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Automated Anesthesia Record Keeping by Engineering Work Station Four Years Experience

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Abstract

Although automated anesthesia record keeping (AARK) is gradually spreading through anesthesia practice, there are only three institutions that use AARK in Japan. Our institution developed and implemented an AARK engineering work station in 1992 after three years preliminary trial. Physiological monitors, anesthetic gas concentration, blood gas analysis, and electrolytes are interfaced with each computer. Drug administration, fluids, events, and remarks are input through a touch screen. These on-line and off-line inputs into a computer workstation result in a electronic anesthesia record with more complete information than is available from a conventional hand written anesthesia record. Colored anesthesia records are printed out at the end of the case. Remote reference of other rooms' trends is recognized as a useful tool of supervision. Survey proved that most of the anesthesiologists in our department preferred AARK. The system has several areas to be improved if it is to become an anesthesia information system that include pre- and post-operative patients' data for quality assurance process, billing, and inventory.

Key words : Records, Anesthesia. Monitoring: automated record keeping

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Introduction

We have developed a new, automated anesthesia record keeping system combined with an anesthesia work station and have been using the system in clinical practice since September 1992. During these four years, over 10000 cases have been recorded. In this report we will introduce our system, describe its advantages and weak points, and report the results of surveys to evaluate the system.

Anesthesiologists receive large amounts of information from patient monitors which must be entered manually on an anesthesia chart. The amount of information available may be overwhelming at times and either unconsciously or purposely, anesthesiologists may edit the information included on the record[1]. The aim of the AARK system is to keep accurate and objective anesthesia records. The system frees anesthesiologists from the charting chore and allows them to pay more attention to the patient. All records generated by the AARK system are stored in a hard disc. In the future, we are planning to extend the network throughout the University Hospital Information Center.

System design and characteristics

DOMAIN system is the distributed processing system for the purpose of both general and interactive graphic applications and sets of powerful personal-workstations and server computers interconnected on high performance local area network. Fig.1 shows an

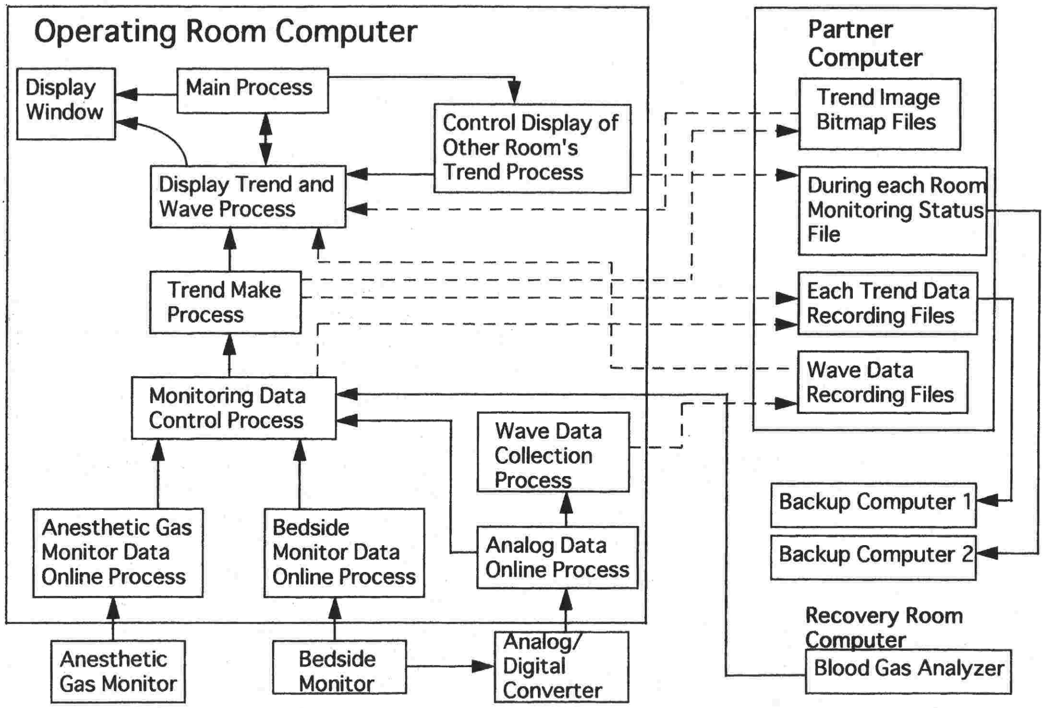

Fig. 1 Overview of process and dataflow on the computer work station of operating room.

