Application of Information Technology ■

Remote Analysis of Physiological Data from Neurosurgical ICU Patients

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Abstract Recent technical advances in Internet-based client/server applications and new multimedia communications protocols are enabling the development of cost-effective, platform-independent solutions to the problem of remote access to continuously acquired physiological data. The UCLA Neurosurgery Intensive Care Unit (ICU) has developed a distributed computer system that provides access over the World Wide Web (WWW) to current and previously acquired physiological data, such as intracranial pressure, cerebral perfusion pressure, and heart rate from critical care patients. Physicians and clinical researchers can access these data through personal computers from their offices, from their homes, or even while on the road. The system creates and continuously updates a database of all monitored parameters in data formats that can readily be used for further clinical studies. This paper describes an extension to this system that allows for remote interaction with and analysis of the data via the WWW. Physicians can now pose a limited, predefined set of clinically relevant questions to the system without having to be at the patient's bedside.

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Most patients in an intensive care unit (ICU) require continuous supervised monitoring for extended periods of time. Various electronic monitors are often used for this purpose. The problems of access and utilization of the ubiquitous physiological data streams such monitors generate has grown, as has the complexity and variety of the ICU monitors. In general, companies developing ICU monitors assume a scenario in which physicians and nurses are continuously available in the ICU to analyze and interpret the monitor's output. Unfortunately, this scenario is often far from reality. Physicians are rarely at a patient's bedside. Nurses must attend to many patients and may not easily access all physiologically relevant parameters without physically going into the patient's room.

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Since the timing of changes in patient status cannot easily be predicted, on-call physicians and critical care personnel are summoned to the ICU at odd hours in order to interpret the monitor's data. Meanwhile, the clock is running; the physiological profile of a patient can rapidly deteriorate. It has long been the physician's dream to have immediate access to the patient's detailed record of physiological data from such remote locations as the home, the office, or even from a plane, car, or hotel room.

In a recent paper[1] we described a system based on the World Wide Web (WWW) and the Internet for accessing continuously monitored physiological parameters from postsurgical and post-trauma patients in the UCLA Neurosurgery ICU (7WICU). However, reading multiple streams of raw data may not be sufficient to make an accurate diagnosis even for the most experienced clinician. Additional calculations are often necessary to assess how the monitored parameters compare with the normative physiological ranges for the particular patient's condition. This paper describes extensions to the current system that allow physicians to use the WWW to answer a limited but clinically useful set of quantitative questions about the monitored ICU patient data.

Background

UCLA Neurosurgery ICU Monitoring Environment

The 7WICU at the Division of Neurosurgery is an eight-bed, state-of-the-art facility with an advanced monitoring infrastructure that includes two independently networked systems of bedside monitors. The first is dedicated to continuous electroencephalogram (EEG) monitoring (Nicolet Biomedical, Inc., Madison, WI). The second (the focus of this project) is devoted to continuous monitoring of physiological parameters (Marquette Electronics, Inc., Milwaukee, WI).

The data generated by the Marquette monitors account for about 90% of all recorded physiological parameters. Typically, information is displayed on a monitor, spot-checked by nurses, and lost as it scrolls off the screen. Marquette has provided a limited solution to the data storage problem by allowing some of the data trends to be archived on a personal computer that is connected to a central monitoring station that networks all bedside monitors. Using proprietary Monitoring Review Terminal (MRT-II) software, this setup does not allow data to be further analyzed or easily disseminated. It was the task of this project to design and develop a system capable of continuously storing all monitored physiological parameters in a database that could be accessed and analyzed by physicians from remote locations via the WWW.

Use of the WWW to Access Patient Information

In the past, remote access to patient data has met with mixed success, which often depended on the nature of the data itself. For instance, radiological image transfer has drawn most of the attention of physicians and software/hardware developers interested in remote access to patient data. One obstacle to remote access is the diversity of personal computers and the lack of a platform-independent software development environment capable of supporting the multimedia nature of these data. Solutions to such obstacles are rapidly being created in the development of WWW-based applications.

