

## Is free and open source software for making web sites on the Internet available for computerization of hospital support functions?

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**ABSTRACT** There is a large amount of free and open source software for making web sites on the Internet. While many web-based hospital information systems have been used at hospitals, is such software also available for supporting hospital functions? Hospital staff developed the system allowing the electronic support of various hospital functions using such software and incorporated it experimentally into an existing network at a hospital. The availability of this system was examined by records left on a server in three categories according to EHR System Functional Model. Direct Care EHR-S functions that are well supported by already existing hospital information systems require little further computerization. However, some other hospital functions were computerized using such software. Although the new system has been in place for over 3 years, no problems have yet occurred. Such free and open source software has a possibility to be available to computerize some hospital functions.

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Key words : **Computerization, Hospital functions, Free and open source software, Internet, Local area network**

### INTRODUCTION

Information technology has been applied to the computerization of medical work, such as the development of receipt, order entry, and electronic medical records systems. Although the introduction of such systems involves huge investments, they have been implemented at many hospitals in Japan because they are very useful<sup>1)</sup>. This trend toward computerization is a result of national policy in Japan, based on the Ministry of Health, Labor, and Welfare guidelines regarding the application of information technology to health and welfare issued

in 2001<sup>2)</sup>.

There are various work functions at hospitals and they have been classified to three categories according to EHR System Functional Model proposed by HL7: (1) Direct Care functions, (2) Supportive functions, and (3) Information Infrastructure functions.

Direct Care functions (1) are defined as work related directly to medical treatment or patient care.

Supportive functions (2) are defined as work not related directly to medical care but that provides necessary support for medical care, such as the

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production of summaries of inpatients' clinical courses during hospitalization, communications regarding patient information to be forwarded to other institutions, and reports regarding incidents at a hospital, etc. Some of these have been added to electronic medical records as standard functions<sup>3-4</sup>, but they were added to hospital information systems only as optional functions, either because of the costs involved in customizing the software packages of these systems or because of the lack of availability of these options. Therefore, these functions are often not computerized even at institutions where hospital information systems have been implemented.

Here, Information Infrastructure functions (3) are defined as work not related directly to medical treatment or patient care that is necessary at institutions of various types, such as notification of events or conferences and reservation of equipment. As this type of work is necessary at hospitals as well as in the enterprise, groupware applications developed for enterprise use have sometimes been introduced in hospitals<sup>5</sup>. However, the requirement for groupware applications is not always recognized at hospitals as they are not related directly to medical care, and they are not introduced because of budget constraints even when costs to do so would not be particularly high.

Decisions regarding the computerization of work at hospitals must take into account not only the effect on hospital management but also cost, as the implementation of such systems will usually incur significant financial investment. However, appropriate computerization of hospital functions will lead to improvements in the work environment when guessing from the history such as receipt computer system or the order entry system. With the consent of the management at a general hospital that had an existing order entry system but where it had been difficult to implement further computerization, hospital staff developed an experimental

information system to provide support for hospital work and improve the work environment. Although few papers on groupware used in a hospital have been published, some researchers have reported the effectiveness of groupware systems in medical treatment or health care field, such as counseling guidance for patients with metabolic syndrome<sup>6</sup>, the management of patients with residual brain tumor disease<sup>7</sup>, collaborative relationships with physician practices<sup>8</sup>, workflow in critical care units<sup>9</sup>. To reduce the cost of implementation, the information system was developed using free or open source software for general use available on the Internet. We investigated the availability of this system and discuss its advantages and disadvantages in comparison with proprietary systems developed by third-party vendors.

## METHODS

A new system was introduced in 2003 at Hamamatsu Rosai Hospital (HR), which has 21 departments, 400 beds (350 beds at present), and about 500 staff, and is one of the hospitals founded for worker's health by Labor Welfare Corporation under the control of the Ministry of Labor (currently, the Ministry of Health, Labor, and Welfare) of Japan. Table 1 shows the main systems that had already been introduced at HR prior to this study. Hospital staff implemented a variety of functions to support hospital work or improve the work environment in the new system. These were designed such that they would not require changes to the hospital workflow, could be used by hospital staff at any time and place, and be useful as part of the existing assisting hospital information systems. As employees were not required to use this new system, the new system was not promoted to the staff at HR aggressively because this system was experimental, but performed personal instruction for individual staff who expressed an interest in using the system after December 2003 when almost

Table 1. Existing systems at HR

Introduction	Department	System	Network
1996	All departments	Nursing support	Collaboration with the order entry system after 2000
1996	Ophthalmology	Ophthalmologic support	Embedded in order entry system after 2000
2000	All departments	Order entry	For ordering medications, examinations, and reservations
2001	Neurosurgery	Radiographic information	Between the department of Neurosurgery and the rooms of radiographic examination
2002	All departments	Order entry	For ordering operations, radiography, and injections
2002	All departments	Clinical pathway management	Embedded in order entry system network

The LAN connected to the Internet does not connect with the systems shown in Table 1.

all contents of the new system had been prepared. As one of the staff at HR had nicknamed the new system "HAMAX" in the first stage of introduction, it has been called "HAMAX" at HR and this name is used in this report.

About 100,000 patient information records including patient name, address, date of birth etc. were exported from an order entry system and imported into HAMAX prior to implementation. After its implementation, additional patient information has been input into HAMAX by users or staff in charge of the Division of Collaboration between the Hospital and Other Institutions as required. Other institutional information was not prepared when HAMAX was implemented, but has been input gradually by either individual users or staff in charge after implementation of the system. User information was registered by volunteer staff when HAMAX was implemented and additional information has since been input by staff in charge in the Division of General Affairs.

