to the server when in the actual process of downloading from and uploading data to the server.

System configuration and implementation

System configuration of the outside server

System configuration of the outside server with data flow and functions are illustrated in Figure 2. Dynamic web pages for the patient's side are based on HTML (Hyper Text Markup Language)/PHP[23] on a FreeBSD4 (Operating System) with an Apache HTTP Server.[24] PHP is a widely-used general-purpose server-side scripting language that is especially suited for web development with databases and can be embedded into HTML. The database for recording data from patients temporarily is realized using MySQL,[25] which is a relational database system that is suited for web-based applications. "PHP/MyAdmin" is also available to manipulate databases directly from outside as needed. The reasons that the system on the doctor's PC is also developed with PHP/MySQL are mentioned in the following section.

System configuration of the PC at the doctor's side

System configuration of the PC at the doctor's side with data flow and functions are illustrated in Figure 2. The doctor's side-system is also constructed with HTML/PHP and a PEAR module[26] (PHP Extension and Application Repository) with an Apache HTTP Server on Microsoft Windows XP and MySQL for the database. The main reason for using these tools is that they can be freely downloaded from the Internet and are very easy to install into a PC. It is especially useful because PHP runs on almost any operating system including Windows, Macintosh, and UNIX. Therefore, it is suitable for heterogeneous network systems due to its cross-platform operability. Moreover, PHP is easy to learn to program web applications, and it continues to offer many advanced features and improve its stability for the future. MySQL is also designed to run properly and quickly by providing PHP on the Apache Server and available for the structured query language (SQL) which is the most common database language as the de facto standard of today. Narrative data on the database in the outside server are downloaded over SSL using "FFFTP" which is also common file transfer protocol (FTP) software available free of charge on the Internet.[27]

The patient's-side requirements

Patients need to have a PC and/or a cellular phone with a web browser function, a media player on the Internet

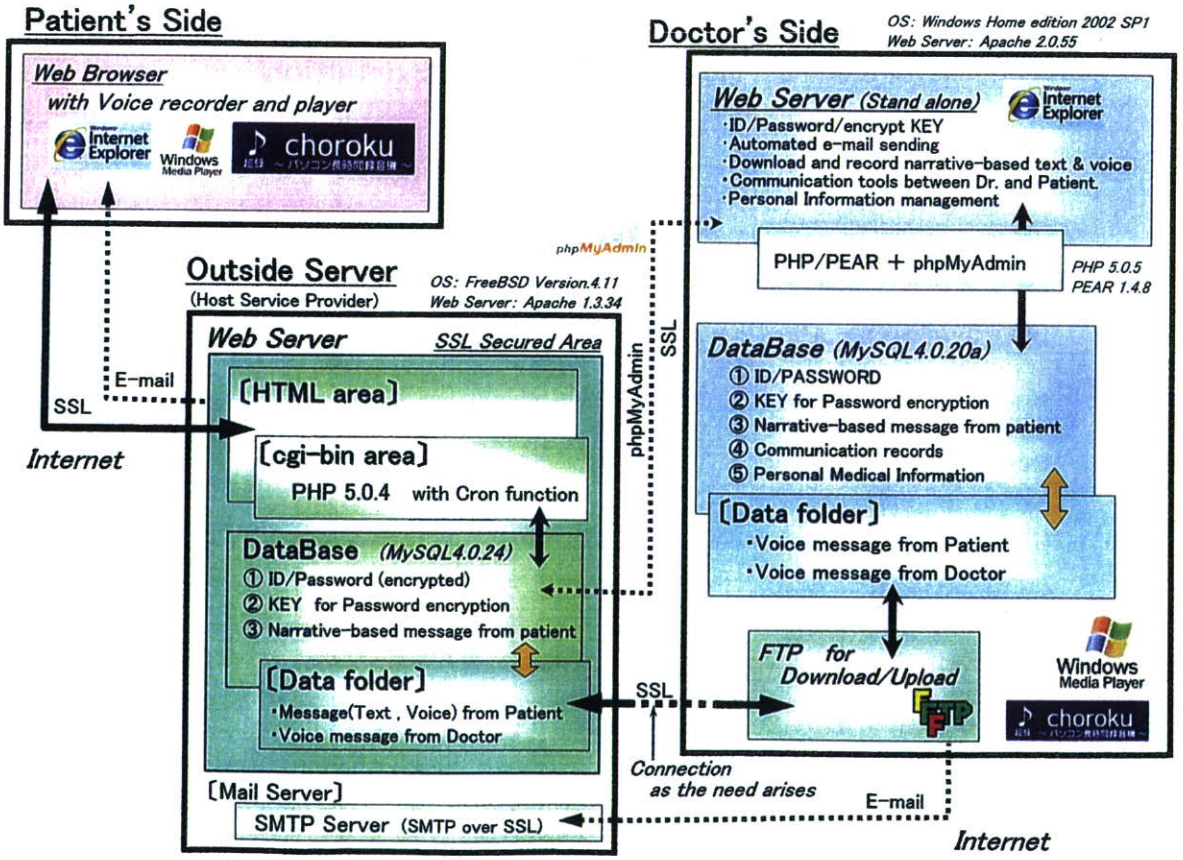
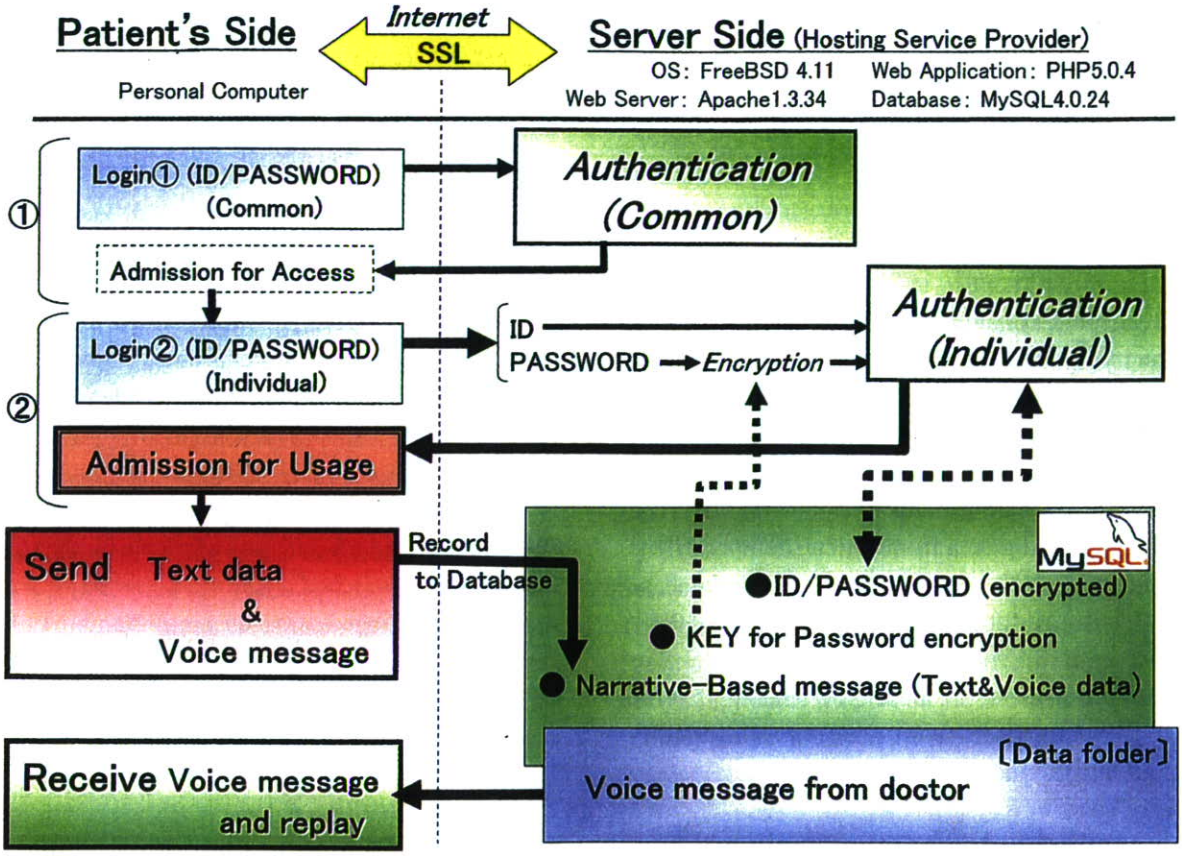
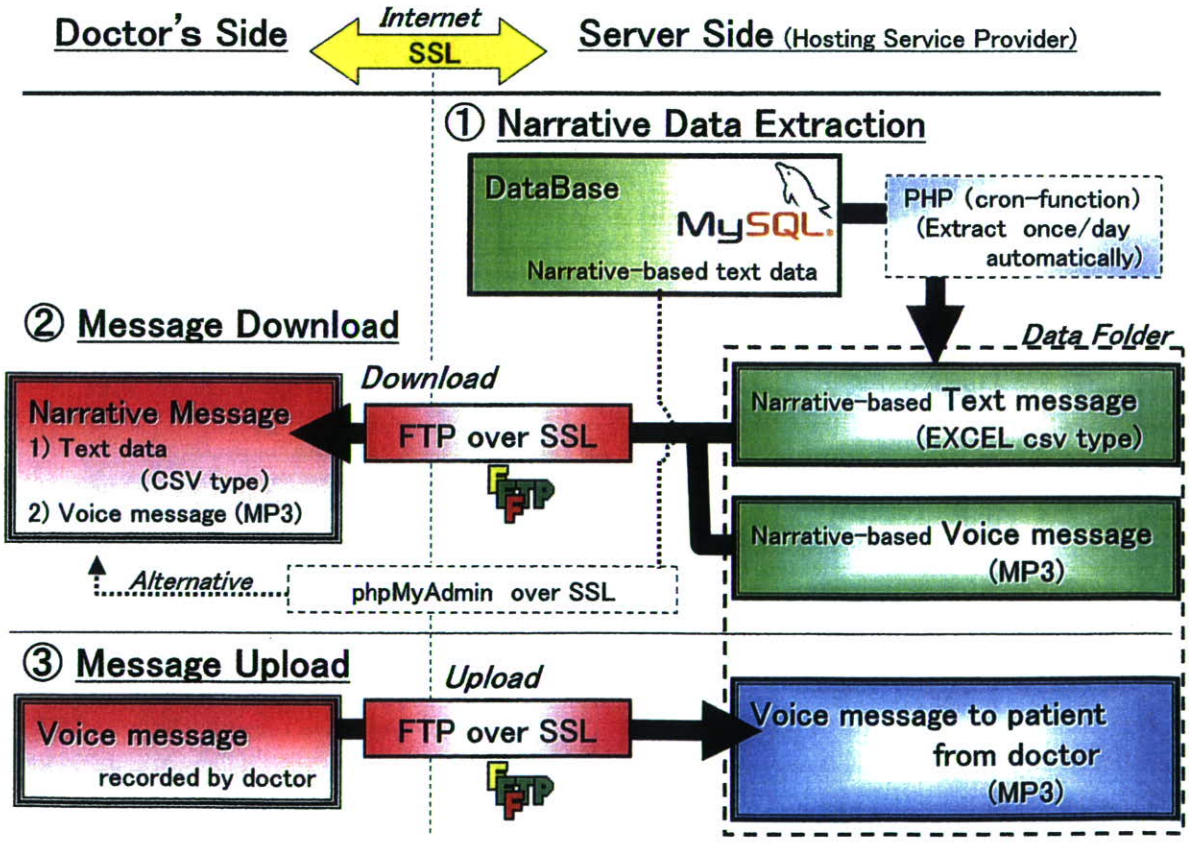