Accounts of successful WWW-based Clinical Information Systems (CIS) were recently reported in the literature. A group at the Columbia–Presbyterian Medical Center reported on their development and experience with a prototype of a "Surgeon's Workstation" that uses the WWW to provide remote access to patient data, specifically to laboratory test results.[2,3] A group at the University of Minnesota Hospital and Clinic deployed a WWW-based CIS that also makes available laboratory results and supports laboratory order entry.[4] They demonstrated that deploying CIS on top of the WWW can lead to a substantial decrease in the amount of effort needed to install client services. Cross-institutional clinical care research is often encumbered by unique system designs coupled with a lack of standards in electronic medical record systems. Surmounting this difficulty with multiplatform, multiprotocol, WWW client-server technology is a current project at the Boston Children's Hospital and Harvard Medical School.[5] Another WWW-based system was deployed at the Mayo Clinic Foundation.[6] This project involved a prototype interface that collects links to some of their 200 major clinical databases onto a single home page; PERL[7] scripts were incorporated to allow users to spawn and process inquiries and to pass the Structured Query Language (SQL) response onto graphing or simple cross-tabulation utilities. This system also addresses some issues regarding privacy and patient confidentiality, and it provides solutions to the user authentication problem for users within the Mayo Clinic's Internet firewall. Specifically, they use Kerberos and encrypted information transfer within the firewall and do not permit ftp, rlogin, telnet, Gopher, or WWW packets from outside to pass. The above-mentioned projects demonstrate the WWW's extraordinary potential for rapid prototyping and the enormous flexibility of WWW-based applications.

Design Objectives

In contrast to previously reported systems, our objective was to construct a system that could remotely access and query continuously acquired physiological data. This system had to be used on most standard computer platforms (e.g., PCs, Macs, and Sun and SGI workstations). It had to be relatively cheap to develop and have the same or very similar graphical user interface (GUI) on all supported platforms. In addition, the system had to be accessible by computers both from within our institution and from outside via a widely available network such as the Internet. These computers could be connected directly to the network or via modems. Finally, we wanted a system that would provide physicians with clinically relevant data in a timely manner and allow them to ask some clinically relevant questions about the data. These specifications led to the development of a system that is available over the WWW to end users and is composed of a series of hyperdocuments written in the Hypertext Markup Language (HTML). It incorporates a set of Common Gateway Interface (CGI) tools for data processing, and it can be viewed over the Web by using the Netscape Navigator v2.0 (Netscape Communications Corp., Mountain View, CA).

Hardware/Network Configuration of the Data Access System

The remote ICU data access system involves a number of specialized physiological monitors connected to a central hub (MBX) and is integrated with additional computer hardware and networking components. These include an IBM PS/2 model 80 personal computer, which runs the Marquette Review Terminal (MRT-II) software on top of an OS/2 Warp-3 operating system (Fig. 1). This computer, which is connected to the MBX via a serial RS-422 port, serves as an intermediate data repository station for up to 72 hours per patient. The MRT-II is also used to log patients into the system. Furthermore, this computer is connected to an Ethernet network at the 7WICU. The Ethernet network transfers data not only from the Marquette monitors but also from the continuous EEG bedside monitors to a Sun Sparc 10/51 workstation located in the Brain Monitoring and Modeling Laboratory (BMML). The sun workstation is in the core of the system. It runs several software packages, which are described in the next section. The Sun workstation is connected to the token ring network of the Division of Neurosurgery. This network is further connected to the Internet via the UCLA School of Medicine's fiber-optic backbone. Remote access to the Internet for physicians and clinical researchers is provided via a Small Computer Systems Interface (SCSI)-based terminal server (Central Data, Champaign, IL) connected to the Sun workstation. Several high-speed modems (28.8 Kbps) were connected to this terminal server for local dial-in access.

Software Integration Tools

To achieve the project's objectives, multiple high-level software packages had to be integrated: UNIX system administration tools for Internet access automation, tools for statistical data analyses and plotting, and tools for HyperText markup and WWW hyperdocument serving. The following paragraphs briefly describe the most significant of these tools and how they were used in the framework of this system.

The analytical and statistical core of the project was written in Splus (Statistical Sciences, Inc., Seattle, WA), an interactive graphic environment for data analysis developed by AT&T Bell Laboratories in the early 1980s.[8] A powerful tool for data analysis, Splus provides users with convenient features for exploratory data analysis and graphics, modern statistical techniques, and creation of stand-alone Splus applications. Different from most other popular statistical software packages, such as SAS, PSTAT, and BMDP, Splus uses object-oriented programming techniques. For this project, Splus version 3.2 was installed in the BMML on a Sun Sparc 10 workstation running SunOS version 4.1.3. Splus is used to generate the plots of the physiological parameters in Postscript, to calculate descriptive statistics, and to do HTML mark-up of the files served on the WWW.