#### Hardware and software

Among the networks at HR shown in Fig. 1, the LAN connected to the Internet was utilized for HAMAX. This LAN connected almost all divisions, such as the outpatient division, inpatient divisions, doctors' rooms, rooms for various uses, *etc.* However, due to budget limitations for LAN construction, a 54g wireless network was used to connect the first floor with floors 2 to 6 as well as some parts of the first floor, although a 100BASE-

T/10BASE-T Ethernet cable network was used throughout the majority of the first floor. Therefore, the connection speed was not uniform throughout the network. Each client terminal had a fixed IP address and was connected to a modem via a router equipped with a standard firewall. The client terminals were comprised of employees' personal computers (PCs) and seventeen PCs provided by HR to allow employees to connect to the Internet. All PCs were running Microsoft Windows 2000 or Windows XP (Microsoft, Redmond, WA). Two servers were embedded within the LAN – a gateway server running Windows Server 2003 where a software VPN was installed to permit both network administrators and the vendor responsible for the former server to connect to the LAN *via* the Internet; and a server for HAMAX running the free open source operating system RedHat Linux 8.0 (Red Hat Inc., Raleigh, NC), which was included on the appendix CD of a book<sup>10</sup>. PostgreSQL 7.2.2 was used as the database software. The specification of the HAMAX server is shown in Table 2.

Various HAMAX contents were made by modifying open source software developed in PERL and JAVASCRIPT (Table 3) by hospital staff. They have been open to the public on the Internet for the purpose of creating general websites. The start menu of HAMAX after logging in was made by modifying the design of Webmin<sup>11</sup> (Fig. 2), which was also supplied on the appendix CD of a book<sup>10</sup>. Taking the future uses and further development of HAMAX into consideration, free and open software

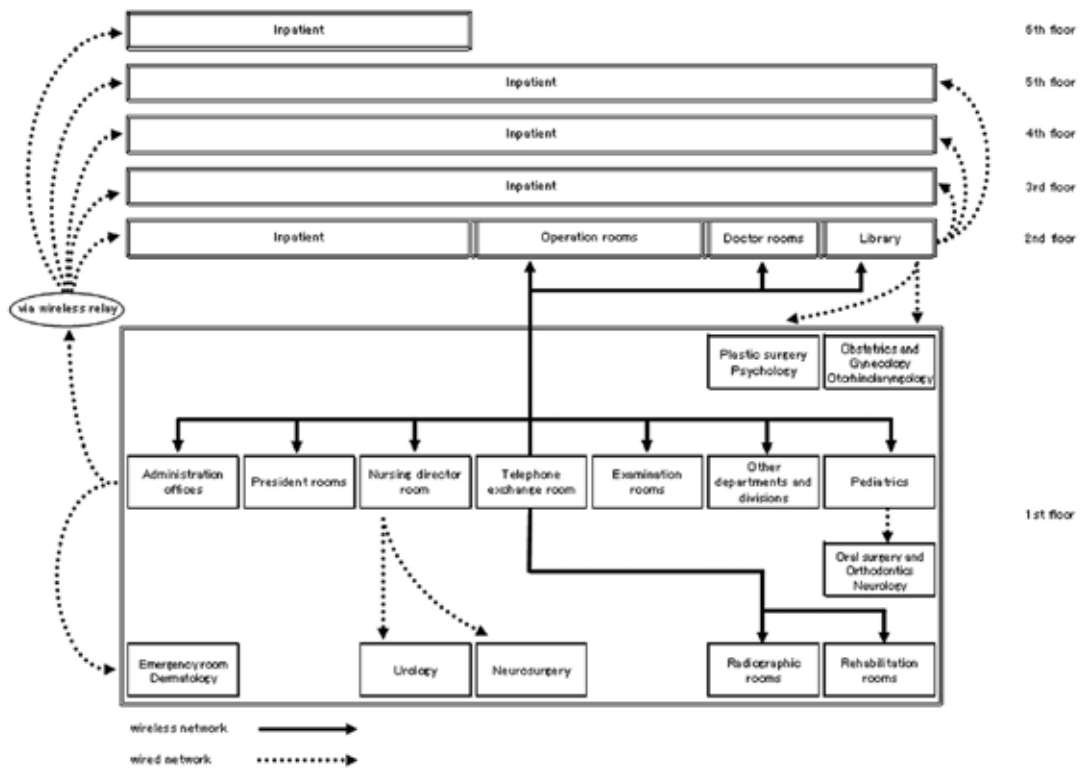


Fig. 1. Network at HR

A 54g wireless network connected the first floor with the second to the sixth floor and also some parts of the first floor. The gateway to the Internet was located in the telephone exchange room.

Table 2. Specifications of HAMAX server

Purposes	Software	Roles
OS	Linux v2.4.18-14	
Mirroring	Software Raid 1	
Boot	GRUB	
Storage for backup	DVD-RAM	
Web Server	Apache v2.0.40	
FTP Server	WU-FTPd v2.6	
DNS Server	BIND v9.2.1	
Database Server	PostgreSQL v7.2.2	
	perl-DBD-Pg v1.13-5	PostgreSQL interface for PERL 5
File Server	Samba v2.25	Common files between Windows and Linux
Standard Modules for Linux	Sendmail v8.12.5	
	config v10/Berkeley	
Free CGI Modules	Perl v5.8.0	
	Python v2.2.1-17	Generation of PDF format files with figures
	wvWare v2-0.0.8	Extraction of text from Word files
	ReportLab v1.1	Generation of PDF format files with figures
OS management	Webmin v1.130	

Almost all modules shown in Table 2 were included in RedHat Linux 8.0.