Figure 2. System configuration with data flow and functions of each element

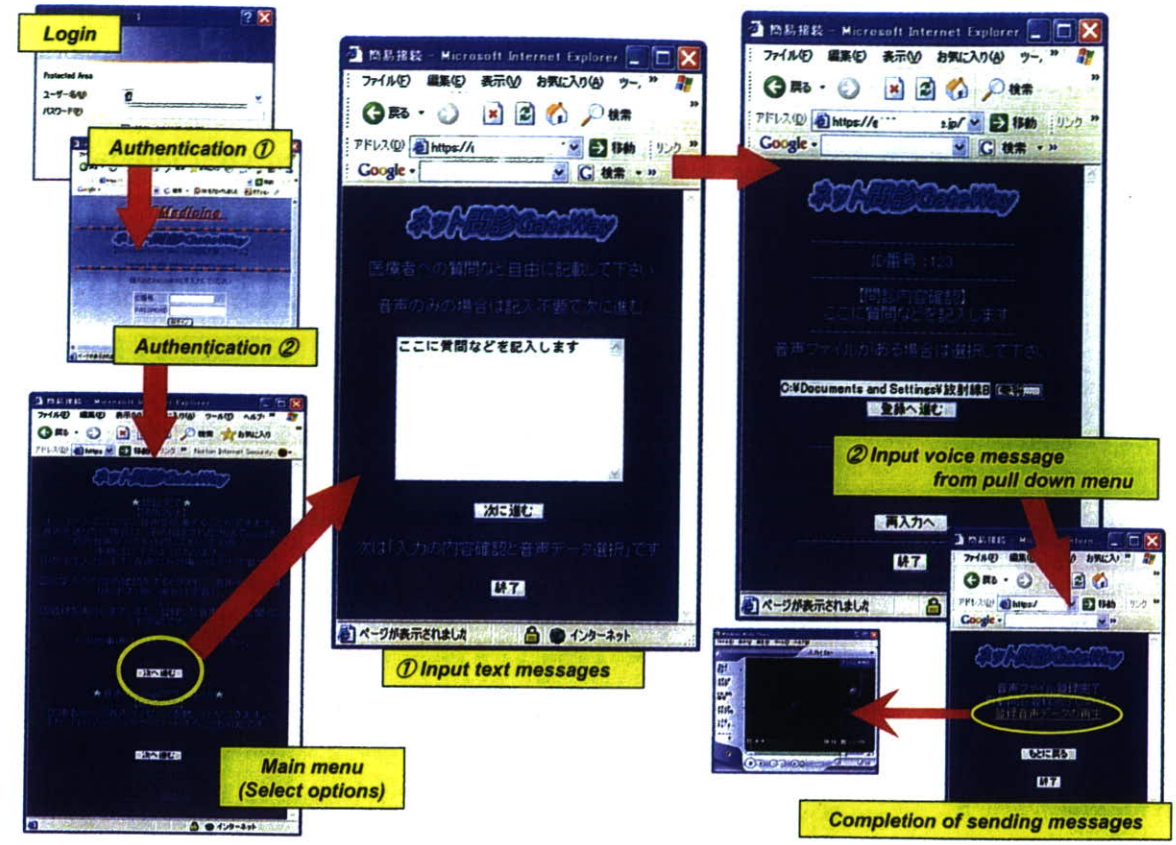


(a) For the patient's side

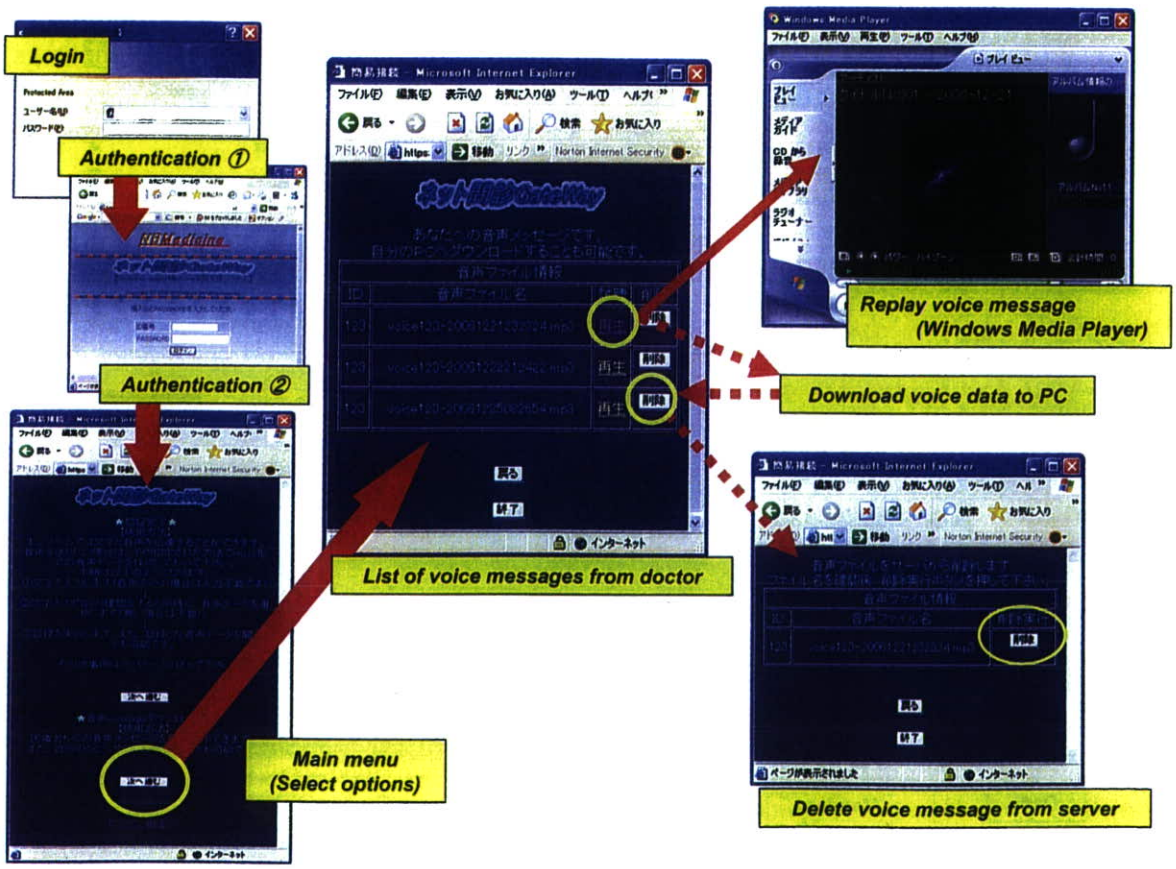


(b) For the doctor's side

Figure 3. Flowchart of operations

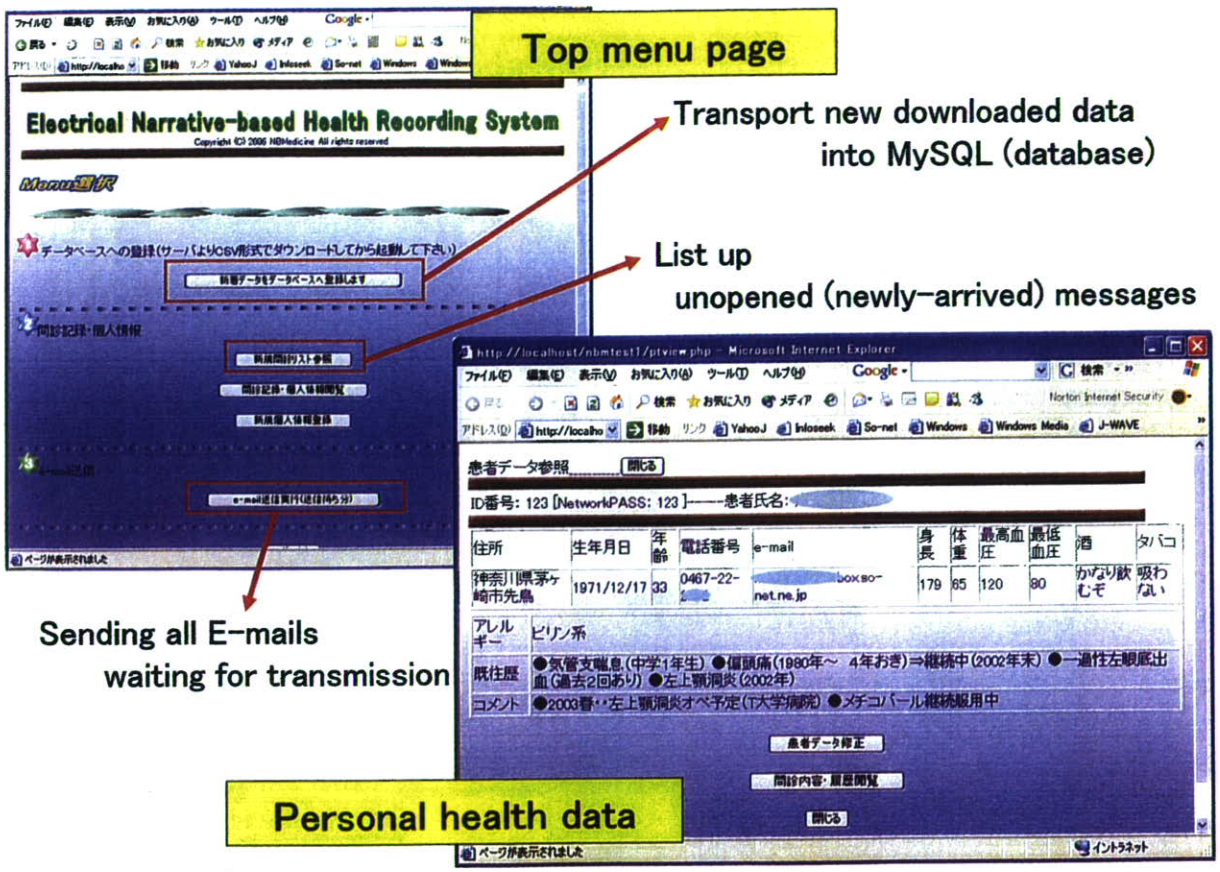


(a) Sending a narrative message

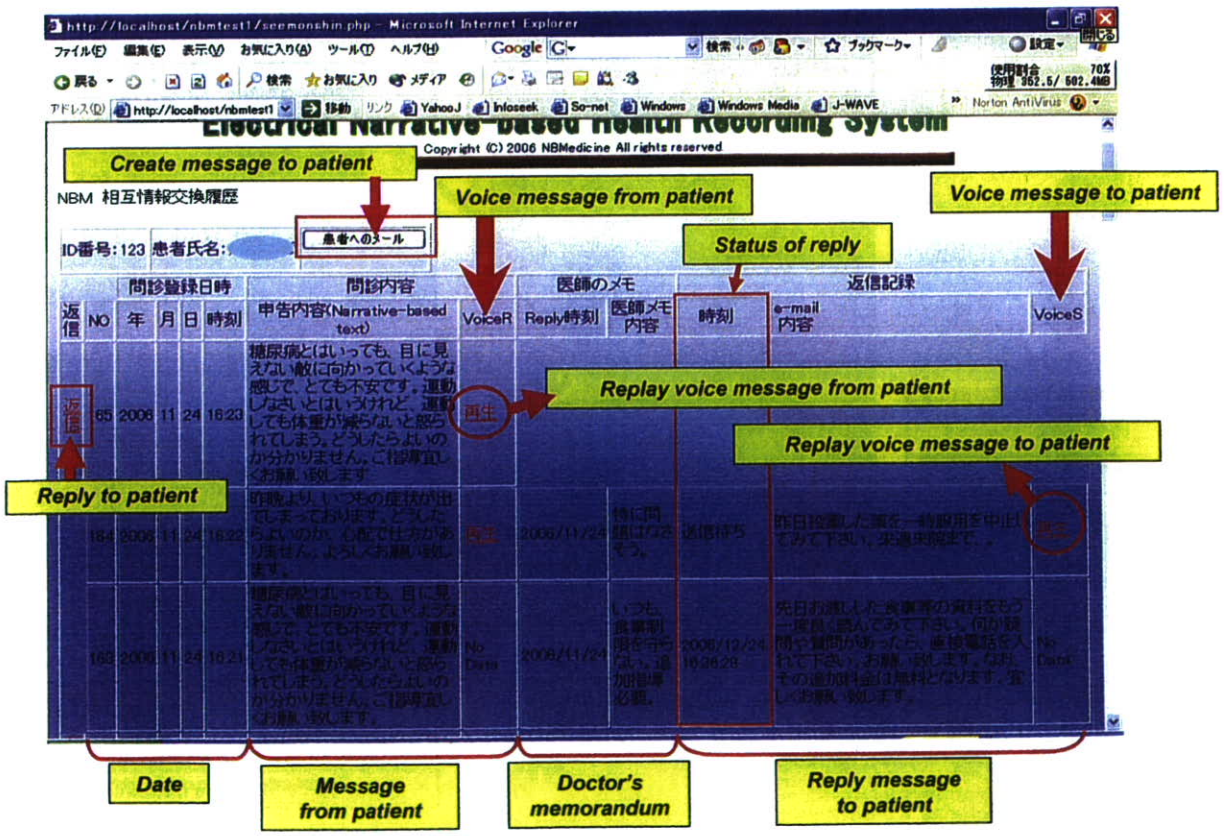


(b) Receiving and deleting a message from the doctor

Figure 4. Operational screens for the patient



(a) Top menu and personal data



(b) Sorted lists of communications history

Figure 5. Operational screens for the doctor

connection environment, and a mailer on their PCs or cellular phones to receive e-mail. Patients need a voice recorder that can convert voice messages into electronic MP3 data, which can be freely obtained from the Internet and installed in their PC beforehand[28] (Figure 2).

Security and confidentiality

There are many potential problems in the network using the Internet, because anybody could connect their PC to the server and modify data stored in the database if there were no measures taken to assure security. In order to ensure the confidentiality of the server, several security features are included in the system. Individual ID/passwords are required to be input after the authentication with common ID/passwords on the top page during each login session. Thus, two steps of authentication are necessary to login to the system. This individual password is to be encrypted by a DES (data encryption standard) algorithm before stored into the database and inverse operation is not possible. Therefore, it would be almost impossible to decipher any of the passwords even if someone could somehow access the data. All of the patients' personal and private data are only stored in the PC at the doctor's side, which is used as a "stand-alone" PC and intended to be connected to the server only when actually in the process of downloading from and uploading data to the server. Furthermore, the outside server supports 128 bits SSL with the RC4 (Rivest's Cipher 4) algorithm, the best version for the latest web browser.

Functional overview

The system's functions and the operation process are explained with some examples of the operation screens as follows.

The patient's-side system and web server

The flowchart of how the system operates from the patient's side is shown in Figure 3a, and screen shots of the operation for the patient are shown in Figure 4a, b. First, the patient has to enter two sets of ID/passwords as authentication to access admission for usage. All stored individual passwords in the database are encrypted by the "Encryption key." Therefore, no real password data are in the server and authentication is performed between encrypted passwords. After this authentication, patients can send their own narrative messages and/or electronic voice data (MP3), which has been recorded in advance, directly into the database in the outside server over SSL. Patients can also replay their own voice messages just by pointing and clicking a button on the screen after sending a set of data. On the other hand, patients can receive e-mail messages from their doctor through simple mail transfer protocol (SMTP) server over SSL and also replay and/or download any of the previously sent voice messages on the web browser. The patient is to delete these voice data from the server to help ensure security. Except for voice messaging, all of the functions mentioned above are also available to the patient from a cell phone.

The doctor's-side system and web server

The flowchart of data download and upload is shown in Figure 3b. Stored narrative-based text data are scheduled to be extracted from the EXCEL CSV-type by PHP-script-file automatic batch processing at a preset time (the "cron function"). The doctor will temporarily access the server to download the sets of narrative-based texts and voice data to the doctor's-side PC by FTP over SSL. Each set of voice data is linked to the correlated text data by the particular file name, which is generated and assigned automatically. The doctor can also download the data by PHP/MyAdmin over SSL as an alternative option. Voice messages as replies from the doctor's side are to be uploaded to the server for 2-way narrative communications between the doctor's side and the patient's side.

The PC at the doctor's side

Some screen shots of operations for the doctor are shown in Figure 5a, b. In terms of security enhancement, the PC is basically used as a "stand-alone" terminal. The top menu page is displayed after proper authentication has been made. There are function keys on the top menu. All narrative-based data downloaded from the server can be stored in the MySQL database just by clicking a button. Moreover, there are other buttons to select a patient, register a new patient, and send e-mails, individually and/or collectively, among other functions.