To ensure high-level security while serving patient data on the WWW, we decided to use the Netsite Commerce Server (Netscape Communications Corp.,

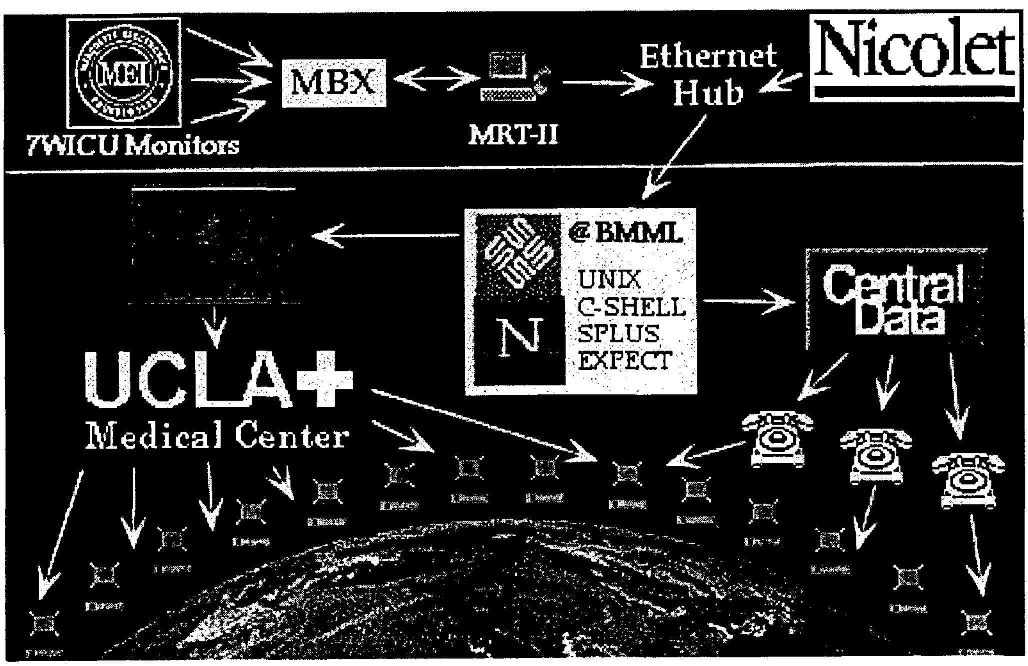

Figure 1 Diagram of the network connectivity and the hardware and software components of the remote access system in the 7WICU and BMML.

```
#!/usr/local/bin/expect --
# .poll.mrtlink -- automatic ftp connection to MRTLINK IBM PS/2 80
# Author: Val Nenov

spawn ftp mrtlink.medsch.ucla.edu
set ftp_id $spawn_id
expect {*Name*}
send "username\r"
expect {*Password:*}
send "the_password\r"
expect {*ftp>*}
send "cd DBMGR\r"
expect {*ftp>*}
send "prompt\r"
expect {*ftp>*}
send "binary\r"
expect {*ftp>*}

foreach i {DBM00 DBM01 DBM02 DBM03 DBM04 DBM05 DBM06 DBM07 DBM07} {
      send "cd $i\r"
      expect {*ftp>*}
      send "lcd $i\r"
      expect {*ftp>*}
      send "mget *.dt\r"
      expect {*ftp>*}
      send "cd ..\r"
      expect {*ftp>*}
      send "lcd ..\r"
}
expect {*ftp>*}
send "quit\r"
expect eof
```

Figure 2 A script written in Expect and executed on the Sun workstation automatically pulls the physiological data from the MRT-II computer.

Mountain View, CA) instead of such commonly used FREE http servers as the CERN or NCSA. This server is a high-performance, reasonably priced software package for conducting secure electronic commerce and communications on the Internet and other TCP/IP-based networks. We run version 1.1 of the Commerce Server on the Sparc 10 to serve HTML documents in both secure and insecure modes.

In addition to making the data remotely accessible, the present system creates a database that holds all monitored data in formats suitable for future statistical analyses. For this purpose, we use commercial-strength database management tools: Informix-Online (Informix Software, Inc., Menlo Park, CA). Additional software packages provide HTML front-end and report-generation facilities for the Informix database.

Data Flow

Before data are made available to the HTTP server to be put on the Web, it is handled by several software routines. Figure 1 illustrates the data flow through the system. Raw physiological data are acquired by the Marquette monitors, transmitted automatically via the MBX box, and temporarily stored on the IBM PS/2 computer. Data transfer is achieved by the MRT-II software package provided by Marquette. The PS/2 computer located in the BMML is where the patient identification information is entered. Data are keyed only once by BMML personnel or staff nurses when the patient is admitted to the ICU or moved from one bed to another. Patient discharge is automatically logged by the software.

The HTTP server does not directly access any data on the MRT-II. Instead, data is fetched automatically by the Sun workstation at prescheduled time intervals by means of a short Expect script.[9] Expect is a powerful language suitable for automating Unix systems administration. This script automates the File Transfer Protocol (FTP) between the MRT-II and the Sun workstation. Figure 2 illustrates the core code of the batch FTP procedure.