overview of process and dataflow on the computer workstation of the operating room. Each workstation is a single user computer with a high resolution bitmap-display and an hard disk. Each server-computer is organized as the control server for peripheral equipment and the file server or gateway to other networks. Every workstation and server-computer share common network wide demand paging virtual memory system based on the concept of object. This system provides users and programs with the environment which is able to access every system resource uniformly and indifferently to the location on the network. This enables us to check remote references of other operating room's trend. The bit map-graphics-terminal of each user can display texts of multi-fonts and graphic outputs, and execute the independent program at the same time on the multi-windows. Each program can display outputs to the own window. Fig.2 shows the scheme of the hardware in the central server. The host computer is consisted of a Hewlett Packard (DN 3500, Kawasaki, Japan) set up with 697 M byte hard disc drive. Another host computer is constantly working for backup of the system. Fifteen disk less computers compose the local area network (LAN) using the token passing ring net. The basic operation system (OS) is AEGIS using PASCAL as a programming language. An anesthesia trend graph is shown on a 15 inch color display in each operating room. Invasive blood pressures are sampled every four seconds. The values are filtered by one minute running average and stored every one minute. Signal validation and rejection are accomplished by the programmed algorithm.

The patient's demographic data is downloaded to the system by a secretary on a day before anesthesia. Several characteristics of the system are as follows:

(a) Trended output from monitors

Trended real-time records are shown on a 15 inch color display, including ECG and blood pressure wave forms. It is possible to trend these wave forms and to print them out within 24 hours.

(b) Intuitive data entry

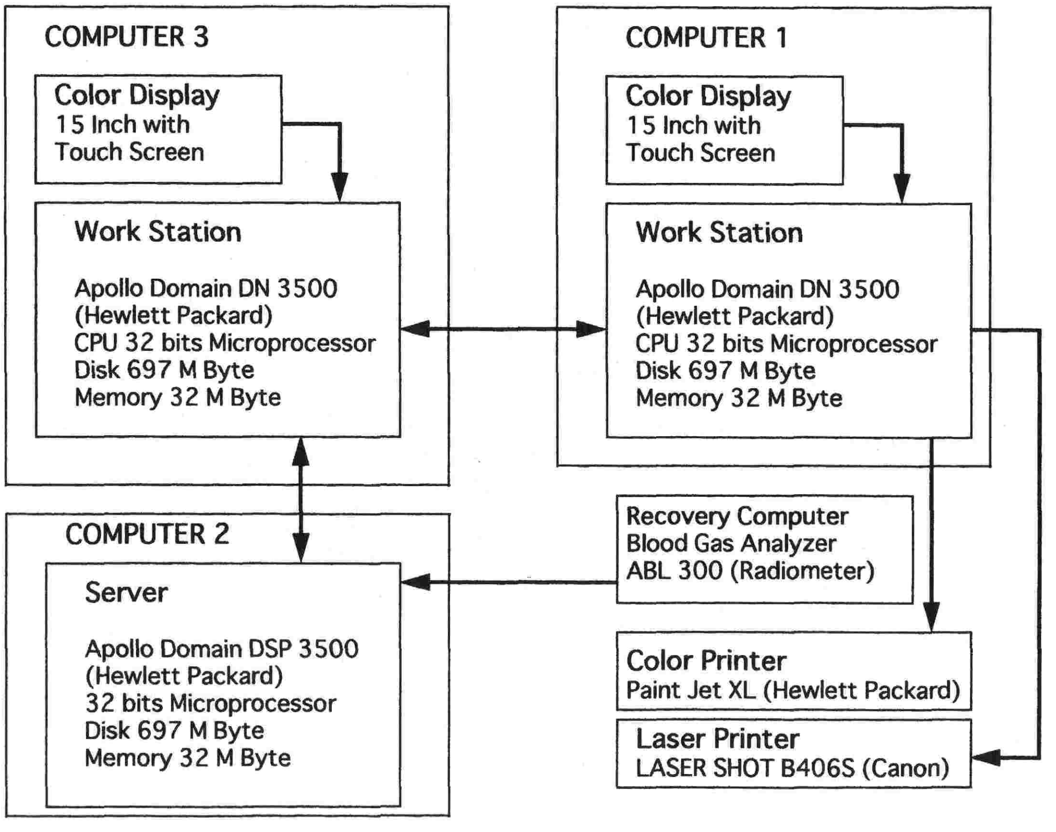

Fig. 2 Structure of hardware (anesthesia center).

