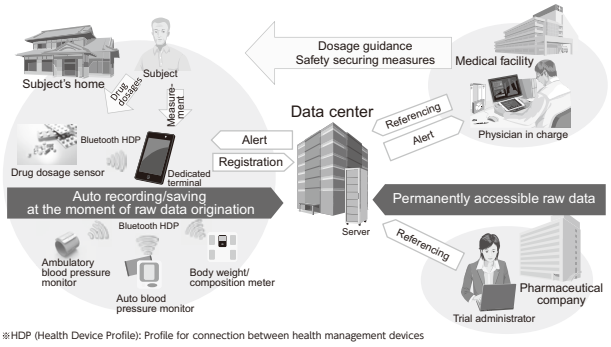

Fig. 10 Diagram of the cloud service for the real-time, online collection of drug dosage detection and vital sign data.

(3) Usage of the data saved in the server

The data sent from a device to the dedicated terminal at the same time as a drug dosage record or a vital sign measurement is stored as raw data in the server at the data center. This data is recorded with high reliability, authenticity and storability and with reduced entry errors and patient effort.

The physician in charge of the trial can access the raw data of his or her patient (trial subject) stored in the server at any time. Under the condition in which readability is established, the physician can also check the alerts given to a subject for forgetting a dosage or vital measurement. Real-time data and the past history are referenced in the graph format. We believe that, when the physician in charge becomes aware of such information, it will be possible to ensure drug dosage compliance by preventing forgetting or overdosing, predict the potential of acute deterioration of a patient based on vital signs, and take prompt measures for the prevention of an increase in disease severity.

We believe that this service will make it possible to ensure drug dosage compliance, collect accurate vital sign data and enable highly reliable data management and lead thereby to improvements in the trial quality and the prevention of trial deviation and dropout cases. This situation can also be expected to reduce the trial period for the drug commercialization process and speed up the development of new drugs.

4. Conclusion

The approximate medical expenses of the Japanese Government in FY2013 was 39,300 billion yen with a growth of 2.2% from the previous year. This figure exceeds 10% of the gross domestic product (GDP), which is higher than the average for other developed countries.

For the pharmaceutical drugs that occupy a large share of the medical expenses, there are statistics that more than 25% of patients have experienced forgetting drug taking and 33% have failed to obtain any therapeutic effects. These figures suggest that drugs costing more than 50 billion yen are wasted every year and that additional medical expenses become necessary due to the deterioration and recurrence of diseases by forgetting to take the correct drug dose.

We will contribute to medical care by supporting diagnoses and treatments and by adopting the approach described in this paper. We will also continue our endeavors to reduce the wasteful medical expenses that contribute adversely to the overall national medical bill.

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Vol.9 No.1 Special Issue on Solutions for Society - Creating a Safer and More Secure Society

Vol.9 No.1
January, 2015

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