Table 3. Free or open source software used in the development of HAMAX

Functions	Free or Open source software and Free figures
Login menu	Webmin v1.130 <sup>11)</sup> , Control of PostgreSQL with programs <sup>14)</sup> , Certification in Apache with PostgreSQL <sup>17)</sup>
Manuals for medications	WWWBBS v3.0 <sup>23)</sup> , Control of PostgreSQL with programs <sup>14)</sup> , ICD10 and ICD9-CM <sup>20)</sup> , JAPIC <sup>15)</sup>
Reports of MRSA patients	Simple BBS Type2 v2.02 <sup>23)</sup> , ReportLab v1.1 <sup>12)</sup> , Output of FDF from HTML <sup>15)</sup> , Controlling PostgreSQL with programs <sup>14)</sup>
Reports of tuberculosis patients	Simple BBS Type2 v2.02 <sup>23)</sup> , ReportLab v1.1 <sup>12)</sup> , Output of FDF from HTML <sup>15)</sup> , Controlling PostgreSQL with programs <sup>14)</sup>
Records of messages in the Division of nursing	Web Forum v4.2 <sup>15)</sup> , Mini BBS Excellent v1.30 <sup>23)</sup>
Letters regarding patient information	Simple BBS Type2 v2.02 <sup>23)</sup> , ReportLab <sup>12)</sup> , Output of FDF from HTML <sup>15)</sup> , Dynamic PDF <sup>16)</sup> , Control of PostgreSQL with programs <sup>14)</sup>
Summary during hospitalization	Simple BBS Type2 v2.02 <sup>23)</sup> , ReportLab v1.1 <sup>12)</sup> , Output of FDF from HTML <sup>15)</sup> , Dynamic PDF <sup>16)</sup> , Control of PostgreSQL with programs <sup>14)</sup>
Ordering of medical references	Simple BBS Type2 v2.02 <sup>23)</sup> , Control of PostgreSQL with programs <sup>14)</sup>
E-mail within hospital collaborating with PHS	Simple BBS Type2 v2.02 <sup>23)</sup> , Mini BBS Excellent v1.30 <sup>23)</sup> , pop3.pl v0.3.6 <sup>21)</sup>
Conferences at hospitals	Mini BBS Excellent v1.30 <sup>23)</sup> , WebAN v3.3, Controlling PostgreSQL with programs <sup>14)</sup> , wwWare v2-0.0.8 <sup>22)</sup>
Hospital schedule	WebDiary v1.06 <sup>23)</sup> , Password Editor v1.1 <sup>23)</sup>
Reservation of equipment	YoYacker v1.01 <sup>23)</sup> , Password Editor v1.1 <sup>23)</sup>
Records of committee minutes	Mini BBS Type2 v2.02 <sup>23)</sup> , Output of FDF from HTML <sup>15)</sup>
Bulletin boards	Simple BBS type2 v2.02 <sup>23)</sup> , Web Forum v4.2 <sup>23)</sup> , Mini BBS Excellent v1.30 <sup>23)</sup> , FreeBBS 2000i v1.02 <sup>23)</sup>
Intranet for divisions	Mini BBS Excellent v1.30 <sup>23)</sup>
Others	Simple BBS Type2 v2.02 <sup>23)</sup>
Management tools	Light Board v6.2 <sup>15)</sup>
Figures	G-TOOL <sup>24)</sup> , Arata family collection of material for WWW <sup>25)</sup>

With the exception of JAPIC<sup>15)</sup>, which was provided for free on a CD by a medical enterprise, all free or open source software used in the development of HAMAX was downloaded from the Internet.



Fig. 2. Start menu of HAMAX

There are several buttons in the upper part that represent detailed contents, such as E-mail limited within HR, support of doctor's work, support of nurse's work, notification from HR, *etc.*

Note: As the figure is a screenshot from the actual production system, the text in the figure is in Japanese.

available on the Internet was utilized that can be modified and re-distributed. Although this LAN was not connected with the network for the order entry system, HAMAX was not made accessible to the public on the Internet because it contained various types of confidential information, including patient data. To print or display data to be input at a client terminal in the default PDF format, character data were transformed from FDF format files on the server with input form data and figure data were transformed to PDF files directly using both ReportLab<sup>12)</sup> and a free *PYTHON* module<sup>13)</sup> on the server. The default PDF files were prepared with Adobe Acrobat 5.0 (Adobe, San Jose, CA). This technological knowledge was acquired from the Internet<sup>14-16)</sup>. The FDF and/or PDF files were printed after display at client terminals.

#### *Login menu*

To enter HAMAX using a standard web browser, users must not only input their ID and password for certification in Apache with PostgreSQL<sup>17)</sup>, but the MAC address of the client terminal must also be registered in HAMAX. This registration can be done automatically through the management menu. The information acquired from the certification is also utilized for input to other contents. As shown in Fig. 2, there are several buttons in the upper part of the start menu of the system that present functions, such as E-mail limited within HR, support of doctor's work, support of nurse's work, notification from HR, etc.

#### *Support of medical work*

##### 1 Manuals for medications

To display the manual for any given medication, the user inputs up to 4 characters of the name of the medication, and then selects the appropriate entry from a displayed list. Free manuals for medications in PDF format provided by PAPIC have been registered in the system<sup>18)</sup>. As these manuals have

been updated twice per year at HR, a function for updating the HAMAX database was added to the system.

##### 2 Reports of MRSA or tuberculosis patients

As this function was essential to record the information of both patients and reporters, there was little need to customize a free bulletin board except a function to send these data to the database. When a report was input, E-mail limited within HR was sent to the head of the committee for preventing infection. Printing a report in PDF format was possible at client terminals after display in PDF format.

##### 3 Record of messages in the division of nursing

As nurses alternated among three teams in a division, they passed messages to the next team using written notes. This function was implemented as an electronic message board in the Division of Nursing as a trial.