A second data path is established between the continuous EEG monitors and the Sun workstation. The interface to the EEG data has a different design compared with the interface to the Marquette physiological data. Instead of transferring the EEG data with the FTP to the Sun workstation, the data is left on the hard or optical disks of each EEG machine. These volumes are mounted through the Network File System (NFS) on the Sun workstation. This setup eliminates the need for data duplication, since the EEG data is substantially more (about 1 Mb per minute for 32 EEG channels at a 256-Hz sampling rate) than the data acquired by the MRT-II system.

```
#!/bin/csh
# .mrt2s -- Marquette to S-plus data conversion
# Author: Val Nenov

/usr/local/bin/conbin -b -c"MRT.vitals.dt" -f vitals.dt vitals.dj4
/usr/local/bin/consplus -b -t vitals.dj4 vitals -unenov
/usr/local/bin/conbin -b -c"MRT.patient.dt" -f patient.dt patient.dj4
/usr/local/bin/consplus -b -t patient.dj4 patient -unenov
rm vitals.dj4 patient.dj4
chown nobody vitals
chown nobody patient
mv vitals .Data
mv patient .Data
echo Running Splus in directory $cwd ...
Splus < .proc.bed.S.in >& $CURRENT_BED/.proc.bed.S.out
```

Figure 3 A segment of a C-shell script that calls built-in Data Junction routines (e.g., conbin and consplus) to convert the raw physiological data from the proprietary Marquette binary format to S-plus format.

Once available on the Sparc station, the physiological data is reformatted automatically from the proprietary Marquette format to S-plus format. This is done by a C-shell script, which calls the Data Junction software (Tools & Techniques, Inc., Austin, TX). Figure 3 shows the core of this routine. The original raw data is then discarded, and only S-plus data objects are placed for permanent storage on optical disks. An optical 1.2-Gb disk drive (Plasmon Data, Milpitas, CA) is connected to the SCSI chain of the Sparc station.

Data crunching by the S-plus package is a crucial data processing stage in the present version of the system. The routines written in S-plus not only create a database of S-plus objects which contain the physiological trends data for the entire stay of the patient in the ICU but also generate the trend plots in postscript format, perform some basic descriptive statistics on the data, and populate some HTML tables. The interface between the HTTP server and S-plus is written as a C-shell script (csh), which is spawned by a CGI process and which calls S-plus in a batch mode while passing relevant variables to it. Figure 4 shows the core of this S-plus code.

Although S-plus is closely coupled with the data stream, it is important to note that we are not dealing with a real-time data stream from the bedside to the Web client. Instead, we have a sequence of processing stages with intermediate data repositories in various formats. In other words, in the present version, the S-plus module cannot perform real-time filtering and therefore cannot be used for driving data alarms. Depending on the amount of data (number of channels, sample rate, etc.), S-plus can potentially be used for real-time data filtering; however, we have not done experiments yet to assess its potential, and we are currently using S-plus only for post hoc analysis.

To permit real-time data transmission to remote sites, we are in the process of testing a Java-based extension

```
# This set of S-plus commands are called by:
# Splus BATCH .proc.patient.S.in .proc.patient.S.out
# from the 7WICU directory and it should create the necessary Splus objects
# in the corresponding PATIENTS/patient? and BEDS/bed#? directories

bed <- getenv("CURRENT_BED")
paramsDB <- "/sdlg/INTERNET/NEUROSURGERY/7WICU/.Data"
bedDB <-
 paste("/sdlg/INTERNET/NEUROSURGERY/7WICU/BEDS/",bed,"/.Data",sep="")
bedURL <- paste(
      "<a href=http://neurosun.medsch.ucla.edu/7WICU/BEDS/",bed,"/",sep="")

attach(bedDB)
attach(paramsDB)
options(object.size=5e12)

get.patient.name()
get.codes()
format.vitals()
postscript.all.codes()
get.full.codes()
patient.info()
postscript.print.all()
q()
```

Figure 4 A text file (called by the C-shell script in Figure 3) that contains S-plus commands processes the data, formats it into HTML tables, and generates the data plots in postscript format.

BED # 4

7 West Neurosurgery ICU, Electronic Patient Record

Name: Jane Doe
ID: 999-99-99
Date of birth: 9/25/1930
Sex: female
Attending physician: Martin, NA
ICU monitoring FROM: 8/9/1995 **TO:** 8/10/1995 **Total of 2 day(s)**

Vital signs monitored:

#	par	sub	Monitored Parameter	units	code	min	max
1	ECG	HR	Heart Rate	bpm	(1,0,0)	69	125
2	PO	SAO2	Oxygen Saturation		(11,0,0)	94	100
3	PO	PPR	Peripheral Pulse Rate (SAO2 module)		(11,1,0)	67	94
4	CPP	CPP	Cerebral Perfusion Pressure	mmHg	(12,0,0)	69	140
5	ABP	AR2	Arterial Blood Pressure	mmHg	(2,2,0)	D52	S221
6	ICP	IC3	Intracranial Pressure	mmHg	(5,3,0)	2	53

