原 著

The Use of A Perioperative Patient Information System for Improved Point-of-care Data Management

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Abstract

Electronic network of anesthesia patient information facilitates patient data flow and reduces administrative workload. We have developed a peri-operative information system which covers preoperative patient evaluation, operating room scheduling, staff assignment, electronic anesthesia record keeping, automated anesthesia billing, and quality assurance. Along with pre-, intra-, and post-operative patient data flow, each client computer and specific applications were implemented in a point-of-care setting. Analog wave form archiving and abundant perioperative database would contribute to educational and research purposes.

Implications: The system covers pre-, intra-, and post-operative phases and has several characteristics which commercial systems do not have. The system facilitated both administrative and clinical anesthesia processes.

Key words: information technology, electronic anesthesia record, perioperative data management, point-of-care

Introduction

Information technology (IT) plays an important role in economics, society, and medicine. Considering clinical anesthetic practice, patient data management, including anesthesia record keeping, is efficiently performed by IT. In the past two decades, anesthesia-related IT focused mainly on producing intra-operative electronic anesthesia record keeping system (EARK)[1,2] and pre-operative patient evaluation system[3,4]. EARK provides us not only accurate documentation of clinical anesthesia practice, but also an abundant database from which we can retrieve educational, clinical and administrative information[5~7]. Recently, the anesthesiologists' role in the hospital has become expanded from an intra-operative patient manager to a peri-operative physician. Accordingly, EARK functions are required to include pre-operative and post-operative patient information in order to be a complete peri-operative patient information system. In constructing such a system, each pre-, intra-, post-operative phase should be managed as one system by hooking up workstations of each phase to an information network rather than having stand-alone systems for each of the three phases. Although intra-operative EARK and pre-operative evaluation systems have been reported as being useful, a peri-operative anesthesia information system has not been reported.

Hospital information systems and the hospital laboratory system have relevant patent information concerning the management of anesthesia. Optimal management of anesthetic patient data is achieved by hooking up an EARK with the existing hospital information systems. Patient driven data flow and facilitation of the anesthesia working process can be

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achieved by implementing a peri-operative patient data management system at each point-of-care. Based on the above concepts, we have developed a peri-operative patient data management system called HODMS (Hokkaido University Operating Room Patient Data Management System). HODMS was developed as a basic EARK with some added attributes for pre- and post-operative management.

System structure

The system is based on a client-server principle which is a series of autonomous terminals with built-in capability to store and manipulate data. These are designed for use with Windows NT and SQL (structured query language) servers (Fig.1). Windows NT was selected as OS (operating system) for its multi-task availability and high level of security. A SQL server was selected as the system database. The system software was developed by using two programming languages, Visual Basic and Visual C++. Visual Basic was used for data input which requires consistent graphical user interface (GUI) such as menu bars, buttons and dialog boxes for off-line data entry by users. Visual C++ was used for data collection from physiological monitors and anesthesia record printing and trending. These development tools provided speedy software design and reduced the cost of programming.

Our hospital information system (HIS) uses NEC® systems for ordering and laboratory servers. HODMS and HIS are connected by four telephone cables through modems using the RS232C protocol. The interface program was specifically developed for the two systems. All the communications are triggered by HODMS. HODMS receives patient demographic, laboratory and nursing schedule data from HIS. HIS receives OR scheduling data from HODMS.

Peri-operative patient data flow and OR staff working process

Along with the anesthesia working process, corresponding application software is implemented at each point-of-care (Fig.2).