After selecting a patient, the doctor can look over the lists of the patient's personal health data and, if necessary, make corrections. Another page gives sorted lists of communications history data to date in the left portion of the page, and yet another page can be selected for only unopened messages for which replies have not yet been created or linked to a separate page to be emailed later at the appropriate time. Voice data can be replayed merely by clicking a button. Doctors can record their own memoranda, instructions, and messages for each individual patient. This new system enables doctors to use voice messaging as well as text data for replies.

Although voice data need to be uploaded by FTP on the present system, all text replies for all patients will be automatically transmitted as e-mails and collectively by just clicking a button on the top menu through SMTP over SSL. After sending the reply, the time of transmission is naturally automatically recorded on this page.

Methods

At the initial trial of this experimental pilot study, a prototype of a doctor's PC was connected to a 12 Mbps ADSL Internet line, and another computer on the next desk was assumed to be a PC at the patient's side. The web server of the described system was implemented in the shared area by an outside server. Assuming IDs and Passwords for 3 patients, some narrative texts and voice data were randomly sent to the database after each authentication. Two days later, all the data were downloaded on the PC at the doctor's side and stored in a MySQL database. After checking the list of narrative data and reading them, replies were created for each patient, and emailed to them at that time. After all the replies were processed, they were verified to have been sent correctly.

In the next step, 3 pepole (ages 77, 72, 45) were selected to use this system for 2 weeks as patients who are unfamiliar with how to operate a computer. First, they were carefully and thoroughly taught how to use the system in full detail. After several communications with us, personal interviews were carried out to evaluate the functions of the system. In this pilot study, we focused on the evaluation of operability and functions because it was difficult to apply this kind of novel system to actual patients in an actual and most likely undesirable medical environment based on the current health insurance system in Japan as previously mentioned.

Results

All the system's functions worked properly in this trial. To check security, we tried to login to the web site with various incorrect ID/Passwords. As a result, the system proved to be secure and reliable against unauthorized access. All encrypted passwords in the database were checked and confirmed to be impossible to be deciphered in every case. The results of the initial trials with the 3 pepole revealed that they were all interested in this system, mainly because it is easy to transmit their own conditions, ideas, and concerns to the medical staff at any time and receive a reply. One of them could use e-mail on the PC, but the other two could only use their cell phones as e-mail receivers. However, no major functional problems were observed during the various stages of the entire trial operation in terms of communications. The 3 people acting as patients especially felt that voice messages were easy to use compared with e-mail text messaging. One of them expressed a strong desire to actually use the system in her own medical care for her chronic hypertension, if the medical system would allow it. Overall, the patients felt comfortable using the system.

Despite these advantages, some problems were also pointed out. It was difficult for one of the patients to use the voice recording system because it is not like a web browser, which seems to suggest that there is room for improvement in the functions. Another potential problem was that two of the patients requested real-time conversation capability on the Internet, i.e., they sometimes wanted replies from their doctors immediately, or at least as soon as possible. Since the concept of this system is an asynchronous operation, this request is presently unfeasible.

Discussion

This study presents a new, low-cost, asynchronous medical communication system that could be used now, with little added work and a high level of security. An actual clinical field test has not yet been conducted, and therefore, remains warranted in order to arrive at a more conclusive assessment. However, the results of this experimental pilot study along with those of various previous reports suggest that, in the near future, this type of system could possibly be an essential communication tool between patients and doctors, and patients and medical staffs. We now raise three main discussion points as follows.

