Evaluating the Workload Reduction of Automatic Vital Data Transmission

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Abstract As a conventional hospital information system (HIS) requires clinical staff to record data, the introduction of an HIS deprives those staff of time for direct treatment and care. This paper introduces the first commercial automatic vital data transmission system that records patients' body temperature, blood pressure, pulse rate, and arterial oxygen saturation in the clinical environment of Kyoto University Hospital. The results of task-and-motion analysis and system logging show that the system reduces the time required to record vital data by 40%. Furthermore, the system is expected to eliminate human error that may occur due to nurses failing to input data, or inputting erroneous data. To maximize the benefit of using information and communication technologies, the development of medical sensors that can be interfaced directly with a ubiquitous health-support information environment, namely an HIS, is indispensable.

Keywords: ubiquitous computing, sensor network, vital data recording, point-of-care system, hospital information system.


1. Introduction

The principal reasons for introducing a hospital information system (HIS) are clinical process and safety improvement. However, the introduction of an HIS deprives clinical staff of time for direct treatment and care, as they must record the necessary data. Even point-of-care systems (POCs), which are expected to facilitate fast and accurate data input, may decrease the subjective productivity and objective performance of nurses due to limitations of personal data assistants (PDAs) and laptops used as the bedside input tools [1-3].

To free nurses from data input and avoid human error during the recording of data, the authors have previously proposed to let sensors to record and log data, and directly interface with a ubiquitous computing system known as an HIS [4]. In this paper, we describe the first commercial pluggable vital sensor system and its application in the clinical environment of Kyoto University Hospital (KUHP).

2. Materials and Methods

2.1 Introduction of an Automatic Vital Data Transmission System

We used the Omron Healthcare HBP-1600 in our HIS. As shown in Fig. 1, the HBM-1600 consists of blood pressure and pulse rate monitors, a thermometer, and a pulse oximeter. The measured body temperature and blood oxygen saturation (SpO2) are transferred to the main component via near-field communication (NFC), and these data together with the blood pressure are sent to a server via a wireless local area network (WLAN) when the “Send” button is clicked.

A barcode reader system was used to relate the obtained vital signs to the patient [5, 6]. KUHP introduced a Bluetooth access point (BTAP) system (Takebishi) [4] that allows Bluetooth devices to connect with the HIS via a WLAN, as well as a 1500 Bluetooth-based barcode reader.
(Koamtac KDC300) connected to the BTAP system.

**Figure 2** shows the workflow of the vital data collection. A nurse first reads the barcode on a wristband of a patient and the barcode attached to an HBP-1600 to relate the device to the patient. Following measurement of the patient’s vital signs, the nurse transmits the data by clicking the “Send” button. The vital data server receives the relation from the barcode reader server and transmits the obtained data to the electric patient record (EPR) server with the patient ID. As the nurses read their staff ID at the beginning of their shift, the staff ID is also sent with the obtained data. Finally, the EPR server records the data in the patient’s health record.

### 2.2 Workload Analysis

To evaluate the effect of the system, we conducted a workload analysis for nurses before and after the system was introduced in the ward of the thoracic surgery department on September 17, 2012. We conducted a time-and-motion study on August 30 and 31 (before introduction), and on September 27 and 28 (after introduction). Thus, the nurses had one week to adjust to the new system.

In the time-and-motion analysis, ten nurses during the daytime shift (from 9 am to 5 pm) were observed. The start and end of each vital data measurement and recording were recorded. We measured the time spent to record the body temperature, blood pressure, pulse rate, and arterial oxygen saturation. Each observer followed a nurse and recorded his/her activities using voice recorders as shown in **Fig. 3**.

In addition to the time-and-motion study, we analyzed the operation logs of the HIS. KUHP introduced IBM’s HIS named CIS. In standard operation, nurses log vital data through the “care flow”. To open a data-input window, a nurse can click on a graph of the target day in the care-flow screen, as shown in **Fig. 4**, and data can be recorded using the keyboard. We collected the operational log of all the terminals at the ward during the period of the time-and-motion study, using the Cyber Operation Monitor logging software (Cyber Laboratory, Inc.). **Figure 5** shows an example of the log data.

### 3. Results and Discussions

**Figure 6** and **Table 1** show the time spent inputting target vital data (the time when nurses are facing the HIS terminals to input the vital data) before and after introducing automated data logging, together with the time spent reading the barcodes and transmitting the data following implementation of the system. The result shows that introduction of the system saved four to five seconds in the logging of each piece of data, or approximately 40% of the total time.

**Figure 7** and **Table 2** show the time spent logging the complete vital data (the time when the data input screen is open), which includes body weight, water intake and output, breathing rate, body temperature, blood pressure, and arterial oxygen saturation, before and after introduction of the automated system.