1. Pre-operative phase

a) Patient registration to HODMS

An operating room secretary enters the order of the OR schedule into HODMS. Patient demographic data and preoperative laboratory data are acquired on-line through the electronic linkage with the hospital information system and the hospital laboratory system using the patient ID. Once HODMS receives the patient information, this can be shared on the HODMS network and passed to the next point-of-care. This enables us to avoid duplicated patient information input at each point-of-care and facilitates operating room flow of patient management.

b) Operating room scheduling and staff assignments

Listed operation orders are passed to the operating room scheduling application. The head nurse manages operating room scheduling. Most of the cases are automatically assigned to blocks allocated to each department. The other cases are "dragged and dropped" from the list. In our hospital, the weekly operating room schedule for the next week is made on Thursday afternoon. Representatives from each surgical department meet and discuss the creation of the schedule. A HODMS client computer with 50 inch plasma display is located in the meeting room, and shows the weekly operating room schedule. Any alteration to the schedule is registered at that meeting and transmitted to each HODMS client through the main database server computer.

After the meeting, anesthesiologists and operating room nurses make staff assignments. Finally, once scheduling has been completed, it is sent to each surgical ward through the electronic linkage with hospital information system.

c) Pre-operative patient evaluation

All anesthesia cases, except local cases, are evaluated at the pre-anesthesia clinic. Two client HODMS computers are allocated in the pre-anesthesia clinic for pre-operative evaluation. Pre-operative evaluation information consists of history, physical examination, ASA physical status, Mallanpati grade. Patient history is entered using a keyboard, the other information is selected by clicking buttons and table lists. Pre-operative patient abnormalities are listed on the table and stored in the database server for the retrospective

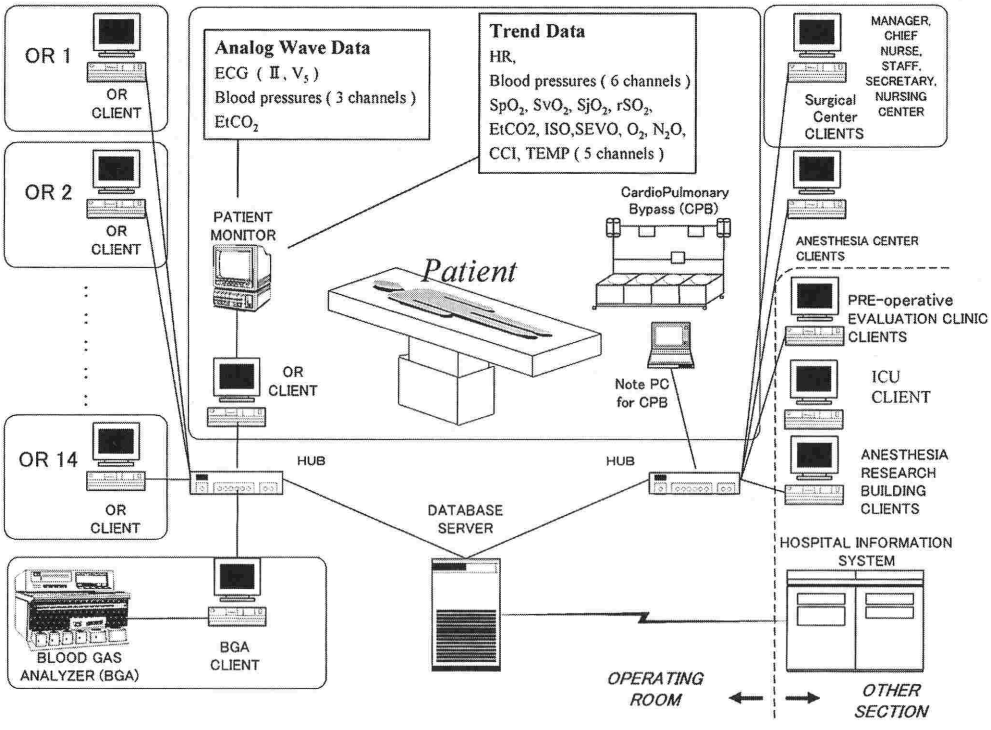

Fig.1

(1)HARDWARE

COMPUTING PLATFORM

As a main database server we have selected Hewlett Packard (HP) NetServer LX Pro which is a Pentium-based machine with a 48 GB hard disk drive. An HP NetServer LX Pro with 24GB hard disk drive was selected to support one back-up and four application servers. Trend data and wave form data files plus all other relevant data are stored in the main database server. A database backup server stores all the main database information in a real time manner. An application server stores trend and wave form files. One of the utility servers is used as a gateway communicating with hospital information system through RS232C protocol.