The system's importance in terms of NBM and its functions

Patients' trust in their healthcare providers may affect their satisfaction and health outcomes, and the time of the medical examination was also positively associated with that trust between the patient and the medical provider.[29] However, these days, patients and doctors tend to minimize the time they spend for face-to-face interviews because, in most cases, a small medical staff has to take care of a large number of patients making it difficult to provide adequate or proper care to each patient. Therefore, more effective medical examinations should be performed in the consultation rooms. Under

such time constraints, physicians' perspectives may exclude crucial patient-oriented data due to one-sided medical examinations.[15] A report has demonstrated that physicians left patient-centered information unexplored 72% of the examination time.[30] In light of this fact, the results of trial operations suggest that it would offer patients opportunities to summarize information about their physical conditions and concerns in advance, including delicate matters that are difficult to discuss, and also communicate their own ideas and beliefs about their illnesses through 2-way narrative messages. This system allows physicians to send messages, as voice data, directly to patients at home, anytime they feel there is such a need, even on a continuous basis. A mutual exchange of voice messages would be necessary for that and effective to develop the illness narratives based on each patient's own individual perspective. This means that this system could allow effective information sharing and mutual understanding in the practice of NBM, even if the length of time of the medical examination itself is brief. Therefore, these functional operations would actually extend and virtually save valuable time for medical examinations. Moreover, it is also expected to increase the mutual trust and to encourage patients' initiative toward their therapies by offering medical examinations based on the data recorded in their own words. At the same time, with this system, progress reports from patients can easily be included.

Therefore, not only does it serve as a communications tool for therapeutic processes at home but it also greatly helps family physicians and/or medical practitioners to offer continuous guidance by reviewing the lists of medical histories including the final results in each case. Based on these points, family clinicians consider this system to be effective for home medical care as a supporting tool to facilitate the practice of NBM in the current medical environment. Our proposition is also one of the ideas regarding the methods of electronic narrative records raised by the proposers of NBM.[13]

Voice data is available on this system for people with a low level of IT literacy such as the elderly or physically and/or mentally challenged patients. This new option would be useful to select the method of communication based on the patient's characteristics because originally NBM is medical care that focuses on the patients' own words (the narratives) spoken at medical examinations. However, according to the results of this pilot study, although patients could replay voice messages from their doctor on the web browser, they need to learn and become accustomed to using the voice recorder, or the system should be improved making it simpler so that patients could use it more easily. Patients not familiar with IT, could at least then learn to operate and become comfortable using the web browser screen on their computers and/or cell phones. The next system should be modified, by combining these functions, making an easier GUI (Graphical User Interface) on the web browser.

Although a lot of reports are focused on the telemedicine interfacing between hospitals and clinics, no work to date has focused on the medical communications system using a hosting service provider between the patient and the clinic via the Internet. Recording patients' physical conditions and medical examination results on the EMR system using IT has actually been studied.[31-34] However, the system proposed in the present study is one in which patients and physicians can mutually exchange narrative information directly via an outside server as free text and/or electronic voice messaging using the Internet.

Advantages of system construction

This new system has been completely developed by free software tools for web applications except for the costs of the outside server. Apache for the web server, PHP/PEAR for the web application, MySQL for the database, FTP for downloading and uploading data, voice recorder and popular web browser are all free software that can legally be downloaded and installed via the Internet. The hosting service provider does not only provide the web server but also a great variety of functions for its management. It should be noted that the workload for the server settings and maintenance are not required in this system. Outsourcing server maintenance also eliminates the responsibility for security management, and doctors can use their own PCs as stand-alone terminals, resulting in ensuring a high level of security and confidentiality easily and inexpensively. Since this system would be easy to implement, its introduction would greatly contribute to the promotion of medical informatization in clinics.

Security and confidentiality of patients' personal information

Assuming the actual clinical test for the future, all data exchanged via the Internet are protected by SSL to prevent any leakage of information. Recently, communications on the Internet over SSL is a popular way to protect data from hackers. SSL enables encryption of all messages exchanged between a server and client's PC and prevention of wiretapping, falsifications, spoofing attack, among others. Therefore, SSL is used in cases of

exchanging confidential information concerned with personal privacy.

Actually, however, it is virtually impossible to construct a web system that is completely safe from hackers today. Considering security enhancement, this new system is, therefore, designed to minimize the risk of compromising the system and information leakage. There are only individual IDs and encrypted passwords as personal information in the database of the outside server. Most personal information is stored in the PC at the doctor's side and used mostly as a stand-alone workstation. Therefore, the doctor accesses the Internet as briefly as possible to use the server. All personal data will be linked with the personal information at the doctor's side. Therefore, information leakage is unlikely to occur because personal information is only stored in the PC at the doctor's side.

Future development and evaluation

The telemedicine system utilizing the Internet will most likely become widely used in the near future. As described above, this newly developed system, emphasizing patients' "narratives," could support medical examinations with NBM, a crucial concept for future medical care with the home doctor system, trials for which seem to indicate the potentiality of easy system introduction. This latest system still has room for improvement in its functions and operability. Based on these points, we are planning to develop yet another improved system with better human interface functions and security enhancement and to evaluate further clinical functionality in an actual medical environment to confirm the validity and efficacy of this concept. However, the health insurance system needs to be fundamentally reformed, including medical informatization, in order to utilize this kind of system in clinics.

Conclusions

In the present study, considering the importance of patient's direct participation in EMRs, which is focused on NBM, we have proposed an electronic medical communication system using the Internet. NBM is an indispensable concept of clinical medical care and the practice of EBM. This system reduces the need for the simultaneity of medical examinations (face-to-face medical examinations) as much as possible and supports the effective sharing of mutual beliefs and perspectives on the patient's illness as well as providing any medical information between the doctor and the patient via text and voice messages. Our proposal is also one of the ideas regarding the methods of recording patients' narratives that was raised by the proposers of NBM. Though the products of the EMR system have been extensively developed in the market, the rate of its use in clinics remains low. However, we believe that this proposed system, which would support NBM with less construction and maintenance workload, would function as an indispensable tool for family clinicians along with the spread of patient-centered primary care.

Acknowledgment

This research was partially supported by a Grant-in-Aid for Scientific Research (A), No. 15209022, 2003-2005 from the Ministry of Education, Culture, Sports, Science and Technology.

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LL-IN5260-H (Tuesday • 12:15 PM)

A Problem Centric Organization and Spatial-temporal Representation of Patient Records

V. Bashyam, Los Angeles, CA • D. Bennett • L. Boyadzhyan, MD • L. D'Avolio • W. Hsu • G. Rees • et al (vbashyam@ucla.edu)

PURPOSE/AIM OF THE EXHIBIT: (1) Learn how NLP can be used to extract clinically relevant concepts (e.g., problems, findings, anatomy) from patient documents. (2) Demonstrate how findings are associated with spatial and temporal descriptions and how this information is visualized using a 3D model and timeline to enable quick navigation to source documents.

CONCLUSION/SUMMARY: This exhibit demonstrates how clinical documents, including radiology reports, can be easily navigated using a problem-centric organization and descriptors extracted from a patient record using natural language processing (NLP). An implementation in the domain of neuron-oncology is demonstrated. The system introduces a new paradigm for viewing targeted summarizations for a patient case and for efficient navigation to documents of most relevance to the current clinical question(s).

LL-IN5261-D (Monday • 12:15 PM)

Radquery: An Inexpensive Approach to Searches in Radiology Report Databases

B. Desjardins, MD, PhD, Ann Arbor, MI • C. Hamilton (benoitd@umich.edu)

PURPOSE/AIM OF THE EXHIBIT: We present a method to perform full text searches of radiology reports for the large number of departments which do not have this ability as part of their radiology or hospital information system, using a Microsoft Access front-end and a server back-end containing a full copy of the radiology report database.

CONCLUSION/SUMMARY: We have presented a simple approach that is easy to implement in most radiology departments, to search the database of radiology reports for teaching, research and administrative purposes. This exhibit specifically targets departments that do not have such tools. Important considerations in the design of this system are: 1) IRB and HIPAA issues are of primordial consideration. 2) the system is easy and inexpensive to develop, modify and maintain, 3) the approach works very well.

LL-IN5262-B (Sunday • 12:30 PM)

Implementation of Collaborative Healthcare in Grid-based Cross-Enterprise Images Sharing with IHE XDS-I Integration Profile

(FDA)

J. Zhang, PhD, Shanghai, China • J. Sun, PhD • Y. Yang, MS • J. Jin • T. Ling, MS • K. Zhang, BS (jzhang@mail.sitp.ac.cn)

PURPOSE/AIM OF THE EXHIBIT: A number of hospitals in Shanghai, China are piloting an EHR solution. In this presentation, we will demonstrate the implementation of collaborative healthcare between multiple hospitals in a grid-based image sharing system fully aligned with the IHE XDS-I integration profile.

CONCLUSION/SUMMARY: A solution has been installed in four hospitals in Shanghai and tested for collaborative operation on shared image data. The results are extremely positive and demonstrate that the collaborative features implemented in a grid-based sharing system can scale effectively to serve for regional collaborative healthcare.

LL-IN5263-D (Monday • 12:15 PM)

Impact of Single Sign-on and Synchronized Patient Selection by IHE-ITI EUA (Enterprise User Authentication) and PSA (Patient Synchronized Applications) at Implementing Existing PACS and CPOE/EMR

Y. Ando, MD, Chiba, Japan • M. Mukai • T. Tanikawa • T. Nakashima • H. Sonoda★ • Y. Hayashi★ • et al (ando_y@nirs.go.jp)

PURPOSE/AIM OF THE EXHIBIT: To understand the concept of Coordination on Sign-On/Patient Selection and its merits and demerits To experience the effectiveness of the single-sign-on and synchronized patient selection by using the IHE-ITI EUA and PSA function To realize how to login and change the patient in the EUA/PSA environment

CONCLUSION/SUMMARY: In Japan, physicians have to operate multiple applications (PACS/EMR) in one clinical unit. We defined the context area of the context manager defined by the HL7 CCOW. We developed the libraries to enable the EUA and PSA functions. We modified six existing information systems to use the EUA/PSA libraries. These modifications require the considerable effort, but otherwise we achieved good seamless operation. The EUA/PSA function is indispensable for multiple information systems.