The user interface and data entry are intuitive. For data entry, we use a multi-window touch screen on the display. We consider that a key board and a mouse are not appropriate interfaces in the operating room where sticky fluids and blood products may spill. Events, drugs, fluids, blood loss and remarks are entered through the touch screen. This man-machine interface is easy to learn for novice users.

(c) Drugs

Drugs are classified according to their pharmacological characteristics. This classification facilitates drug selection. Drugs administered in a repetitive manner are entered in the DRUG column. Single use drugs are entered in the SPOT DRUG column.

(d) Flexible program expansion

The computer is interfaced with several devices and monitors. Fig.3 shows the structure of hardware in each operating room. On-line linked variables are ECG, invasive and noninvasive blood pressures including arterial tonometry, central venous pressure, pulmonary artery pressure, heart rate, SaO_2 by pulse oximetry (SpO_2), end-tidal carbon dioxide concentration ($ETCO_2$), anesthetic gas concentrations, respiratory rate, body temperature, blood gas analysis and electrolytes. In the cardiovascular operating room, continuous cardiac output and mixed venous oxygen saturation values, 6 channel blood pressure (Two radials, superficial temporal, femoral and pulmonary arteries and CVP) and 5 channel temperature (esophageal, bladder, rectal, forehead and foot) modules are included. Greater interfacing with devices and monitors decrease manual data entry.

Interfacing with new monitoring devices in the operating room may cause a problem with some programming. Our program AEGIS uses PASCAL and has high extensibility. The system provides an easy

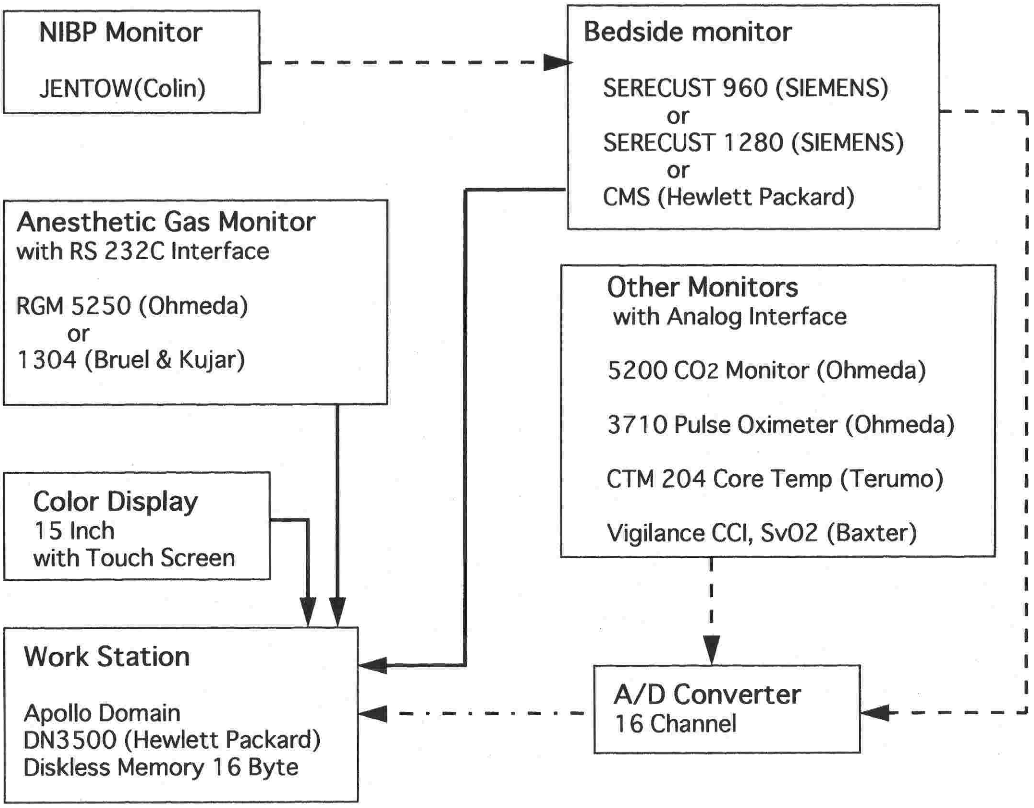

Fig. 3 Structure of hardware (operating room).

interface with an anesthesia gas monitor, an arterial tonometer and others. Table 1. shows physiological monitoring devices used in the system.