CLIENT PC

As a client computer, HP Vectrta with 1280MB hard disk drive was allocated to each operating room.

DISK ARRAY DRIVE

Disk drives of the servers consist of RAID5 using FastWide SCSI-2 array controllers. In case of disk crash, a stand-by backup drive activates automatically.

A/D BOARD - ANALOG TO DIGITAL CONVERTER

A peripheral Component Interconnect (PCI) is used as an A/D board. The characteristics of PCI are high conversion speed, high resolution (16 bit) and a wide variety of libraries controlled by applications. PCI makes multi-task processing possible. A sampling rate of 200 Hz used on 8 channels simultaneously results in high fidelity of digitized data. An A/D board power supply is located outside a CPU in order to avoid undesirable electromagnetic noise.

NETWORK PLATFORM

The main concerns of a backbone local area network (LAN) are speed, network availability and fidelity. We have selected Switch as a backbone 1G bps high speed bus-flexible structure with 6 port module slot. Six Port module consists of four 100VG boards, one 10 base T board and one FDDI DAS board. Main network is structured by 100 MB 100VG-AnyLAN (IEEE802.12). Network cables are Category 5 UTP cables. optical fiber cables were used for distance over 200m and longer. Demand priority method minimizes network collision and maximizes network efficiency. The operating room segment, where a number of data generated, is separated from other segments to increase network efficiency. SNMP module was applied to control network. Since connecting more than one printer to the network increases setting availability, a total of three color printers for anesthesia records were set up in the holding area but these printers are regarded as a single printer based on logic that any printing order is automatically assigned to the first available printer.

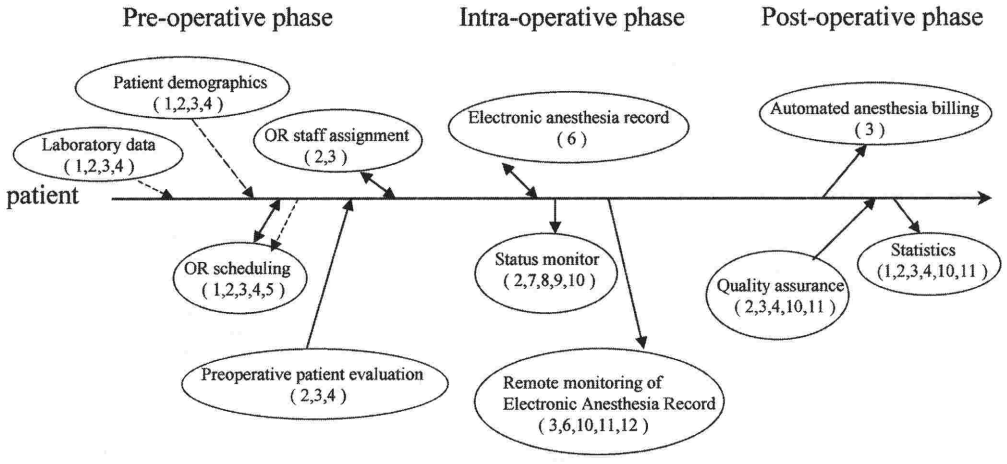

Fig.2 Patient-driven data flow in HODMS (Hokkaido University Operating Room Data Management system) throughout pre-, intra-, and post-operative phase based on the point-of-care information network.

Arrows towards patient indicate data input into HODMS, and arrows from patient indicate data output from HODMS. Dotted lines indicate the electronic linkage between HODMS and hospital information systems.

analysis. These pre-operative data are available at each HODMS client computer both in the operating room and anesthesia center.