LL-IN5264-B (Sunday • 12:30 PM)

Patient Centric Authorization for Cross Enterprise Healthcare Information Exchange in HealthGrids

(FDA)

S.G. Erberich, PhD, Agoura Hills, CA • J.C. Silverstein, MD • A. Chervenak, MD • C. Kesselman, MD (stephan@isi.edu)

PURPOSE/AIM OF THE EXHIBIT: 1. To introduce standards based Patient Centric Authorization (PCA) model based on X.509 certificates and SAML assertions. PCA allows secure and HIPAA compliant cross enterprise healthcare information exchange, storage, and management. 2. To present hands-on Enterprise PACS image workflow in PCA enabled HealthGrids

CONCLUSION/SUMMARY: 1. How standards based open-source Grid technology can be used to solve securing PHI for image exchange, storage, and management. 2. How PACS can be extended to a Grid PACS for clinical of research applications. 3. Use of distributed data storage replication to provide fault tolerance and disaster recovery from the Grid.

LL-IN5265-H (Tuesday • 12:15 PM)

A Novel Security Model for Data Hiding in Medical Image Using High-Capacity Digital Watermark and Steganography Technique

K. Miwa, RT, Kanagawa, Japan • T. Umeda, PhD • N. Fukuchi • S. Yamamoto, PhD • A. Okawa, MBBS • H. Tachibana, PhD (kenta5710@gmail.com)

PURPOSE/AIM OF THE EXHIBIT: To hide patient information and its medical images are transmitted on telemedicine environment, this exhibit provides a novel security model in medical image using high-capacity digital watermark and steganography technique.

CONCLUSION/SUMMARY: We have proposed an integration security system with digital watermark and steganography technique. This technique was suitable for the different type images format, MR, CT, CR and so on. Also the new store capacity for hiding of these technique are unnecessary, while keeping a high fidelity of stego-image (embedded medical images) by objective image-quality evaluation (more than 40 dB of PSNR). Security model is useful for transmission and store of medical information and images.

LL-IN5266-B (Sunday • 12:30 PM)

A New Software Platform for a Combined Analysis of Coronary Arteries and Left Ventricular Cardiac Function from CT and MRI

C. Kuehnel, MS, Bremen, Germany • A. Hennemuth, MS • T. Boskamp, PhD • H. Peitgen, PhD (kuehnel@mevis.de)

PURPOSE/AIM OF THE EXHIBIT: We present prototypical software for diagnosis support and therapy planning of coronary heart disease. It allows combining advantages of different imaging modalities by integrating results from cardiac CT vessel and function as well as MR perfusion and late enhancement analysis. Morphological and functional information are directly associated.

CONCLUSION/SUMMARY: Experience novel interaction and visualization methods for combined result exploration in cardiac images. Become familiar with the combination of different findings from cardiac CT and MRI analysis for dedicated diagnosis and targeted therapy planning. Learn about limits of the AHA-conform 17-segment model and the variation of supply areas. Become familiar with an advanced software assistant for the combined analysis of coronary arteries, myocardial function and perfusion from MR and CT images.

LL-IN5267-D (Monday • 12:15 PM)

Software Tools for Pharmacokinetic Modeling in the Analysis of DCE-MRI Data

H.O.A. Laue, PhD, Bremen, Germany • S. Behrens • H. Peitgen, PhD

PURPOSE/AIM OF THE EXHIBIT: DCE-MRI data offer new possibilities for diagnosis in oncology: Insight into the underlying physiology like the vascularization of a tumor becomes feasible. We present tools for the evaluation of dynamic MR data on the basis of pharmacokinetic modeling, comprising solutions for important calibration topics as T1 relaxation and plasma concentration.

CONCLUSION/SUMMARY: Experience model based analysis in oncology on the example of prostate and brain tumors. Learn about the determination of permeability and interstitial volume with T1 weighted images and the calibration of models with measurements of tissue relaxation and plasma concentration. Gain experience on evaluation techniques for T2* measurement for blood flow and volume.

★ - Financial disclosures are listed in the Disclosures section.

電子透かし技術を用いた医用画像の秘匿性確保・著作権保護システムの構築

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Development of Data Hiding and Copyright Protection system on Medical Images Transmission and Storage Using Digital Watermarking and Steganography

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With digitization of medical information, a problem to infringe privacy and right of an organization occurred. As a result, Medical image security technology including a code is important as measures to this problem when medical images and their pertinent patient information are transmitted. We have proposed an integration security system with Digital watermarking and steganography. Nothing the differences between MR, CT, and CR , it can be seen that the proposed model is suitable for different image types. It shows a high data hiding capacity, while keeping a high fidelity of stego-image (embedded medical image) by subjective vision evaluation and objective image-quality evaluation (more than 40 dB of PSNR). Security model is useful for transmission and storage of medical image.

Keywords: Security , Watermarking, Steganography, Information Hiding, PSNR

1. はじめに

近年、医用情報の飛躍的なIT化により地域医療連携が推進され、患者を他施設へ紹介する際、患者の診断用医用画像をCD-Rに記録して配布する施設[1]や、他施設へネットワークを通じて医用画像を伝送する場合など、個人情報を含んだ医用画像が院外に持ち出される機会が増えている。そこで、個人情報保護の観点から医用画像に対する高い水準のセキュリティが要求されている。医療施設でもセキュリティ対策として公共回線であるインターネットを用い、データを暗号化し、あたかも専門回線のように使用できるVPN(専門私設路)の利用や認証局による認証などネットワークを用いた医用画像の伝送時のセキュリティ対策は確立されつつある。しかし、それらのシステムの構築・運用の際、大規模な設備と専門・高度な管理が必要となる。医用画像の伝送システムは初期費用を少なくしながら、簡便性とセキュリティを確保することが不可欠とされている。

そこで、デジタルデータの中に電子的に付帯情報を埋込み、高い機密性、完全性、可用性を確保可能とする電子透かし技術が医用画像伝送システムに利用できる[2～4]。電子透かし技術の安全性の立証や医用画像に対する適用の有用性は確認され[5,6]、本著者らも電子透かしが医用画像に対して適用可能なことを既報している[2,7]。しかし、より実用性および汎用性の高いシステムとするには、医用画像の伝送時のみならず伝送前後での保管の際にも安全性を確保することが要求される。

本研究では医用画像に対するより高いセキュリティを確保するために、電子透かしと秘密通信の一手法であるSteganography技術とを統合して簡便かつ廉価なセキュリティモデルを構築した。また、モダリティによって画質に影響の度合いが異なる可能性があるため、モダリティ別の画像を使用し、埋込み後画像の画質評価を行った。

2. 方法

本研究では、ビット置換法を用いた電子透かし、Steganography技術を利用して医用画像埋込みを行うプログラムの作成を行い、画質評価を行う。

2.1 統合システム概要

本研究において提案したシステムの概要を図1に示す。

モダリティから発生したDICOM画像をJPEGに圧縮する際、施設名や患者情報などのヘッダー情報を電子透かしとして埋込む。また、その付帯情報を含んだJPEG画像の秘匿性確保のためにsteganography技術を用いてダミー画像にJPEG画像を埋込む。これらの操作を本研究で開発したソフトウェアで一括処理する。

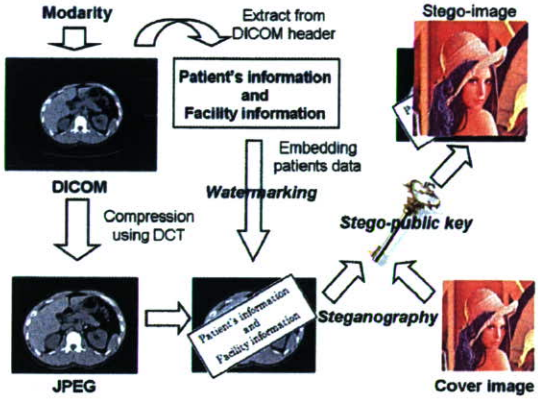


図1 The integration security system

Using DCT converts DICOM to JPEG format, while embedded digital watermarking included text file decoded patient information from the DICOM header. As information to conceal the JPEG image including the digital watermark, it has been embedded into cover image using Steganography.

2.2 埋込み方法

本研究では埋込み法としてビット置換法を用いた(図2)。本処理においては、画素が持つ濃度値に僅かな変化を与えることで情報の埋込みを可能とする。

まず、デジタル画像のRGB成分画像より画素を8画素単位で取り出して、それぞれの濃度値を読み込む。それに平行して、埋込み対象となる情報を順次1バイトづつ取り出していく。次に取得した埋込み対象情報を濃度値の最低位ビット(LSB: Least Significant Bit)に1ビットづつ上書きする。これにより8画素を用いて1バイトのデータを画像内部に書き込むことができる[4,8,9]。この上書きによって、一部の画素において濃度値が変化する事になるが、それは±1の範囲にすぎないので、人の目では色の違いを判別できない。よって、画像に情報が隠されていることを気づかれる恐れが無い。

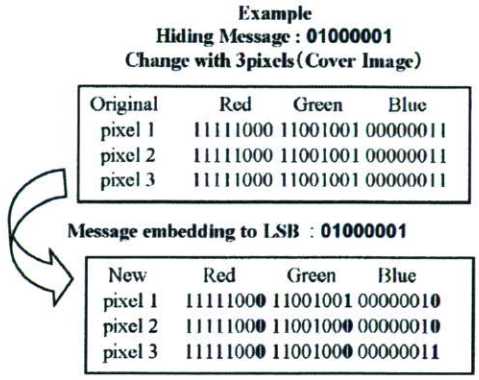
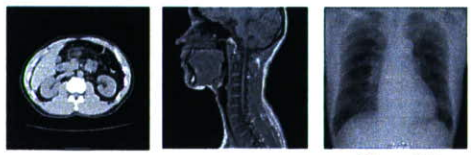


図2 Embedding Algorithm

We either add or subtract one from the value it represents, if we change the LSB bit in a byte.