(e) Multi-task function

The system can operate 54 tasks simultaneously. Priority for interruption processing is so clear in this network that data collision seldom occurs.

(f) Restart function

In case of a computer crash, the system is provided with a re-start function. By turning off the power supply and then turning it back on, we can choose a re-start menu on the touch screen. The trends until the crash are stored and we can continue to record the anesthesia chart. But the trends during the crash period are not documented. This period is usually less than 5 minutes.

(g) Remote reference of other operating rooms

In the anesthesia center, we can monitor anesthesia

Table 1 Pysiological monitoring devices and computers which comprise the system.

Components of the system
Computer
Apollo Domain DN3500 (Hewlett Packard, Andover, MA, USA)
Physiological monitors
Primary monitor
SERECUST 960, 1280 (Siemens, Danvers, MA, USA)
CMS (Hewlett Packard, Andover, MA, USA)
Respiratory gas monitor
RGM5250 (Ohmeda, Madison, WI, USA)
1304 (Bruel & Kjaer, Naerum, Denmark)
NIBP monitor
JENTOW (Nippon Colin, Komaki, Japan)
Cardiac output & Svo_2
Vigilance (Baxter, Irvine, CA, USA)
Core Temperature
CTM 204 (Terumo, Tokyo, Ja

records of a specific room or all rooms. Cross-reference between computer workstation is possible. When a staff anesthesiologist is supervising two rooms, he or she can get information about what's going on in the other room.

(h) LAN with laboratory and intensive care unit

Blood gas analysis and electrolyte data (Na, K, Cl, Ca, pH, P_{CO_2}, P_{O_2}, H_{CO_3}, base excess, hemoglobin, hematocrit, blood sugar) are on- line linked with computer workstation. Laboratory data are shown on the computer workstation. Two cardiovascular operating rooms are on-line linked with intensive care unit. ECG, blood pressure wave forms are simultaneously observed in the ICU and can be stored in a computer of the ICU.

(i) Colored anesthesia record

At the end of anesthesia, a letter-sized anesthesia record is printed out using a laser jet printer (Hewlett-Packard). It takes about 3 minutes to complete. Fig.4 shows a representative computer-made anesthesia record. Operation time, anesthesia time, drugs and fluids balance are automatically calculated at the end of anesthesia and printed out on a chart.

During cardiovascular cases, 6 channel blood pressure and 5 channel temperature records can be printed out in addition to the usual anesthesia record (Fig.5). Information about anesthesia time, anesthesia method, agents, catheters and others are automatically printed in the right column of the anesthesia record. These variables can be utilized as a source of automated billing and inventory.

(j)Retrieval

For data retrieval, we can use any variables such as name, date, surgical procedure, blood loss and others. Retrieval is usually completed within 15 minutes. The anesthesia record can be reprinted anytime. ECG and blood pressure wave forms can be retrieved within 24 hours because of the limited capacity of the hard disc. The trended data can be stored for three years.

(k) Anesthesia report

Daily and monthly anesthesia reports are also automatically made. Patient's ID, name, age, gender, date of surgery, diagnosis, surgical procedure, proposed surgical time, real surgical time, and anesthesia time, are gathered from pre-operative and intra-operative data and integrated into anesthesia report. Recently we have developed a program to calculate the difference between proposed and real surgical time. We are using the data to improve operating room utilization and for warning to some surgical staff.