#### *Support of supportive functions*

##### 1 Communications regarding patient information to be forwarded to other institutions

The information of doctors needing to send a letter regarding patient information to other institutions is acquired from the login information. The information of both the patient and institution to which the letter is to be sent is input via the keyboard or from the database. *JAVASCRIPT* was used to input a prototype letter with either a fixed form or a form made by the users. Data are input (Fig. 3) and saved in CSV format in a folder for each user on the server. FDF format files for textual data and PDF format files for figure data generated on the server are printed automatically at the the Division of Collaboration between the Hospital and Other Institutions using free and open software "AutoPrn202" that monitors common folders on the server for files with specified extensions for

The screenshot shows a web browser window with the title '診療情報提供書' (Medical Information Provision Form). The address bar shows 'http://hama.nishu.ac.jp/~tender/letter/index.asp'. The page content includes a login field, a message about patient data, and a table for entering form details. The table has the following data:

作成日	2003-10-25
紹介施設	[Redacted]
紹介先生	[Redacted]
紹介診療科	内小
所属科	循環器科
医師名	[Redacted]
患者番号	[Redacted]
病棟外来	6階西
患者氏名	[Redacted]
患者生年月日	[Redacted]
患者性別	男
患者住所	[Redacted]

Fig. 3. Input menu for letters regarding patient information

The doctor can input many items.

Note: As the figure is a screenshot from the actual production system, the text in the figure is in Japanese. Private information has been redacted.

printing<sup>19)</sup>. This free and open software is no longer maintained and the website was closed in February 2007. Users can also print the FDF and/or PDF files manually after displaying at client terminals (Fig. 4). Common folders on the server available from both Linux and Windows were set using Samba shares. All CSV format files were moved to the specified folder on the server at midnight once a day, while all data included in these files were input into the database automatically. This method was adopted to allow users to correct or delete letters they had written during the day. It was possible to have junior staff input data at the the Division of Collaboration between the Hospital and Other Institutions.

## 2 Summary during hospitalization

The information of both doctor and patient were acquired using the same method as described above for the letters for communication of patient information to other institutions. There were many items to record in summaries during hospitalization and doctors or medical record and information

managers had to input two types of item. First, after the doctor inputs information regarding the required medical procedure or treatment (Fig. 5), the data are saved in CSV format, and an FDF format file for textual data generated on the server is printed automatically at the Division of Medical Records and Information Management to notify medical record and information managers of the generation of a new summary. It is also possible to print manually from client terminals. All CSV format files were moved to the specified folder on the server at midnight once a day, while all data included in these files were input into the database automatically. This method was adopted for the same reasons as described above for letters regarding patient information for communication to other institutions. At some departments where it is necessary for these summaries generated by doctors to be approved by their director, E-mail limited within HR is sent to the director to allow notification and electronic approval. Finally, medical record and information managers input residual items electronically (Fig.

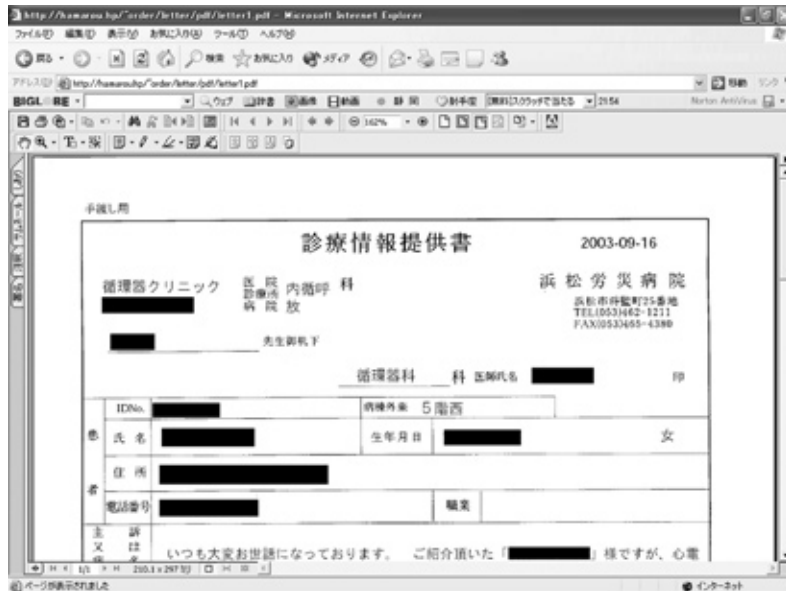


Fig. 4. Letter regarding patient information in PDF format

The PDF file displayed after doctor's input. The data included in the letter were input into the form fields in a default PDF format file. Private information has been redacted.

Note: As the figure is a screenshot from the actual production system, the text in the figure is in Japanese.

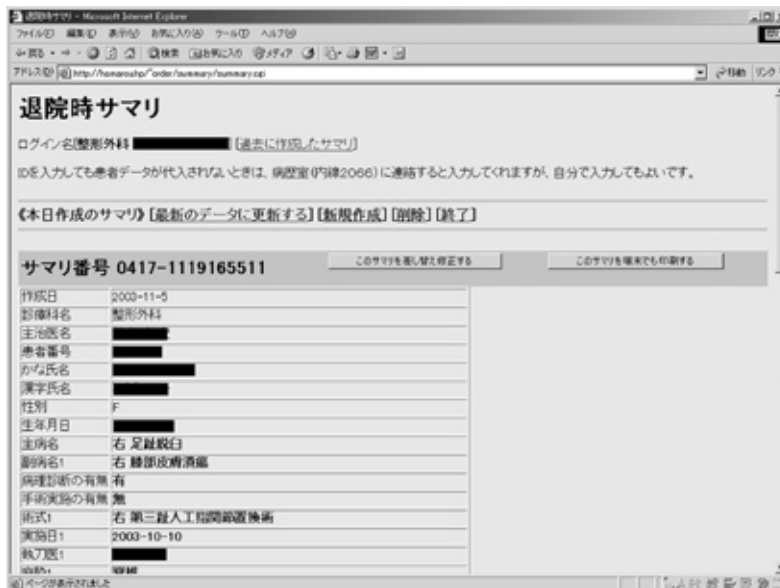


Fig. 5. Input menu of summary during hospitalization by a doctor

The doctor can input many items.