2. Intra-operative phase

a) EARK

On the day of anesthesia, a HODMS client computer in each operating room shows patients assigned to the specific room. Patients assigned to other rooms are not shown. This feature prevents errors in patient identification. Anesthesiologists select the patient on the screen and the EARK is initiated. Almost all the anesthesia related monitoring data are integrated into a single patient monitoring display. Through the RS 232C protocol, all the monitoring data are fed into a client computer thus creating electronic anesthesia record trends. These on line acquired physiological data are shown in Fig.1.

With respect to the spatial configuration of the system, both the monitor display and the anesthesia record display are situated together at the right front side of the anesthesiologist. This setting enables the anesthesiologist to observe the patient, vital signs and the anesthesia record without turning around. Off -line data, such as drugs, fluids, remarks are input through a touch screen or a mouse depending on user's preference.

At the end of each case, anesthesia records are printed out through network printers allocated in both the anesthesia center and the patient discharge areas.

3. Post-operative phase

a) Quality assurance

On the day post anesthesia, anesthesiologists visit patients and inquire about anesthesia outcome and the patient's satisfaction. Major anesthesia-related complications are listed. Patient satisfaction is evaluated by 10 point scale. Anesthesiologists bring hard copies of the questionnaires and check sheets. These postoperative data also are entered into HODMS for quality assurance. Checked sheets are stored in the anesthesia clinic for the proof of delivery of service and billing. In Japan, health care insurance system allows us to add administrative charge when pre-operative and pos-

toperative patient evaluation are performed and documented.

b) Automated anesthesia billing

A complete anesthesia record contains all the variables that are required for anesthesia billing. The EARK contains information regarding anesthetic technique, anesthesia time, monitoring devices, cardiopulmonary bypass, one lung ventilation, induced hypotension and other technical data. This information is used in anesthesia billing. We have developed a billing program based on the "Ika Tensu Hyou" which is a Japanese billing protocol installed in our system.

All the monitoring devices are on-line linked with a client computer and monitoring parameters such as direct arterial blood pressure, CVP, SpO_2, $ETCO_2$, blood gas analysis and others are automatically recognized by the server computer and are processed for billing of monitoring provided.

The billing related variables are automatically checked and processed in the algorithm and resulted in the final statements of account. The billing sheets are printed out on a day after anesthesia and sent to the administrative office. We are planning to create an electronic hook-up with the administrative office.

Table 1. shows a one month comparison between hand-written billing and automated billing. The loss of errors in incomplete out billing sheets amounts to about $25,000 per month. Based on the assumption that the loss of billing in each month is approximately the same as the surveyed month, the automated billing system might save $300,000 per year.

Discussion

Electronic patient data flow in the anesthesia work place facilitates both administrative and clinical processes. Implementation of a peri-operative information system benefits not only anesthesiologists but also nurses and administrators by reducing their workload and saving lost of billings. Unless a functional perioperative patient information system is implemented, multiple repetitions of patient demographic data entry is necessary for a surgical scheduling. The introduction of HODMS and the electronic linkage with HIS has solved problem of the cumbersome repetitive data entry into many stand-alone systems.

In terms of evidence-based- medicine (EBM) , multi-variance cross-patient data retrieval from a huge database enables us to statistically analyze and evaluate our clinical anesthesia practice. One of the advantages of an electronic patient database is easy and rapid cross-patient information retrieval.

From the view point of crisis management, room-to-room, room-to-anesthesia center and room-to-office remote reference of the on-going electronic anesthesia records play an important roll in supervising anesthesia residents and high-risk cases. Most of our staff anesthesiologists have experienced near-mishaps prevented by the early detection by the remote reference function. After the implementation of HODMS, we have had no anesthesia related serious mishaps.

Each year, before the implementation of HODMS, in a government audit of anesthesia billing, about 100 cases were identified as "loss of billing cases". After implementing the automated anesthesia billing function, this was reduced to zero.