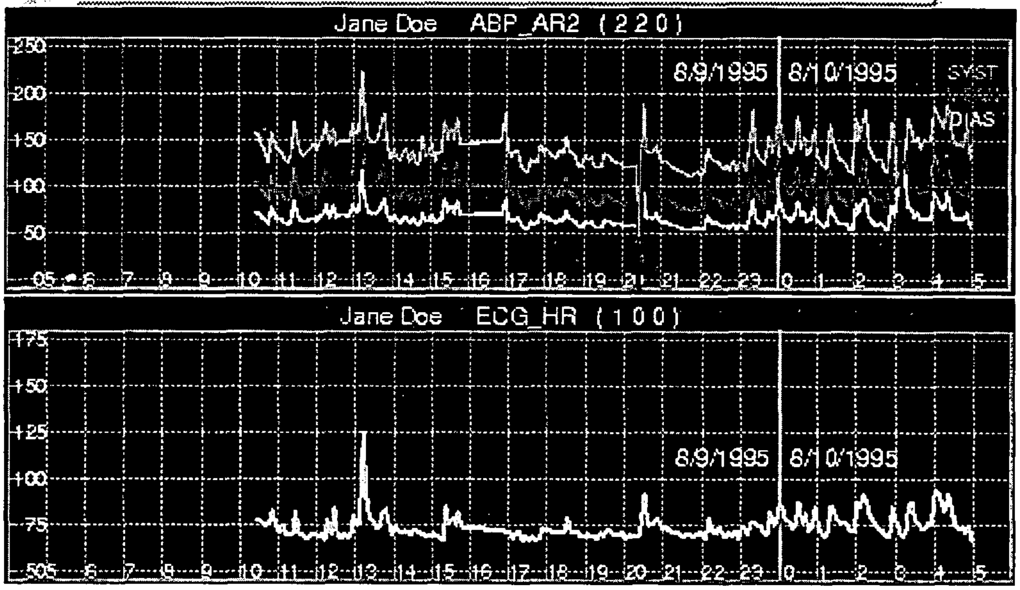

Figure 5 An example of patient-ID information and physiological data displays generated by the system and made available on the WWW. Each plot features a 24-hour chunk of the data. In addition, plots summarizing the whole stay of the patient in the ICU are made available on the Web.

of our system that allows semi–real-time access to the monitored data. In the meantime, the production version of the system is designed to update the HTML hyperdocuments, either at prescheduled times (usually before physicians' rounds at 5 a.m.) or on demand by the physician. In the latter case, the physician can use the Web browser to press the Update button (Fig. 6) for a given bed, and the resulting hyperdocuments are generated and returned within three minutes. This is the time necessary for the Sun workstation to transfer the raw data from the MRT-II to its hard drive, translate the data from the Marquette proprietary data formats to S-plus formats using the Data Junction software, generate the graphs in postscript format within S-plus, convert the postscript to gif using ghostscript (Aladdin Software, Watsonville, CA), assemble the final HTML documents, and transmit them through the network or the modems to the remote site.

User-Friendly HTML Forms and CGI Routines for Data Access

This system was developed with particular attention to the needs of the end user. To create informative and visually appealing hyperdocuments, we used such HTML 3.0 language tools as forms, clickable images, frames, and tables. Figure 5 is an example of such a hyperdocument that features trends of several recorded physiological parameters.

Additional functionality in the system, such as interaction with the S-plus database, was achieved by a variety of CGI routines; CGI is a standard for the interface between external gateway programs and information servers. In this project, the CGI tools, which can be written in any standard computer language, were written in the C-shell (csh), Expect, and PERL languages. These routines allowed us to develop flexible control panels, such as the one shown in Figure 6.

A module that enables physicians and researchers to ask a limited set of clinically relevant quantitative questions about the data was a novel addition to our system. Examples of questions commonly asked in a neurosurgery critical care environment are: What is the highest intracranial pressure (ICP)? What is the lowest blood pressure level in the previous 24 hours? What is the time interval in the last 24 hours during which the ICP was greater than 20 mm Hg?[10]

In its present version the system offers a predefined set of common questions pertaining to critical levels for various parameters; other relevant inputs, such as the time during which we want to examine the data, are provided by the user through a control panel displayed by the client's Web browser (Fig. 7). When the user selects a question and enters the desired thresholds, the system queries the database record of the specified patient and returns the result of the requested calculations. Some critical values, such as the minima and maxima of recorded parameters, are pre-