2.3 対象画像

本研究では、512×512画素の腹部CT画像、256×256画素の頭部MR画像、および1024×1024画素の胸部X線画像の3種類のモダリティについて検討を行った(図3)。また、施設情報を埋込んだ医用画像を埋込むためのダミー画像として512×512画素のSIDBA(Standard Image Data-BAse)標準試験画像Lenaを用いた。



Abdominal CT　Vertebrac MRI　Chest CR

図3 Medical images used in the experiment

2.4 埋込み後の画質評価

埋込み前後の画像の評価としてPSNRを用いた。PSNRは映像品質の客観的な画像評価指数であり、原画と処理後の画像の平均二乗誤差(MSE)で表される(図4)。両画像の相違が大きければこの値は小さくなる。一般的に、PSNR=40dB以上で原画との見分けが難しく、20dB以下になると見るに耐えない画質と言われている[10]。

$$PSNR = 10 \times \log_{10} \frac{255^2}{MSE} dB$$

$$MSE = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left(f(x,y) - f'(x,y) \right)^2$$

図4 The definition of PSNR

3. 結果

本研究により作成したソフトウェアは二つの処理から成り立つ。まず、一つ目はDICOM画像のヘッダー情報から患者情報施設情報を抽出し、JPEGに圧縮する際に、電子透かしとしてその情報を埋込む。その際、圧縮率は75%とした。また、二つ目は電子透かしを含んだJPEG画像をおとり画像に埋込む処理である。

そのソフトウェアを用いる事で埋込み許容容量であればモダリティ画像に関わらず電子透かしとして患者情報埋込み可能であり、その付帯情報を含んだ医用画像をおとり画像に埋込みが可能であった。それぞれの埋込み前後の画像を図5に示す。

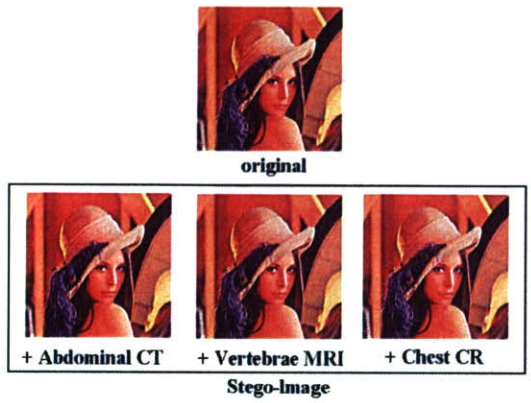


図4 Different embedding in the Stego-image

埋込み前後の画像間に視覚的変化がほとんど無いことが確認できる。埋込み方法として画素の濃度値を僅かに変更することにより埋込みを行っているので、画像容量が変化しないことが確認できた。また、埋込み前後の画像劣化を客観的に示すために行ったPSNRの値を表1に示す。どのモダリティの種類に関わらず、PSNRが40dBを超えていることから画像が劣化せず、埋込み対象の容量のみに依存することが確認できた。

表1 Imperceptibility using PSNR(dB)

Stego-Image (Cover Image + Medical Image: JPEG)	Image-Capacity (kB)	PSNR (dB)
Abdominal CT	32	48.90
Vertebrae MRI	6	54.54
Chest CR	128	41.72

The degradation in cover images are presented.

4. 考察

本研究で構築したシステムは、モダリティに依存せず、埋込み許容容量内であればいずれの画像でも埋込可能であった。埋込み法として、ビット置換法により画素の濃度値を僅かに変化させることにより埋込みを行っているので、埋込み前後で画像容量の変化はなかった。また、本システムではSteganographyを用いたので、人間の視覚的に医用画像埋め込み前後での画質変化を知覚できないのに加えて、PSNRの結果から画像の統計的性質などにおいても不自然さを検出されないことが確認できた。よって、ダミー画像を閲覧されても、医用画像が埋込まれていることを推測されないと考えられる。 したがって、異なる施設間で医用画像の送受信・保管時など、万が一、画像が流出した場合でも医用画像の秘匿性は十分確保できると考えられる。

また、電子透かしの著作権の保障、Steganographyの高い秘匿性という利点を統合することにより医用画像の伝送前後に関わらず著作権保護と秘匿性確保とが同時に得られると考えられる。また、本研究で構築したシステムは、フリーウェアのツールを使用しているため、医用画像伝送の際に各施設の初期投資及び運用コストを少なくでき廉価なシステムとなり、全ての処理を自動で行えるので簡便なシステムとなる。

今後、埋込み許容容量が増加することにより、遠隔画像診断など医用画像を施設外に持ち出す際にも、VPNなど特別な暗号化は必要としなくても、一般のネットワークを利用した画像伝送・保管も可能になると考えられる。

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Original Contribution Kitasato Med J 2008;38:1-8

Development of a telesupport system for cancer outpatients

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Objectives: To guarantee a sense of relief, we developed a telesupport experimental system to connect outpatients with their medical facility that can provide continuous support for cancer patients and their families increasing their sense of relief.
Materials and Methods: This telesupport experimental system is composed of a consulting support function to provide patients with physical and emotional support and an observation function.
Results: Using this telesupport system, we were able to obtain objective and subjective information from the test results. Moreover, use of this system by medical staff and patients has provided a means to solve many difficulties in providing adequate treatment.
Conclusion: This system allows cancer outpatients to feel secure when receiving treatment and on into follow-up monitoring and any additional necessary treatment.

Key words: cancer patient support system, outpatient care, telemedicine support, home health care

Introduction

To break away from escalating healthcare costs and the trend toward long-term hospitalization of elderly patients, there has been a recent trend to cut healthcare costs and reduce the length of hospital stays in Japan. As a result, hospitalized treatment is shifting ever more toward outpatient treatment. Surgical treatment, chemotherapy, and radiation therapy are the three major ways to treat cancer, however, these treatments are currently conducted on an outpatient basis, partly due to the revision of medical insurance coverage policies and fees.

Thus, cancer patients continuing to receive outpatient treatment face a number of difficulties in daily living while coping with the treatment regimens.[1] In the home environment, patients must tolerate adverse effects and continue the treatments unlike when hospitalized where they are constantly medically managed. Patients and their families must judge the symptoms and take appropriate actions.

However, patients may feel physical or mental distress from outpatient treatment and may become unable to continue treatment. At the same time, the medical staff is unable to provide sufficient support and instruction to patients due to time and staffing constraints. Therefore, we believe it is necessary to have a treatment environment where cancer patients receiving outpatient treatment and their families feel a sense of relief so that they can consult medical staff whenever necessary. We have developed an experimental telesupport system that connects the medical facility and the patients in their homes, increasing the patients' sense of relief and reducing the load on medical staff.

Materials and Methods

System design

Figure 1 shows the system we developed, and Figure 2 shows an overview of the system in a patient's home. The system in the patient's home uses a personal computer (Dell Dimension 8100; CPU: Pentium4 1.3 GHz; Memory: 392 MB; referred to hereafter as a PC) running Windows 2000 Professional (Microsoft). Table 1 shows the types of vital data obtained and the measurement instruments used. Table 1 also shows the accompanying software for data input into the PC. RS232C cables provided with the software from different manufacturers were used for the connections between these measurement instruments and the PC. In addition, this system has an RS232C automatic switching instrument (CONTEC, COM-4 [USB]) to obtain vital data from

Received 22 October 2007, accepted 25 September 2007
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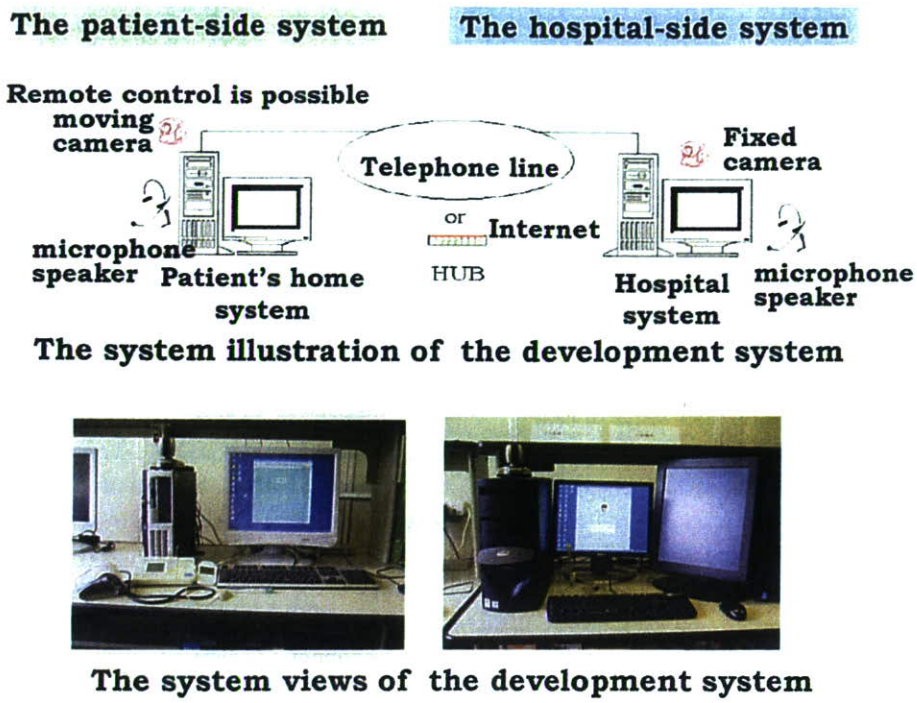

Figure 1. The system configuration

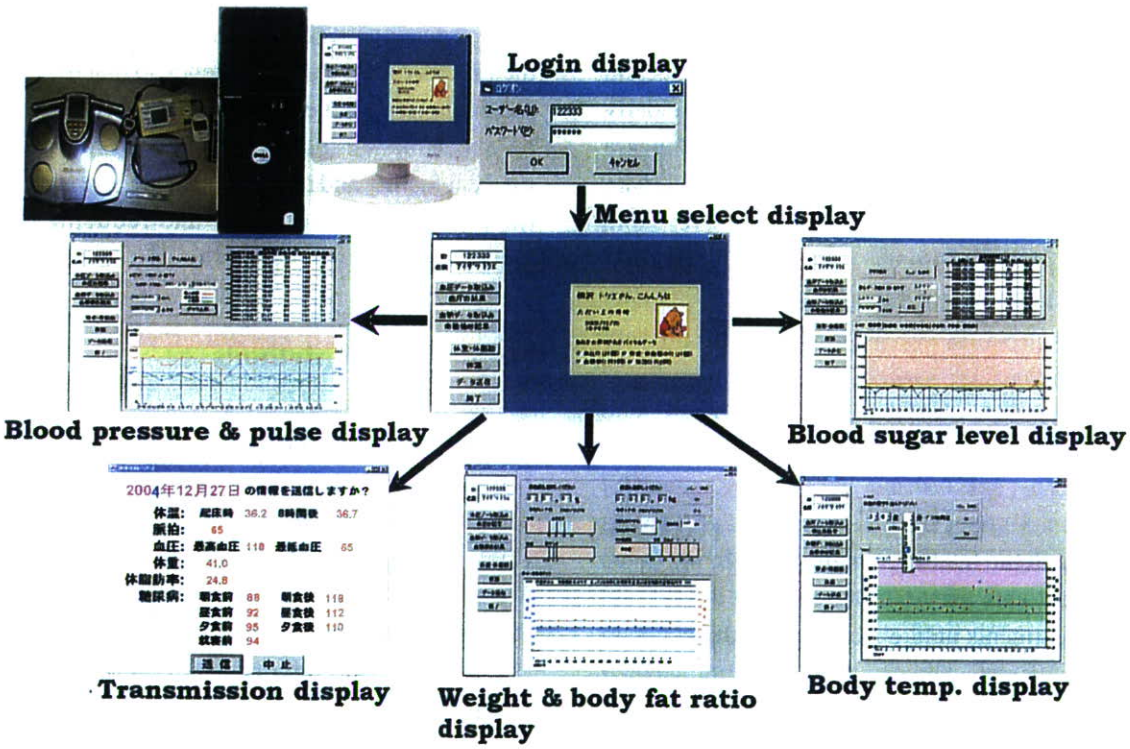

Figure 2. Overview of the system at the patient's home

multiple measuring instruments in RS232C format. For the system in the medical facility, the server accumulating the vital data operates with Windows 2000 Server (Microsoft). The access (Microsoft) was used for the database for the patient data, such as the patient's password, the patient's name and vital data.