Survey

In order to evaluate the system 14 anesthesia residents and 10 staff anesthesiologists were surveyed. Comparison between a handwritten and an automated anesthesia records were judged using a three grade scale: inferior, fair, superior (Table 2). The accuracy of the automated anesthesia record was felt to be fair by 50 % residents and staff anesthesiologists. Forty % residents and 50% staffs deemed it inferior in accuracy mainly due to artifacts. Spatial configuration was deemed inferior by 70 % of staff. We must turn our back toward patients during data input. Legibility was deemed differently by each individual anesthesiologist. Learning period was 1 to 2 weeks both in residents and in staffs. They learn this system in the operating room caring patients. Over 90 % anesthesiologists preferred the automated anesthesia record keeping on the condition that accuracy and spatial configuration would be improved.

Discussion

Since the 1980's some anesthesiologists have regarded AARK as a useful tool that can improve vigilance, medico-legal defense, education, and administration[2~7]. After three years of trial at a satellite hospital, we pioneered the implementation of AARK in the operating rooms of Hokkaido University Hospital in 1990. During the first two years following the introduction of the AARK system, both hand-written and automated anesthesia records were kept. In September 1992, we eliminated the use of hand-written records. In response to our requests a system engineer has improved troublesome aspects of the system, however the system continues to have some problems. We have lost 1.5 % records because of touch screen dysfunction and network accidents. In these cases, anesthesia records were kept by a conventional hand-