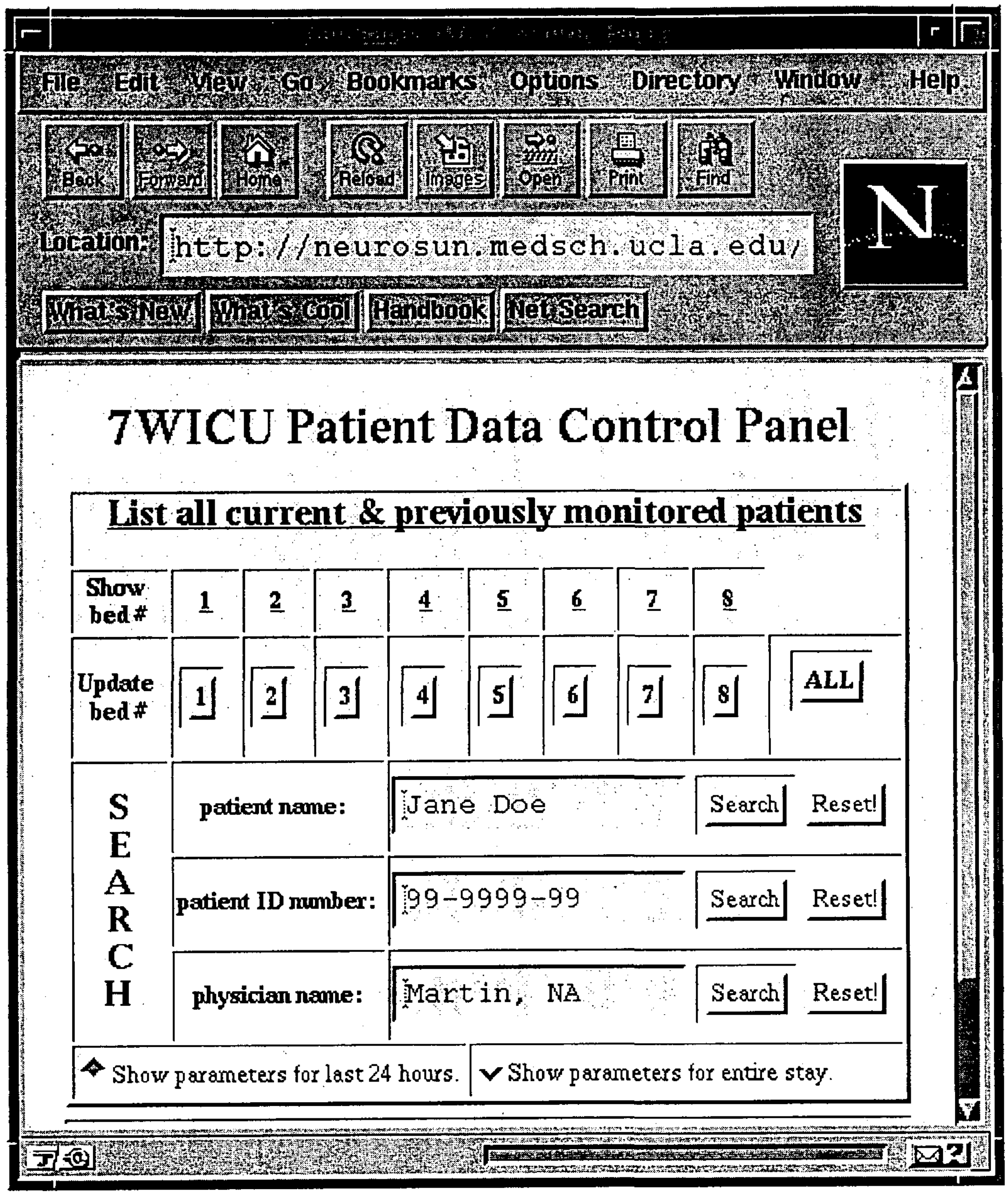

Figure 6 The WWW interface for the 7WICU patient data control panel. The system can update information about a particular patient or about all current patients. In addition, a user can access data regarding former patients by searching on a patient's name, a patient's ID number, or the physician's name.