Note: As the figure is a screenshot from the actual production system, the text in the figure is in Japanese. Private information has been redacted.

6) and the completed summaries are printed (Fig. 7). Both ICD10 and ICD9-CM, downloaded from MEDIS-DC<sup>20</sup>, were adopted for coding names of

diseases and medical treatments. It was possible to have junior staff from the Division of Medical Records and Information Management input data.



The screenshot shows a web browser window displaying an input form. The form contains several sections:

- 患者の有無** (Patient presence): Radio buttons for '有' (Present) and '無' (Absent).
- 血液型** (Blood type): Fields for ABO (A, B, O) and Rh (R+, R-).
- ウイルス検査** (Virus tests): Radio buttons for HCV, HIV, WNV, STS, TPHA, MRSA, and 薬剤耐性 (Antibiotic resistance).
- 死亡区分** (Death classification): Radio buttons for '入院後24H以内', '入院後24H以内', '入院後10日以内', and '非選択'.
- 患者情報** (Patient information): Fields for main name, ID, and department, with buttons for '主病名コード検索' and '副病名コード検索'.

Fig. 6. Input menu of summary during hospitalization by the medical record and information manager  
The medical record and information manager can input many items.

Note: As the figure is a screenshot from the actual production system, the text in the figure is in Japanese.

The screenshot shows a PDF document titled '入院診療要約書' (Inpatient Medical Summary) displayed in a web browser. The document contains a detailed medical summary with redacted private information. The summary includes:

- 患者情報** (Patient information): Name, ID, and department.
- 病歴** (Medical history): Chief complaint, past medical history, and social history.
- 検査結果** (Test results): Laboratory and imaging findings.
- 診断** (Diagnosis): Final diagnosis and differential diagnosis.
- 治療** (Treatment): Medications, surgery, and other interventions.
- 経過** (Course): Summary of the patient's progress during hospitalization.

Fig. 7. Summary during hospitalization in PDF format

The PDF file displayed after input by both a doctor and medical record and information manager.

The summary data were input into the form fields in a default PDF format file. Private information has been redacted.

Note: As the figure is a screenshot from the actual production system, the text in the figure is in Japanese.

### 3 Ordering of medical references

There was a system in place at HR whereby staff ordered reference papers from the library

division using one order form for each paper. Staff in charge at the library division manually input the necessary information into a homemade

library system developed with FileMaker Pro and requested reference papers from appropriate institutions. Therefore, a function to allow staff to input bibliography items directly into HAMAX was developed. The library system imported CSV format data exported from HAMAX to a common folder.

#### Support of Information Infrastructure functions

##### 1 E-mail within hospital collaborating with PHS-Mail

This function was developed in *PERL* and *JAVASCRIPT* customizing free and open software, which included a simple POP3 client program<sup>21)</sup>. E-mail limited to within HR was sent using the SMTP protocol, received using the POP3 protocol, with binary attachments encoded using Uuencode. Each user was assigned a HAMAX user ID but this was usually not displayed. E-mail could be accompanied by documents and/or figures in files with extensions such as .txt, .doc, .xls, .pdf, .bmp, .jpg, etc. The titles of E-mails were displayed

differently according to whether they had already been read (Fig. 8), and they could be moved to custom folders made by the users. E-mail could be sent separately for each employee, division, committee, or all employees. When E-mail was sent, PHS text messages from HAMAX could also be sent at the same time, connecting to a PHS-mail server developed with ASP by NTT DoCoMo and NEC Corporation.

##### 2 Conferences at hospitals

Conferences for the whole hospital at HR had been held twice a year, and all preparation for these conferences had been done manually by the staff in charge. Therefore, functions were developed to support the preparation and progress of conferences, such as registration of presentations (Fig. 9), registration of papers, announcement of the conference, production of conference programs, voting to choose the best clinical pathway at the meeting for clinical pathways, which had been held

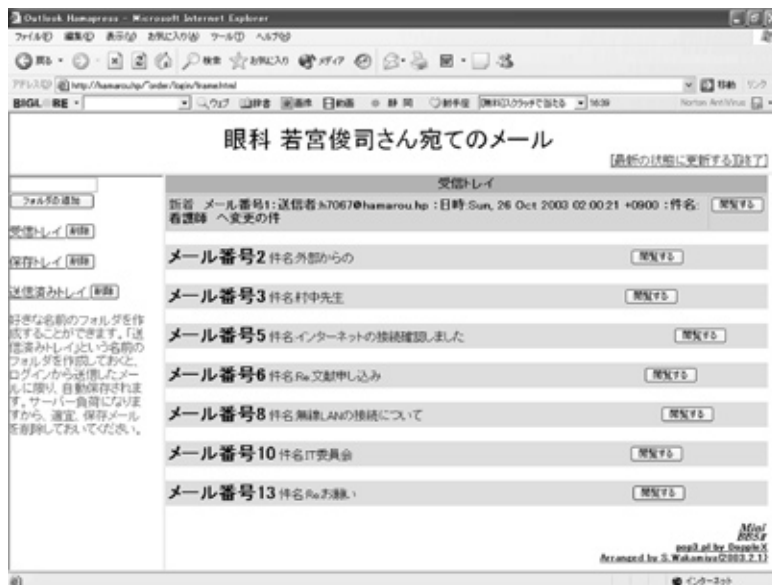


Fig. 8. E-mail within HR collaborating with PHS

The titles of E-mails that have not yet been read are shown in dark grey (really pink), while others are shown in gray. Messages could be saved in customized folders made by the users.