In addition, the system in the medical facility has software that integrates the all of the above and the patient-support system described in the following section: System configuration and implementation.

The user's name (Patient ID) and password are provided by the hospital and used to login to the system. Moreover, fingerprint authentication is also used, enhancing the users' privacy, security, and convenience.

In the experimental system providing telesupport, two systems assumed to be the home-care patient's home system and the system in the medical facility were connected through the public telephone lines and/or via the Internet, sending and receiving real-time visual and audio data and biological information, such as body temperature, blood pressure, pulse, and respiration.

System configuration and implementation

As shown in Figures 3-8, the patient's home system has an e-mail function and camera/voice function as part of the emotional support function, as well as a scale function and a diary function to record symptom distress implemented in the consultation and support system. The self-care system has functions for displaying precautions and side effects, in addition to a function to observe the symptoms.

Table 1. Vital data measurement instruments and accompanying software

Vital Data	Manufacturing company	Hardware	Software
Blood pressure, pulse	OMRON	HEM747-IC	HEMSOFT IC3
Blood sugar level	ARKRAY	GT-1660	MEQNET DM Manager
Weight and body fat ratio	OMRON	HBF-3541T	Self-development
Body temperature	TERUMO	ET-C202P	Self-development

In order to unify the function of each software type, self-development of the software for integration was carried out.