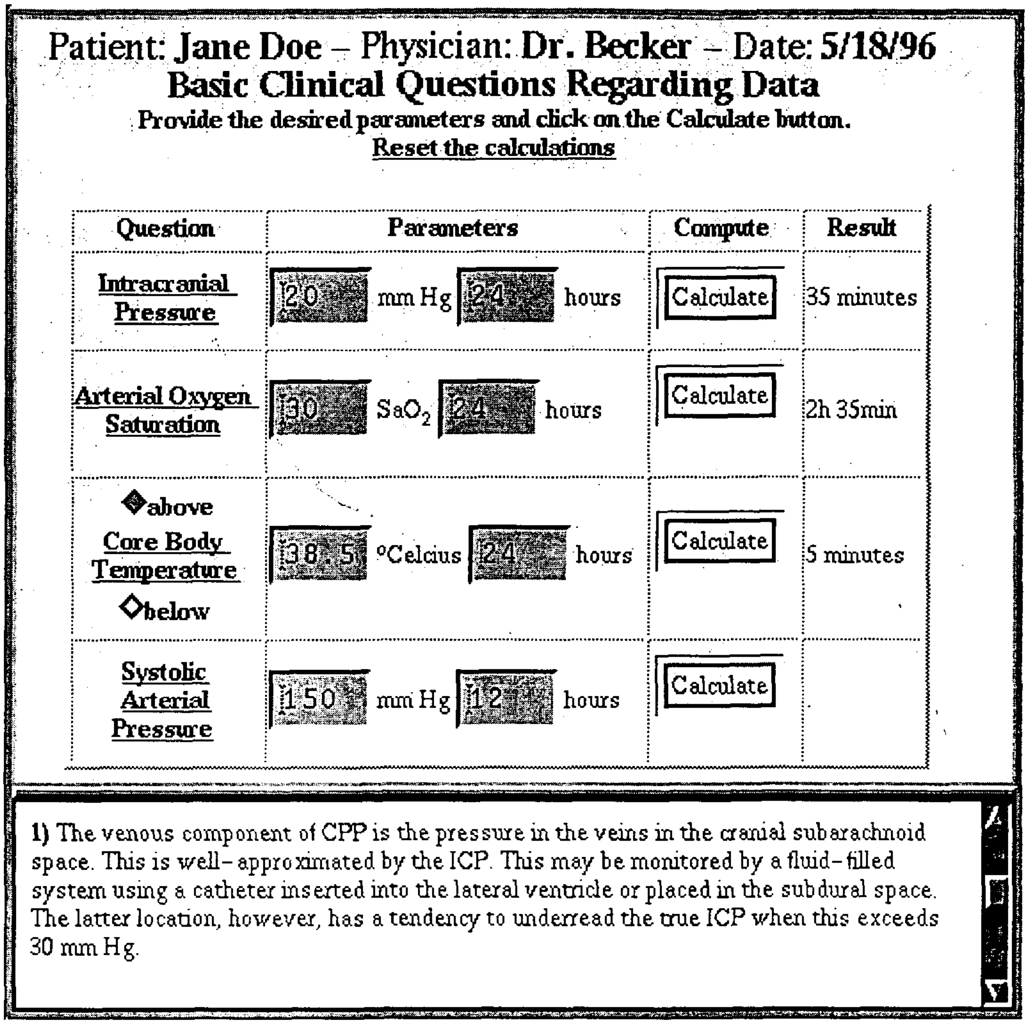

Figure 7 The WWW data analysis interface to ask clinically relevant questions about the physiological past of a patient reflected in the monitored data during a specified time period. Descriptions of the questions are provided in the bottom frame by clicking on the hyperlink in the upper frame. With remote access to this analysis tool, physicians are better equipped to make critical diagnostic and treatment decisions even when they cannot be at the patient's bedside.

computed and displayed in tabular form along with the parameter plots (Fig. 5).

Although all possible clinically relevant questions cannot be represented, our system has been designed so that new questions can be added. Currently, this is done by the system developers in agreement with the physicians. Additional intelligent graphical interfaces could be added to take the programmer out of the loop as much as possible. Such an extension would allow a user to build HTML-formatted macros that query the database according to the user's personal interest. There currently are techniques for building such graphical interfaces, but it is beyond the scope of this paper to address this issue in any detail.

The type of questions currently handled by the system can be answered with straightforward SQL queries. Indeed, we have deployed a standard SQL engine: Informix-Online with a WWW interface. However, S-plus was chosen for its powerful toolbox, which we use for exploratory statistical analysis in several clinical projects, and for its graphics display tools. In other words, both S-plus and the relational database are essential and not interchangeable components of the system.

Performance

Presently, the system users are mostly neurosurgeons, clinical instructors and neurosurgical residents. Users access the data via their personal computers at their offices or homes. The nurses in the ICU have not had sufficient experience with the system, since we do not yet have Netscape running on the computers in the ICU. Nevertheless, at formal and informal presentations, the system was enthusiastically accepted by both physicians and nursing staff.

Usage statistics were collected for nine months starting in June 1995. A script written in PERL was used to access the HTTP server log to create usage reports and to keep track of users and the specific data they accessed. Considering that the number of users currently allowed to access the system is very small (a total of 12 authorized users), we were pleased to find that 27% of them used the system daily and 68% at least weekly to check on their ICU patients. Most feedback concerned the design of the GUI and the appearance of the hyperdocuments. Because almost all users were novices in using the Internet and Web-related software, we had to help them in setting up their network access and getting up to speed with the concepts and details of navigating the Web.