Note: As the figure is a screenshot from the actual production system, the text in the figure is in Japanese.

at the same time as the whole hospital conference, etc. wvWare was utilized to extract text from files in MS-Word format for input into the HAMAX system<sup>22)</sup>.

### 3 Hospital schedule

This function was developed to notify employees of the hospital schedule (Fig. 10) and fulfilled the supplementary role of announcing papers distributed



Fig. 9. Conference held at a hospital

The left column shows menus such as registration of presentations, registration of papers, announcement of the conference, making conference programs, and voting to choose the best clinical pathway. The right column shows the menu for registration of presentations.

Note: As the figure is a screenshot from the actual production system, the text in the figure is in Japanese. Private information has been redacted.

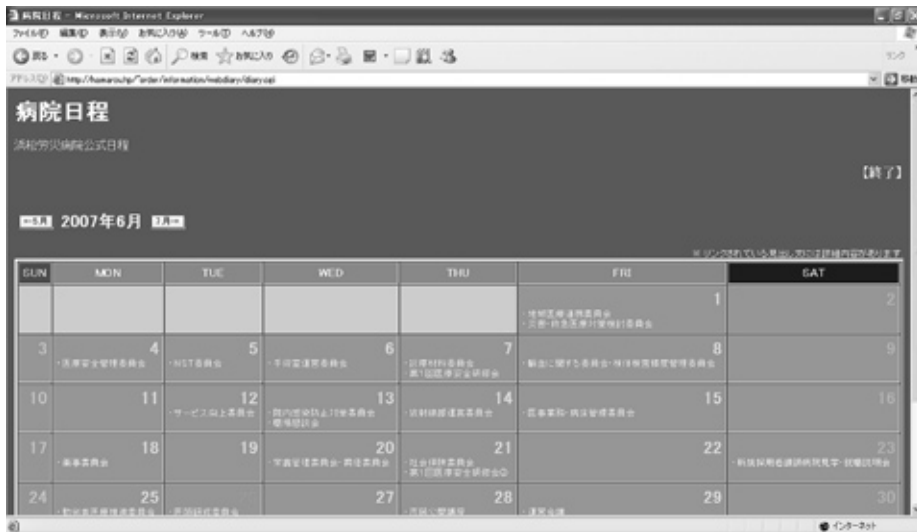


Fig. 10. Hospital schedule

The daily schedule of HR in June 2007 is shown.

Note: As the figure is a screenshot from the actual production system, the text in the figure is in Japanese.

once a month by the hospital. Regular schedules were input automatically using a one-click system and the menu for editing them was the same as the edit menu for the reservation of equipment function.

#### 4 Reservation of equipment

This function was developed to allow employees to reserve meeting rooms and/or large tools, such as projectors. Regular reservation was input automatically.

#### 5 Records of committee minutes

The rules at HR stipulated that the minutes of committee meetings were to be saved as paper-based documents. However, as these were not available to employees, electronic minutes were developed to provide free access to the records of committee meetings in PDF format to all employees. Only members of the committee could add, update, or delete records in each minute book.

#### 6 Bulletin boards

Bulletin boards, such as those for committees, divisions, or all employees, were prepared in the system trial. Although they were initially considered as places where users would exchange their opinions, their purpose was left to the users to decide.

#### 7 Intranet for divisions

Websites for each division available only within HR were prepared in the system trial, and these sites on the intranet could only be updated by members of the respective division. Although they were initially considered as places where members of each division would notify all employees of their activities, their purpose was left to the users to decide.

#### 8 Others

Medical or hospital information, such as standard

values of general blood examinations, clinical pathway manuals, HR rules, etc., could be viewed with this function whenever necessary. As no software for viewing this information was installed at client terminals except Acrobat Reader 5.0 and Notepad included with the operating system, all data were saved in PDF or TEXT format.

## RESULTS

### *System*

On its introduction in May 2003, HAMAX was still lacking a number of components. However, almost all of the components were functional by December 2003, and the server has been running continuously since then without problems (three years and six months at the time of writing). It was necessary to add or update the names of committees in March 2007 because HR underwent a hospital evaluation by the Japan Council for Quality Health Care in April 2007. This required customization of the HAMAX system, and a minor update was made to allow remote control through VPN. The cost of introduction of HAMAX was about 400,000 yen, consisting of the cost of one license for Acrobat 5.0 and a personal computer for use as a server. The total number of client terminals registered in the system was 43, consisting of 17 client terminals belonging to HR and 26 belonging to employees. The actual total number of accesses was unknown as the HAMAX access logs before 6 March 2006 were deleted by the system administrators at HR, but the total number of accesses recorded on the server during the subsequent 15 months was 4615.

### *Medical work*

The total numbers of records registered in HAMAX by 11 June 2007 were as follows: patients, 118,947; institutions, 1,677; employees, 426.

#### 1 Manuals for medications

The total number of medications registered in

HAMAX is 1,597. The system has been updated regularly by the staff in charges of the Division of Pharmacy, and users have been referring to the information regarding medications in the system.

## 2 Reports of MRSA or tuberculosis patients

Reports of MRSA or tuberculosis patients have not been updated since the initial trial, indicating that this feature has not been used at HR.

## 3 Records of messages in the Division of nursing

Records of messages in the Division of nursing have not been updated since the initial trial, indicating that this feature has not been used at HR.

### *Supportive functions*

#### 1 Letters regarding patient information

The total number of letters regarding patient information prepared using this function and sent to other institutions was 632 on 11 June 2007, and the total number of doctors using this function was 19. The total number of letters for outpatients was 195, and all others were for inpatients. Ten of the 21 departments at HR made use of this function.