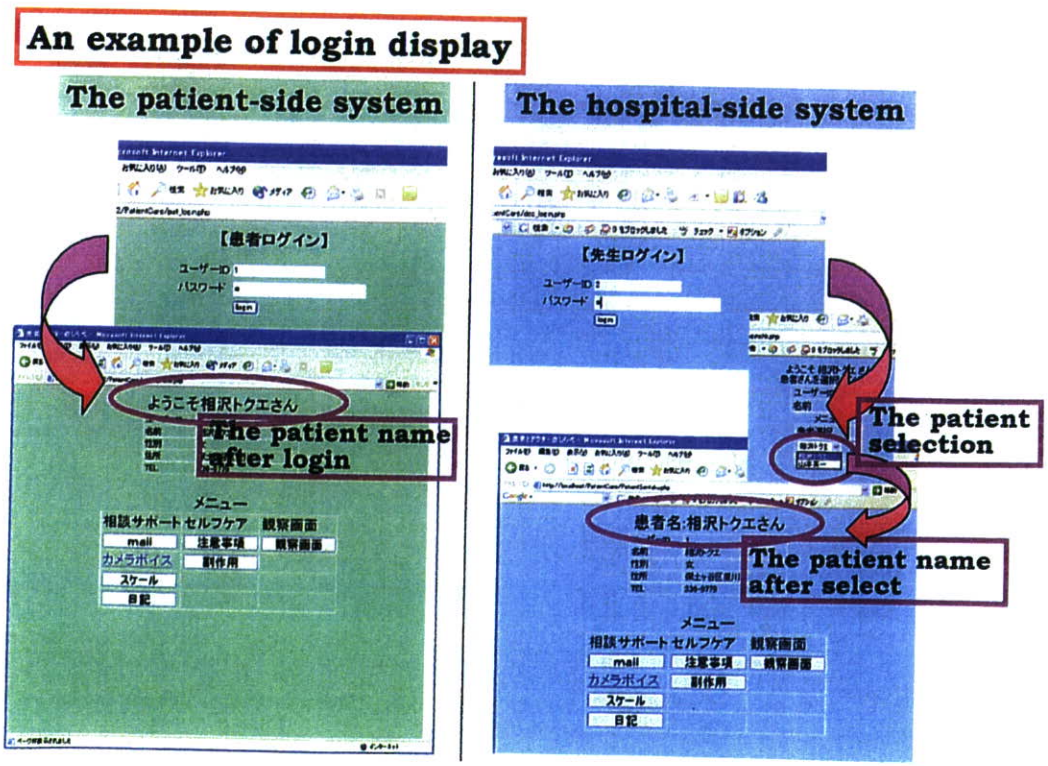

Figure 3. The login screen

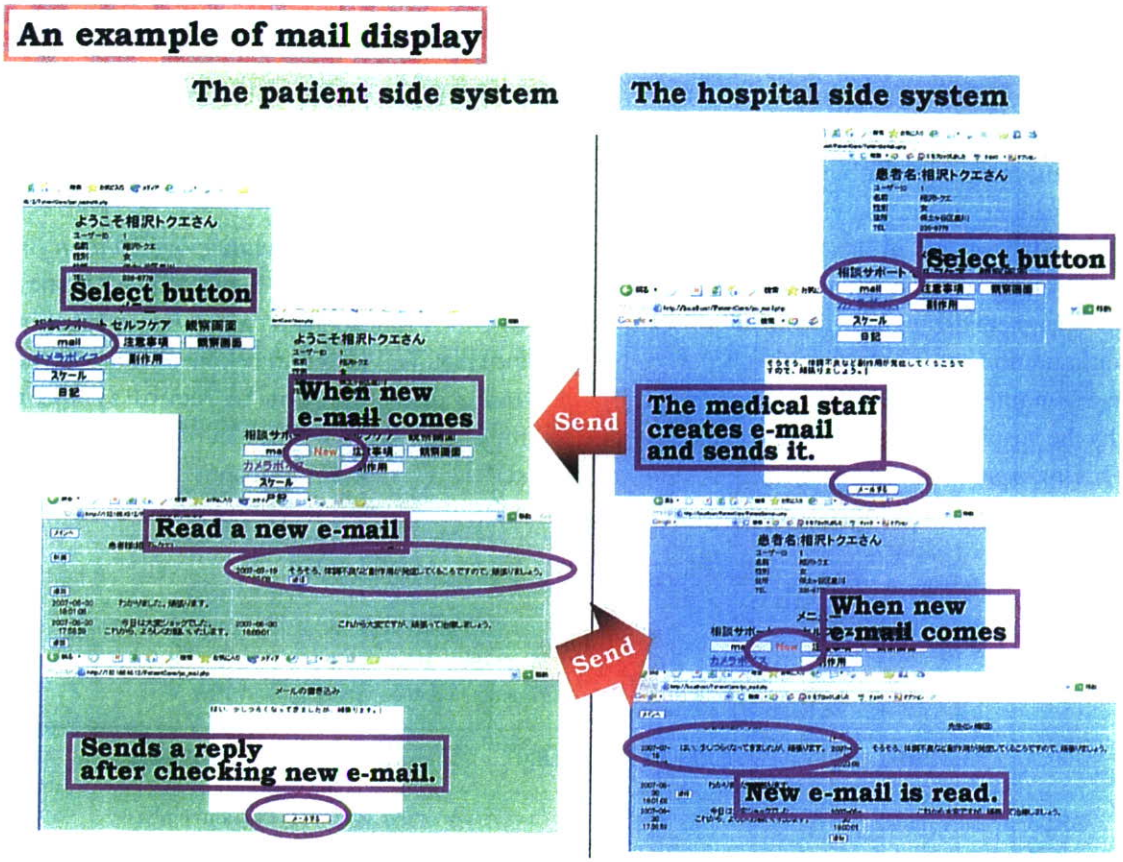

Figure 4. The e-mail operation screen

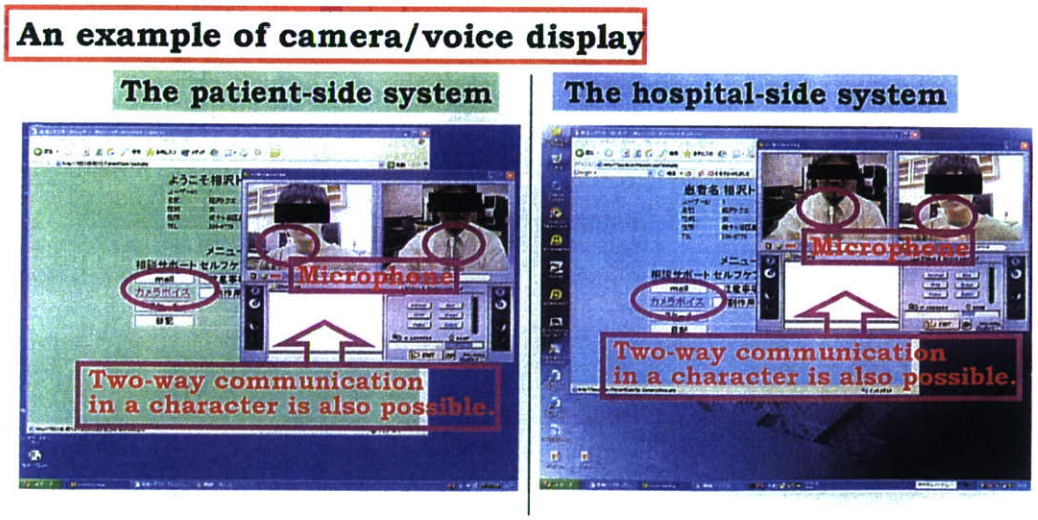

Figure 5. The camera/voice operation screen

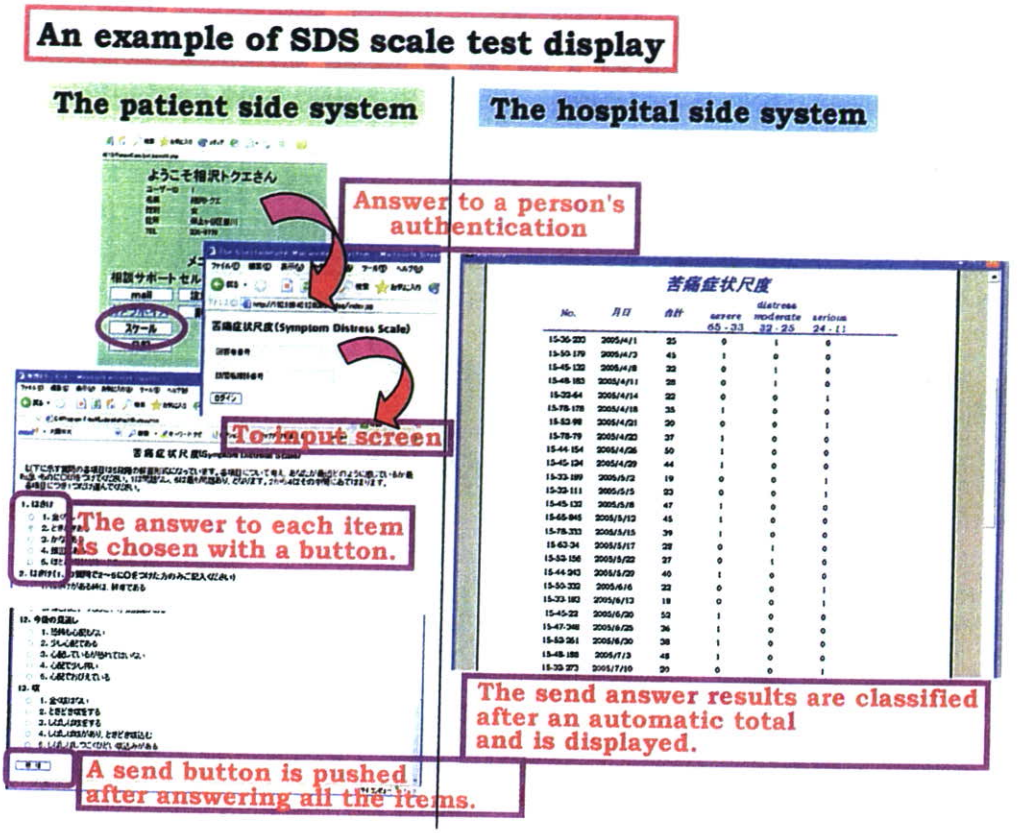

Figure 6. The Symptom Distress Scale operation screen

Figure 7. The screen for areas requiring extra caution in everyday life and how to handle adverse effects

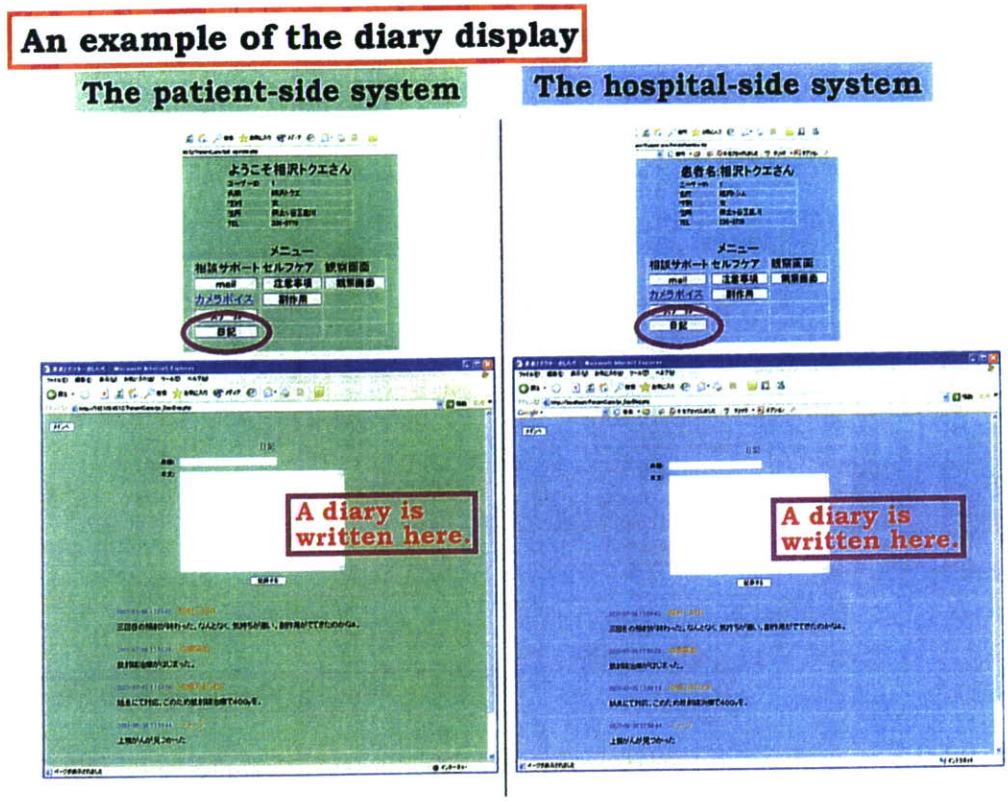

Figure 8. The diary screen

Consulting support system

An emotional support system was created to allow patients to consult their medical staffs, such as physicians and nurses in the medical facility by e-mail. New e-mails are clearly visible on the screen (Figure 4). Patients can directly consult their medical staffs in virtual interviews using the camera/voice system and discuss any worries they may have (Figure 5). With the camera/voice system, the medical staff can monitor the patient's tone of voice and their facial expressions, along with skin tone and color. The camera/voice system also has a chat function so that patients with impaired language and/or auditory function can also make use of the system.

Symptom Distress Scale input system

Based on the factors determined by Katagiri and colleagues,[1] such as "disease and future prospects," "treatments," and "limitations in everyday lives," this system encourages patients to express their feelings regarding their disease. We created an emotional support system for questions and consultations regarding the treatments and a self-care system for somatic symptoms. Chemotherapy has strong adverse effects, which may affect patients' everyday lives, and result in a large degree of physical distress. The Symptom Distress Scale (SDS)[2] is used to objectively understand the degree of distress. However, because the SDS was designed for American subjects, we modified it for Japanese patients.[3] The SDS has 11 factors and 13 items including: nausea, appetite, difficulty in sleeping, pain, fatigue, defecation pattern, concentration, appearance, respiration, future prospects, and coughing. It measures the degree of distress accompanying the cancer treatment. The answers are evaluated on a scale of 1 to 5, with 5 indicating the highest level of symptom distress. As shown in Figure 6, the SDS was created on the screen, so the questions can be answered by pointing and clicking with the mouse. When the patient places a mark at the appropriate place for each item on the SDS, and then clicks the Submit button, the answer is sent to the system at the facility side, the score is automatically calculated, and the final score is immediately displayed. The score is classified into 3 levels so that the patients can easily see their levels of distress. Observations of symptoms, such as cutaneous symptoms, can be saved as image data.

Self-care system concerning somatic symptoms

In the self-care system concerning somatic symptoms, areas requiring extra caution in everyday life, and ways to handle adverse effects can be explained (Figure 7). The diary system was also created to record the patients' daily understanding of their condition (Figure 8).

The signs and symptoms observation system

In the signs and symptoms observation system, shown in Figure 7, a picture of a patients' cutaneous signs and symptoms taken with a digital camera can be uploaded into the system and sent so that detailed observations of a patients' cutaneous signs and symptoms are possible.

Results

Emotional Support Operation

For outpatients, e-mail is a means to convey their concern about problems at any time. For healthcare providers, e-mail has become a means of communication with the outpatients, allowing them to understand each patient's emotional state. The nature of e-mail makes it difficult for the patients to receive an immediate response, however, the system was designed to display a mark when a new e-mail is received.

The camera/voice system requires both parties to coordinate the timing and to be on the system at the same time, but it allows them to speak with each other directly in real-time. Another advantage of this feature is that the healthcare providers can make observations on the color of the home-care patient's face and facial expression through the camera. In addition, this feature increases the patient's sense of relief because it represents virtual in-person counseling. Since the simulated patient using this support function performed virtual interviews with various medical staffs, he expressed the opinion that there was an increased sense of relief.

Input operation of the SDS

Objective information on patients' distress levels can now be obtained using the SDS. In addition, as the data history is accumulated in the medical facility, the patient's current state can be compared with their past condition. A nurse trying this system was of the opinion that it was easy to find out from a patient when the patient was experiencing pain.

Self-care operation regarding somatic symptoms

Healthcare providers can now explain areas requiring extra caution in everyday life through text messages or images. This allows patients to view the information at their own convenience, whenever they want. As a result of patients keeping diaries, the medical staffs could more easily know the patients' conditions.

Observation of signs and symptoms

It is sometimes necessary for the medical professionals to look at the signs and symptoms directly to make a judgment. Patients can send photographic images through their home system to the medical facility, thus allowing the medical staffs to make more accurate observations. Previous data are saved, allowing the current and past conditions to be compared. As a result of these observations becoming easier, this system has also been used for consultations between doctors and medical staffs. Thus, the staffs' sense of relief is increased as well.

Discussion

System operation

We developed a telesupport system to provide mental and physical support to outpatients receiving treatment. With regard to the emotional support function, the patients can consult the healthcare providers about their diseases, their future prospects, and their emotions and feelings regarding changes in the state of their diseases. Patients can express and clarify their feelings by writing them in e-mails directly to their doctors and/or medical staff. The medical staffs can instruct the individual patients how to handle possible adverse effects, or how to manage oral medication through virtual face-to-face counseling. Regarding the physical aspect of the support function, the patients can be instructed on restrictions in their everyday lives or on possible adverse effects. In addition, this system is useful in self-care, allowing outpatients to perform self-monitoring as their SDS and image data can be saved. There have been many studies of telesupport systems, such as weight-loss programs, exercise instruction, and nutritional guidance, used for lifestyle-related diseases,[4] and they have been shown to be effective. Current issues in outpatient treatment include the doctors' difficulties in understanding the patients' awareness of their diseases and their needs, as well as difficulties in understanding the patients' home lifestyles or any other aspects they may wish to report due to the short duration of face-to-face medical examinations.[5] Medical staffs are fighting for quality of patient care within the restricted environment of outpatient treatment. This system is not only beneficial to the patients but also to the medical staffs in that the accumulated subjective and objective information from the past can be compared to the present data to better understand and analyze the patients' conditions. This becomes a richer source of information to help prescribe treatment and/or for follow-up treatment. The communications between outpatients in their homes and the healthcare institutions will provide the patients a heightened sense of emotional relief. Moreover, this allows the provision of timely instructions