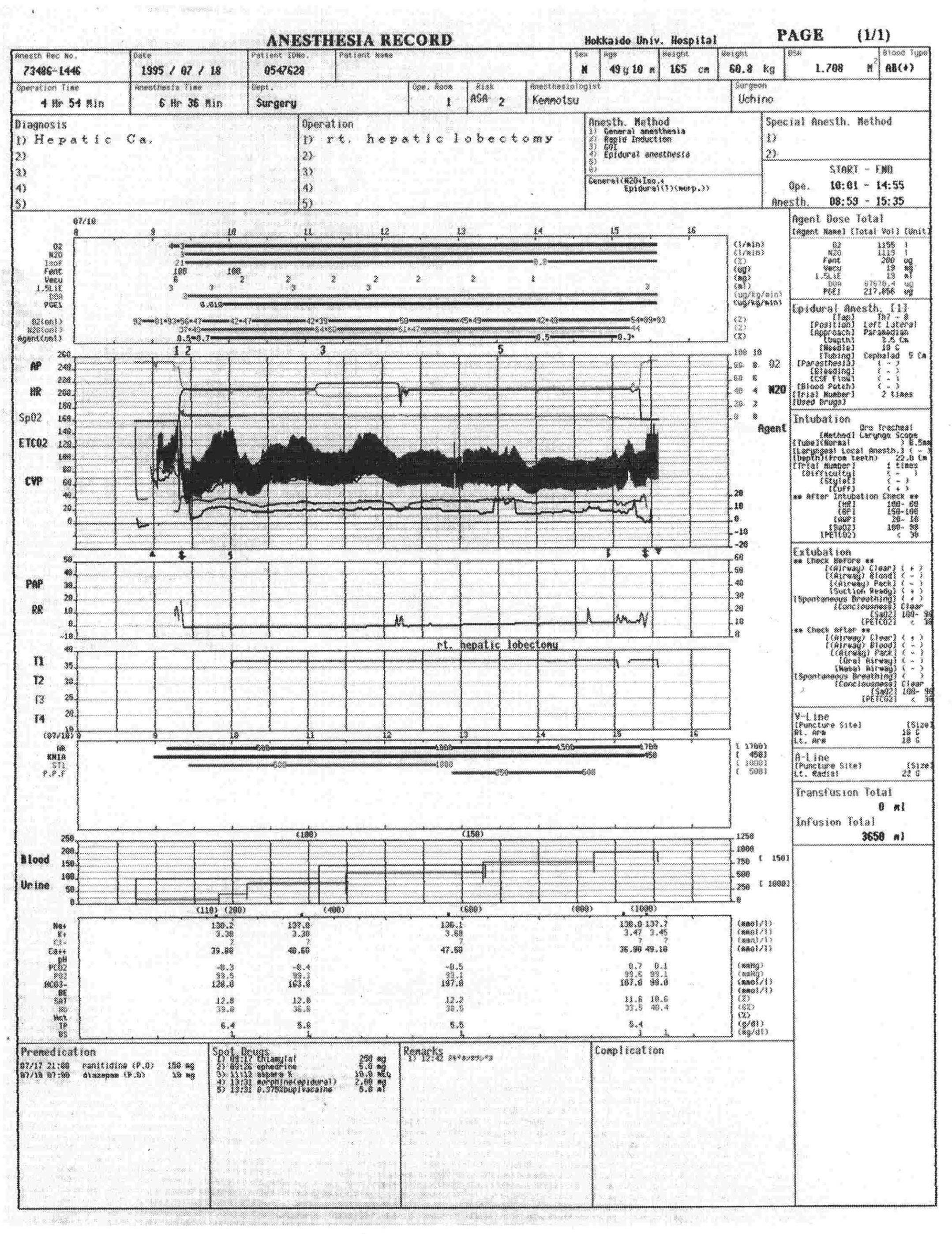

Fig. 4 Colored anesthesia record.

Total amount of agents, information about intubation, extubation, epidural anesthesia, intravenous line, arterial line, Swan-Ganz catheter, and central venous line are printed in the right column of anesthesia record.

written method. In case of network accidents, record-keeping can be re-started, but during these periods of time when the system is down anesthesia records are not documented. Artifacts can be caused by electrical