**Tables 1 and 2** show that recording the body temperature, blood pressure, and arterial oxygen saturation accounted for 126 of a total of 786 data logging events (16.0%). When the nurses recorded the data by hand, these measurements accounted for 101 of a total of 983 (=882+101) logging events (10.3%), with one second

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**Fig. 2** Workflow of the vital data collection system.

**Fig. 4** Data input screen of the care flow.

**Fig. 3** An observer recording activity of a nurse for time-and-motion analysis.
longer required for each input task on average. The mode
time spent on the input process decreased by one second.
The results of the time-and-motion analysis and the
system log analysis were in good overall agreement.

The average time for log data shown in Table 2
decreased more than 10 seconds. As the care flow
visualizes the vital data as a graph, the nurses sometimes
open the input screen to check detailed numerical values
for assessment. Although the authors excluded the case
when the screen was closed by clicking the “cancel”
button, which may mean opening the screen for browsing,
some samples ended with the “OK” button (update the
data) may have included the time for inputting and
browsing the data. Therefore, the huge decrease can be
interpreted as the result of the variances of the samples.
The long-tailed distribution in Fig. 7 supports this
interpretation.

Table 1 shows that introducing the system reduced
the time required for each measurement by five seconds.
As discussed in our previous paper [4], we can assume
62,000 out of 365,000 patients per year are in need of
intensive care at KUHP. Nurses must record the vital
signs every hour for these patients, and twice a day for the

Fig. 5 An example of operation log.

Table 1 Summary of the time-and-motion
study shown in Fig. 6.

<table>
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<tr>
<th></th>
<th>Before</th>
<th>After</th>
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<td>Average(s)</td>
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<tr>
<td>Median(s)</td>
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<td>9.0</td>
</tr>
<tr>
<td>Mode(s)</td>
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<td>7.0</td>
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<tr>
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<td>101</td>
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</table>
other patients. As a result, the nurses need to record 2,218,000 vital signs per year. It follows that the introduction of the system saves 3,080 man-hours per year.

As our previous work estimated the total overtime work of nurses in KUHP to be 144,000 man-hours per year, the system is expected to decrease overtime work by 3%. According to a wage structure survey conducted by the Ministry of Health, Labour and Welfare of Japan, the average payment of nurses is approximately 2,500 Japanese yen (JPY) per hour. Thus, 3,080 man-hours equal 7.7 million JPY. As the regular price of HBP-1600 is 157,500 JPY, the cost reduction of the system is equivalent to approximately 50 terminals. Although the wide variety of costs required for server introduction and the number of terminals required do not allow us to estimate the total cost of introducing the terminals, it is expected that three to five years of operation can easily pay back the cost of introduction.

The results of interviews with users (the nurses) revealed that introducing the system improved their subjective productivity. The nurses welcomed the system as it freed them not only from the laptop console, but also from phone calls from medical doctors, since the doctors can now browse the data on the HIS immediately after they are measured. In addition, automatic recording was reported to free nurses from the time required to input the measurements and from the fear of recording incorrect data. As has been noted previously [8-11], a strong correlation exists between subjective productivity measures and objective productivity measures. Therefore the introduction of the system may indirectly result in a further increase in productivity of the nurses.

To maximize the effect of pluggable sensors, such as those used in the system described in this paper, a reduction in the time required for patient identification should be achieved. In this study, we utilized the existing barcode reader system for patient identification, which requires nurses to manually identify the patients. A semi-automatic patient identification input function, such as the system reported previously [4], may be helpful here.

A further issue is how best to make sensors pluggable. The introduction of the automated vital sign recording system did not decrease the frequency of accessing the vital sign input page, as shown by the data shown in Table 2. As the log-in process itself requires some time, decreasing the frequency of accessing the HIS to input vital data by automatic recording of data such as height, weight, water intake, water output, and blood glucose is an important area with scope to further increase productivity.

4. Conclusions

The authors investigated how to reduce the workload of nurses using automatic vital data transmission in a clinical environment. As has been reported previously [13], the introduction of an HIS deprives nurses of time for direct treatment and care. Minimizing the workload for data input is an important aspect of improving clinical productivity and safety in the information age. To maximize the benefit of information and communication technologies, the development of medical sensors that can interface directly with a ubiquitous health support information environment; i.e., an HIS, is highly desirable.

Fig. 7 Log data analysis showing the time taken to record data before and after introducing the automated system.

<table>
<thead>
<tr>
<th>Table 2 Summary of the log data shown in Fig. 7.</th>
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<td></td>
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References


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