#### 2 Summary during hospitalization

The total number of summaries during hospitalization that were produced using this function was 630 as of 11 June 2007, and the total number of doctors who used this function was 13. The total number of summaries approved by the directors was 356, and the others were not approved. Five of the 21 departments at HR made use of this function.

#### 3 Ordering of medical references

The total number of reference papers that had been ordered with this function was 864 as of 11 June 2007. Doctors, nurses, nutritionists, pharmacists, physical examination technologists, secretaries, and administration staff have utilized this function

widely. Fifty-six employees from 18 divisions and 11 departments have used this function.

### *Information Infrastructure functions*

#### 1 E-mail within hospital collaborating *via* PHS

Although both the actual total number of E-mails and the actual total number of employees who used this function were unknown, the number of mail files left on the server was 1018. The names of folders where the server saved mail files for each user have been updated.

#### 2 Conferences at hospitals

This function has been used in all conferences at HR held twice a year. The menus for conference announcement, registration of presentations, and voting for clinical pathway meetings have been used, but the menu for registration of papers has not been used.

#### 3 Hospital schedule

The schedule of HR has been updated. This function has been used as one of the methods by which HR notifies employees of the hospital schedule.

#### 4 Reservation of equipment

This function has not been updated since it was used as a trial, and therefore this content has not been used.

#### 5 Records of committee minutes

This function has not been updated since it was used as a trial, and therefore this content has not been used.

#### 6 Bulletin boards

This function has been little utilized, although seven posts had been registered between July 2003 and November 2006. These posts included one that stated: "If this function were used more, it would be

easier to exchange staff opinions and improve the work environment at the hospital."

#### 7 Intranet for divisions

Eighteen of the 34 divisions that could manage their websites registered the introduction of each division's activity on initial implementation of the system. However, this content has not been updated since.

#### 8 Others

Seven committees of forty divisions have presented guidelines or management rules using this system.

## DISCUSSION

### *Work environment*

Although the number of users was small, HAMAX was introduced experimentally at HR and was utilized by only those who expressed an interest in the new system. If HAMAX had been introduced as a system that forced staff to change their work habits, the number of users would have been much greater. However, this study still obtained clear results; the useful functions of the system have been used, while those that were not useful have not.

Judging from the number of patients, institutions, employees, and level of user access registered in HAMAX, this system has been updated and is still in use at HR. The evaluation of the developed contents is listed in Table 4.

#### 1 Direct Care functions

As an order entry system, radiographic information system, and nurse support system had already been implemented at HR, little need to be added available contents to functions for support of medical works. Although the order entry system included a function for viewing information related to medications, this function could not be utilized at HR because of cost. Therefore, the function included in HAMAX for viewing the manuals for medications has been used.

The function for reporting information regarding MRSA or tuberculosis patients has not been used at HR. This may have been because staff had only to submit a single paper-based report to staff in charge when patients with MRSA infection or tuberculosis were found prior to the introduction of HAMAX, and thus they may have felt that electronic-based reporting provided no real benefit over paper-based reports with regard to workload.

In addition, the function included in HAMAX for

Table 4. Evaluation of contents

Contents	Evaluation
Manuals for medications	available
Reports of MRSA patients	not used
Reports of tuberculosis patients	not used
Records of messages in the Division of nursing	not used
Letters regarding patient information	available
Summary of admission	available
Ordering of medical references	available
E-mail within hospital collaborating with PHS-Mail	available
Conferences at hospitals	available
Hospital schedule	available
Reservation of equipment	not used
Records of committee minutes	not used
Bulletin boards	not used
Intranet for divisions	not used

Contents that have been used or updated are described as "useful," while those that have not been used or updated are described as "not used."

recording of messages in the Division of nursing has not been used at HR. This may have been because the network connection above the second floor was wireless, and was both unstable and slow, which meant that the nurses did not rely on this function. Another possible explanation is that few of the nurses were accustomed to computer input using a keyboard and mouse.

However, these functions – reporting information regarding MRSA and tuberculosis patients, and recording messages in the Division of nursing – will be necessary following the introduction of electronic medical records and with hospital progression toward becoming a paperless environment. At HR, these functions are currently unnecessary because there is no plan at this institution for computerization of all hospital work.

## 2 Supportive functions

The total number of doctors using the functions for producing letters regarding patient information for communication to other institutions or for making summaries during hospitalization was small, but those users made many letters or summaries with HAMAX. Half of the departments at HR utilized the function for sending letters regarding patient information to other institutions regardless of whether patients were out- or inpatients. Although only a quarter of all departments utilized the function for making summaries during hospitalization, large numbers of summaries were made using this function during the test period. The function requiring approval of summaries by directors worked well. Therefore, these two functions were useful for doctors who wished for the computerization of hospital work. Systems for ordering reference papers electronically have been used in many institutions, and many employees, regardless of occupational category and division, also used this function of HAMAX at HR.

## 3 Information Infrastructure functions

E-mail limited within HR functions as a medium with which employees can exchange information within the hospital. Information is usually transferred in either direction between a hospital and its employees by a variety of means, such as paper-based mail, E-mail, PHS-Mail, oral communication, telephone limited to use within the hospital, PHS, announcements from speakers, *etc.*, which are generally not urgent in the reverse order. Such modes of communication have their own features, and employees usually choose one or more according to the purpose. Paper-based communication is a formal medium at a hospital. Even if other media are used, hospitals always notify employees of formal information in writing. Such paper-based communication is usually slow but reliable. E-mail and PHS-Mail leave electronic records but the information will not reach the intended recipient if they do not check their mail. It is not known when – or indeed if – the recipient will check their E-mail, but transmission of information by E-mail is still useful if time is not a critical factor. Oral communication, telephone, and PHS can send information to the recipient directly, but cannot do so if they are not connected to a receiver. Making announcements over speakers is a one-way method of communication. Within a hospital where most employees are specialists in various divisions and where their daily workloads are high, notification of medical work should be performed with direct media such as telephone, PHS, or oral communication, but notification of Information Infrastructure functions can be done *via* indirect media, such as E-mail, PHS-Mail, or bulletin boards, which can be accessed at the recipient's convenience. As E-mails is usually used on personal computers and PHS-Mail is used only in PHS systems, they are not available to all employees. However, the employees who send information are mainly doctors, nurses, and administration staff, and they usually have access