Data Security and Patient Privacy Issues

Patient confidentiality and data security are critical issues in a medical environment. We use several standard computer security techniques in our system. These include user authentication and authorization procedures, data encryption, and domain restriction. These features are integrated into the Netscape Netsite Commerce Server. Users are authenticated by a double password protection system. One password is provided by the Netscape Server software, which matches the user against the Web server's user database for the 7WICU, and the second password, written as a CGI script, checks the user's Unix account password. Only selected users (mostly physicians and nurses) have been given modem access. Each of these users has been given a separate, password-protected UNIX account on the Sun workstation that, instead of spawning the standard C-shell, initiates a Point-to-Point Protocol (PPP) session. Therefore, modem access to the system is limited and is automatically logged.

Data is encrypted by patented algorithms[11] developed by RSA Data Security, Inc. (Redwood City, CA), which is a recognized world leader in cryptography, with millions of copies of its software encryption and authentication installed and in use around the world. Specifically, we are using a cryptographic authentication certificate originally issued by RSA and currently maintained by VeriSign, Inc. (Mountain View, CA). This certificate is stored on the Sun workstation, and precautions are taken to limit access to this certificate to authorized users only. Adding RSA encryption to the Netsite Commerce Server allows us to place sensitive data on the Web. Although we know that Netscape uses a key length that can probably be cracked by a determined computer expert with access to current technology, the benefits of having a simplified, cost-effective means for remotely accessing patient data outweigh the relatively small security risks. Despite the WWW's seemingly chaotic exchange of information, we can be relatively certain that only people with passwords will be capable of accessing the patient data. As with any Internet account, it is up to the authorized users to keep their passwords private.

Discussion

The broad issue of comprehensive computerized system development for managing electronic patient records has been addressed in several commercial applications. Some of the most prominent are marketed by Clinicomp, Inc. (San Juan Capistrano, CA), First Data Corporation (Charlotte, NC), Hewlett-Packard (Golden, CO), and Emtek (Tempe, AZ). In this pilot project, it was not our objective to incorporate the long list of electronic patient record system specifications included in commercial software products. Instead, we focused on some common weaknesses of most commercial systems: namely, their limited ability to allow remote access and manipulation of acquired data through uniform, platform-independent GUIs, and their notorious lack of flexibility in modifying the GUIs on demand by the end users.

We found that developing a WWW-based patient data display system was less expensive than purchasing existing commercial systems thanks to the availability of inexpensive or free WWW tools (e.g., browsers, servers, CGI scripts) as well as free UNIX toolbox software (e.g., Expect, PERL, C-shell). The real costs of this approach are incurred in software development and maintenance. It took about four months of part-time work for one programmer to design and implement the system. A significant portion of this time was devoted to learning how to use the necessary tools and setting up the software environment (HTTP server, Expect, PERL, etc.). Thus, a person with this specific programming experience could be expected to build a similar system in a significantly shorter time.

Therefore, the development costs seem to be less than what a commercial software manufacturer would charge for delivering a similar (while presumably more robust) functionality through more classic programming and networking solutions. Furthermore, the number of well qualified Web-application developers is rapidly increasing in a very competitive market. Also, the recently invented and well-publicized Java programming language (Sun Microsystems) for developing Internet-based applications can significantly simplify the development of a high-performance, object-oriented, electronic patient-record system that is distributed, secure, and architecture neutral. The rapid development of WWW sites gives hope to institutions with limited budgets that they can afford relatively low-priced, custom-tailored software development.

The system described in this article has a number of limitations and shortcomings. First, it is strictly a data-display system that has limited data-management capabilities (e.g., data storage and retrieval from a S-plus database). Second, it does not provide real-time access to the data. At best, it can display data for three minutes after acquisition. Third, it only supports the Marquette physiological monitors and provides limited access to the EEG monitors. Fourth, the system is still in its infancy with respect to its clinical acceptability and usefulness.

Future possible expansions of the system include, but are not limited to, integration of continuous real-time EEG trending (e.g., percent alpha, total power, alpha/delta ratio), laboratory test data, and the nursing charts (a costly and time-consuming paperpushing process). While applying these WWW-based tools throughout the institution, we are also exploring possibilities for transferring patient information between institutions in the framework of joint clinical and research projects. Within our ICU, we also intend to integrate these tools with COMPATHS, a COMputer Model of PATient Health Status developed in our Brain Monitoring and Modeling Laboratory.[12]

Conclusions

The recently developed WWW client-server tools support new strategies for access to patient records. We expect that mastering medical information resources, which is a standard requirement for clinicians, will become easier with the spread of WWW technologies.

The most prominent advantages provided by these technologies that we have seen so far are the ease of developing custom-tailored software tools and the cross-platform uniformity of data access, as well as the significant reduction in development time (from months to days).

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