Many manufacturers and institutes have developed and introduced a variety of EARKs[8,9]. Although each EARK has characteristics dependent on the operating system (OS), man-machine interface, network structure and a multiplicity of other factors, the basic purpose of EARKs have been to facilitate the anesthesiologists' working process with a resulting increase in vigilance and improved patient outcomes.

HODMS differs from other commercial RARKs in the following ways;

1) Analog wave form archiving for 4 weeks.

The HODMS server can store analog wave forms of ECG, arterial blood pressure, CVP, and $ETCO_2$ in the main database server hard disk for up to 4 weeks. After 4 weeks, these analog waveforms are recorded on digital analog tape (DAT) for permanent storage and the hard disk data is erased. Commercially available central waveform archiving systems can store these wave form data for only 48 hours. It is usually difficult to transmit analog waveform data to other storage devices from current commercial systems. Besides the longer storage period, we can analyze the cause of arrhythmia or ischemic ST

segment change compared with intraoperative anesthesia management recorded data, drug usage, and fluid management. This feature is useful at case conference, case reports and anesthesia resident teaching.

2) Point-of-care networking through pre-, intra-, post-operative phases.

Most of the commercial systems are stand-alone intraoperative EARK. Several institutes are implementing preoperative evaluation systems or postoperative quality assurance systems. These have been shown to be useful systems, but generally are not established networking systems through pre-, intra- and post-operative aspects of our working environment. In HODMS, we have designed and equipped client computers with applications for each point-of-care. This point-of-care networking reduces operating room staff workload, increases efficiency and facilitates patient data management.

3) Automated anesthesia billing

In addition to identifying missed billings, the automated system from EARK has provided more accurate calculation of anesthesia fees than was achieved manually (Table 1). In the Japanese health care insurance system, anesthesia billing is packaged into the surgical fee, so that the anesthesiologist's economic activity has been masked for many years. By using this system, we can demonstrate our economic activity to hospital administration and negotiate funding for the system. The automated anesthesia billing system facilitates accuracy in billing and reduced distractions of a cumbersome manual billing sheet. In terms of cost-effectiveness analysis, the system pays for itself just by identifying missed billing opportunities. The system makes the anesthesiologists' economic contribution to the hospital more apparent.

In Japan, we have only one anesthesia billing protocol for government administered insurance, but in the United States, there are several different providers such as Medicare, Medicaid and private billing. In these circumstances, anesthesia billing might be complex and time-consuming. We assume that HODMS automated billing could play significant role, if implemented in the United States.

4) Multi-variance, cross-patient data retrieval

In most commercial systems, data retrieval is usually limited. For example, patient by patient data retrieval or limited variables such as blood pressure, SpO_2. In HODMS, we can retrieve by all the electronic variables stored through out the pre-, intra-, post-operative phases in cross-patient manner. For example, if enter a query of cardiovascular patients who were given plasma protein fraction from April 1999 to May 2000, HODMS lists the data within 15 seconds. We can trace the incidence of postoperative nausea and vomiting when compared with intra-operative droperidol administration. Such multi-variance cross-patient data retrieval will be useful in EBM in clinical anesthesia.

In conclusion, the development and implementation of an electronic peri-operative anesthesia patient data management system in our university hospital has

Table 1 Comparison between hand writing billing and automated billing. 251 cases were surveyed in June 1997.

Variables	Number of lost cases in hand writing billing	Loss of billing($)
Induced hypotension	4	6,100
prone position	3	2,881
anesthesia time	22	1,710
combined epidural	4	260
cardiac anesthesia	1	940
diferential ventilation	5	4,660
induced hypothermia	5	8,662
Total	44	255,413

succeeded in a clinical anesthesia setting. The efficacy of HODMS has been demonstrated both in the clinical and administrative areas. HODMS has changed the conventional anesthesia-related working process by re-structuring the patient data flow management. In the future, with the wide spread use of HODMS in other institutions, a national anesthesia database will be structured that will allow inter-institutional comparisons that will drive improvement of anesthesia patient care.

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