to personal computers and/or PHS at the hospital. Thus, employees may have used E-mail limited only within a hospital in collaboration with PHS-mail. Many annual conferences held by academic associations are processed using websites. However, as such computerization requires significant financial investment, conferences held at hospitals are usually processed manually. However, as the introduction of such systems would be convenient at hospitals, a conference support function to HAMAX was added and this function has been used at all conferences held at HR since the introduction of this system more than 3 and a half years ago. Hospital schedules were distributed to all employees on a monthly basis in the form of printouts of schedule tables. However, employees do not always keep the printouts, and so the schedule function in HAMAX should be used in conjunction with printouts.

The function for reservation of equipment has not been used at HR. One reason for this is that it was easy to reserve equipment by contacting the staff in charge at the division of general affairs directly because HR is a relatively small hospital. Another reason is that the staff in charge could not exchange reservation notes for this function because of apprehension about electronic record retention even though the system was reliable. Comprehension of electronic record retention policies will also change at HR with the progression of computerization in medical fields. At HR, records of the minutes of committee meetings were not always kept, and there had been no united format of records prior to the introduction of HAMAX. Even if records were kept, they were written in a free format. However, this function in HAMAX was not accepted by the staff in charge as it not only kept records electronically but also required use of a unified format for the whole hospital. However, as it is desirable to have a unified format for meeting minutes throughout the whole hospital, it is hoped that this function will be adopted in future.

It was expected that bulletin boards would become one method for employees to understand each other. However, they were not used at HR. As hospitals are relatively small institutions, it is possible for individual employees to be identified even if they have left their opinions on bulletin boards anonymously. However, the few posts left on the bulletin boards included a suggestion for the greater use of bulletin boards at the hospital. It was expected that intranet sites for each division would be useful for the staff of each division to notify other employees regarding their activities. However, these sites were not updated regularly at HR. This may have been because the staff who were initially interested in this function and who had input contents came to doubt the effectiveness of this function. Paper-based communication is a simple method of information dissemination because recipients can read papers naturally, while transmission *via* electronic media such as websites and E-mail requires active participation on the part of the recipient to visit the websites or check their E-mail. Employees often read articles published in internal magazines regarding the activities in various divisions within the hospital, indicating the prevalence of a culture in which paper-based communications are accepted but electronic media are not. The guidelines or the management rules have probably been used in conjunction with printouts because employees can access them at any time and place.

#### *System*

The number of client terminals registered in the HAMAX system at HR was small, which may have been because HR provided little common client terminals to employees to access the Internet. In fact, almost all of 26 employees registered personal client terminals to HAMAX. These were all doctors and active users. If HR had aggressively proposed using HAMAX to employees, the number of



users might have increased and the results might be different concerning the availability of contents of HAMAX which are shown in Table IV. We feel that the results show HAMAX were available though HAMAX was experimental.

Almost all contents of HAMAX could be developed with various types of free bulletin board, which collect information from users for dissemination to other users. Thus, many types of hospital work were affected by use of these functions in bulletin boards with no relation to work type, such as Direct Care functions, Supportive functions, or Information Infrastructure functions. It is notable that all of the components and knowledge for development of this system, such as software for automatic printing<sup>19)</sup>, a module for generating PDF format files<sup>12-16)</sup>, and a sample POP client program<sup>21)</sup>, *etc.*, were acquired freely from the Internet, and could be customized easily and utilized them for hospital use.

Hospitals generally have many types of work that such hospital information systems do not address. If a hospital has sufficient financial means to invest in computerization, it may be advisable to utilize systems introduced by third-party vendors. However, there may be few hospitals that can customize software, such as groupware applications, by third-party vendors, for computerization of Information Infrastructure functions in Japan. As a method for collecting and showing information at hospitals, it will be useful for these hospitals to utilize free and open software, which can be easily customized to correspond to the hospital's individual requirements. In the present study, the development of HAMAX required the purchase of only one license – that for Adobe Acrobat 5.0. As free and open software in common use is generally reliable and comprehensible, it is useful also at hospitals and can be customized relatively easily. It would be difficult to develop such systems from the very beginning for hospital staff, who are not

an engineer, but customization of existing software reduces the difficulty of development. As an example of specialized software for medical use, the Japan Medical Association provides an open source computerized receipt system that runs on Linux<sup>26)</sup>. A number of open source software packages for medical use are available, such as DICOM viewer<sup>27)</sup>, Osirix<sup>28)</sup>, OpenEMR<sup>29)</sup>, or OpenDolphin<sup>30)</sup>, and there are also commercial vendors that provide products developed using open source software to lower development costs<sup>31)</sup>. It is also possible to utilize free or open source software for general use available on the Internet to lower the costs associated with the introduction of computerized support systems for use in general hospitals.

## CONCLUSIONS

With the exception of Adobe Acrobat, the present system was developed using free or open source software available on the Internet. Therefore, this system can be introduced once an intranet server has been prepared. Development of the present system requires only ordinary techniques to make websites. The introduction of systems such as that described here will not be difficult if hospital staff have had experience in making websites with CGI. The development of systems for hospital use with free or open source software does not require significant financial investment. Although the present system was introduced experimentally at HR, this concept of using free or open source software for general use is a useful method for developing customized systems to support hospital work or improve the work environment at hospitals lacking appropriate existing hospital information systems.

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