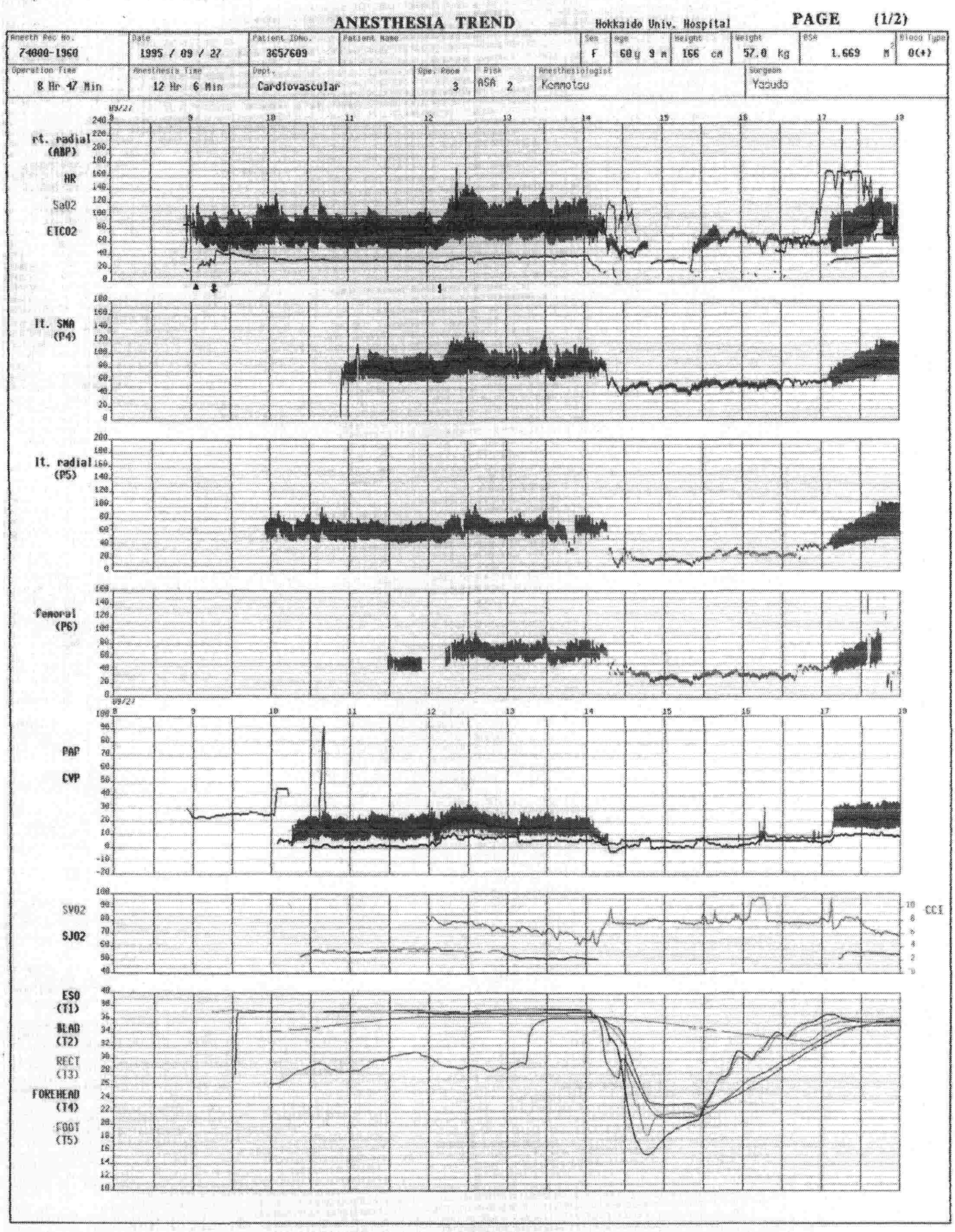

Fig. 5 Cardiac anesthesia record.

6 channel blood pressure, 5 channel temperature, continuous cardiac output are indicated. Standard format anesthesia record is also printed out.

interference in the operating room. This mainly affects the ECG monitors resulting in scattered heart rate recordings. Currently heart rate is determined from a pulse oximeter because ECG is more susceptible to

Table 2 Survey. Interview with 14 anesthesia residents and 10 staff anesthesiologists.

	Accuracy and objectivity			Legibility			Spatial configuration			Vigilance			Database construction		
Grade	Inferior	Fair	Superior	Inferior	Fair	Superior	Inferior	Fair	Superior	Inferior	Fair	Superior	Inferior	Fair	Superior
Resident	50	50	0	35	20	25	50	25	25	20	60	20	55	35	10
Staff	40	50	10	30	30	40	70	10	20	10	90	0	40	20	40

	Learning period				Prospective preference	
	Days	1week	2weeks	1month	Hand writing	Automated
Resident	0	30	50	20	10	90
Staff	10	40	40	10	0	100

Values are expressed as %

electrical interference.

Whenever possible equipment which is invulnerable to electrical interference should be selected. If the pulse oximeter fails, the program will switch to determine heart rates from ECG.

Time delays and touch sensor errors can occur especially in novice users and appropriate training is important. It takes approximately two weeks for an individual to get acquainted with the system. Since most anesthesiologists do not specialize in computer engineering, system engineers should be available to provide technical support. The system was constructed by a single system engineer in our institution. Consequently the system may appear to be a black box to other system engineers to say nothing of anesthesiologists. Close co-operation between anesthesiologists and system engineers is mandatory to improve the system.

A structured database that meets our institutional needs remains to be developed. The current system has limited retrieval programs and does not function optimally. For example, circulating nurses check a billing sheet that includes drugs, monitors, anesthetic procedures, fluids, blood transfusions, surgical procedures, and surgical materials with the exception of surgical procedures and materials, all the other items can be entered using the automated anesthesia record keeping system by the anesthesiologist. If there is a on-line link with billing office, there would be no need for nurses to also enter this information. Also the system has no link with our hospital information system, so preoperative patient's information such as identification number, name, gender, and laboratory data must be input by a secretary. Developing a local area network (LAN) with the hospital information system will reduce work load by avoiding duplication of data input.

There are criticisms of the automated anesthesia record[8~10]. Anesthesiologists may become too involved in generating the anesthesia record and vigilance may wane because there is no need to write vital signs. We think that these criticisms may be true of junior residents. But in our experience, senior residents and staff anesthesiologists are satisfied with the system.

After implementing the system, we have had no serious anesthesia-related mishaps. In case of medico legal problems, the automated record may be helpful because it provides a clear, accurate record[11].

This system also provides a central trend display that is useful for a clinical director supervising the operating rooms. We have had several near-miss situations in which serious sequelae were prevented because the clinical director had noticed problems developing on the central trend display. Quality assurance issues may be processed in a more efficient manner using the database[12~14]. From our four years experience, three major areas of record-keeping appeared to be improved. (1) physiologically convenient spatial configuration, (2) useful database construction for quality assurance, (3) LAN with hospital information system including automated billing and inventory. However, AARK itself does not automatically solve record-keeping problems[15] and the system must be well-designed, if it is to be effective and efficient. We are planning to design a new anesthesia information system which will address these problems. Downsizing, open system, and user friendly man-machine interface with high fidelity will be indispensable in a new system, which we expect will allow increased vigilance, man power reduction, and improvement in patients' care.

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