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The anesthesia information management system for electronic documentation: what are we waiting for?

Eric L. Bloomfield and Neil G. Feinglass

Department of Anesthesiology, Mayo Clinic, Jacksonville, FL, USA

Abstract
The anesthesia information management system (AIMS) will be part of the future of healthcare. An electronic medical records system or AIMS will provide clear and concise information and have the potential to integrate information across the entire hospital system, improve quality of care, reduce errors, decrease risks, and improve revenue capture. The practice of anesthesia requires a medical record system that can capture data in real time. In this article, we describe challenges that must be overcome to establish an efficient electronic medical record system for anesthesiology.

Key words Anesthesia · Data collection · Decision support · Electronic medical record

Introduction

A 2003 report from the Institute of Medicine in the United States outlined a plan for the total automation of hospital record-keeping [1]. The report outlined eight criteria: (1) health information and management, (2) results management, (3) order management, (4) decision support, (5) electronic communication and connectivity, (6) patient support, (7) administrative process and reporting, and (8) reporting and population health. Over the past 15 years, reasons for making the transition to the electronic collection of hospital records have included quality improvement, reduction of medical errors, improved documentation (for legal reasons), and accurate bill capture. However, computerized documentation in the healthcare industry has lagged behind the business sector [2]. The reasons for this delay are not always clear, but may include initial costs, resistance of healthcare workers to change, and difficulty with integration with other information systems in the hospital. In 2004, the United States government established the Office of Health Information Technology to encourage healthcare organizations to adopt new information technologies and to expedite the implementation of these systems.

Because anesthesia records must be kept on a minute-by-minute basis [3], anesthesia providers are expected to document patient care details while administering an anesthesia protocol. Manually documented anesthesia records often lack pertinent and valuable information [4]. As described by Hamilton [5], an electronic medical record (EMR) or anesthesia information management system (AIMS) is inevitable, for three reasons: (1) information in electronic form is clear and concise; (2) electronic forms can be readily transferred to hard copy when needed; and (3) manual records can be biased, incomplete, illegible, and may divert the provider's attention from the anesthesia vigilance. These ideas have been echoed by professional component anesthesia societies and prominent members of the specialty. An AIMS could thus ease the burden of simultaneously monitoring and documenting.

In this article, we examine the unique requirements of a successful AIMS for anesthesia record-keeping. Preoperative, intraoperative, and postoperative considerations of the medical record and decision-making methods will affect the design, deployment, and implementation of an electronic documentation system for anesthesia providers.

AIMS and reasons for its use

For many hospital administrators and chief executive officers, the operating room is a black box. Patients may have common diagnoses and undergo common surgical procedures, but they often have diverse outcomes and

Address correspondence to: E.L. Bloomfield, Department of Anesthesiology/CCM, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA
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different costs associated with their care. The reasons for the disparity are often multifaceted and not well defined. The current medical records system lacks the ability to define and compare outliers, thereby hindering analysis. Furthermore, many medical centers must maintain the high level of care in their practices without effecting change (operating at fixed costs), while reimbursement continually decreases relative to inflation (capitated markets) [6–9]. An AIMS potentially can bridge this economic gap by providing critical data useful for scheduling, operating room use, material management, and improved use of resources in a declining reimbursement environment.

The electronic revolution enters this environment. As a medical specialty, anesthesia has always embraced new technologies, such as the automated blood pressure cuff, invasive monitoring, and monitors that record physiologic trends. Early anesthesia record-keepers were able to obtain data from monitors, and anesthesiologists were able to create an electronic record instead of a paper record [10]. The layout of the electronic record was similar to that of the customary paper record, thereby providing a format that was familiar to the anesthesiologist.

With an AIMS, in addition to physiologic data, other information such as surgical time, cost of medication, resources used, and quality assurance data can be recorded. Many departments have described their experiences with these systems and reported the corresponding cost-efficiencies that resulted from electronic data collation and the use of a simulation model [7,8]. Moreover, electronic systems can search for patient allergies or identify improper drug dosages or contraindications. The system can verify provider attendance during procedures, as required by the Health Care Financing Administration in the United States. In addition, some systems (institutionally or commercially developed) offer a preoperative data entry system that can store anesthetic histories and physical examination findings, and may be used to review preoperative laboratory data and medical histories.

The ergonomics of newer AIMS have improved as computer technology has advanced; in contrast to the traditional keyboard method of data entry, barcoded materials and data entry with a touch screen or mouse are now available [11,12], and voice-activated systems are being refined. Electronic delivery systems allow the caregiver to administer medication without manually documenting the entry [13]. These systems are electronically linked to the anesthesia equipment at the point of care, but departments can also use them to document anesthesia procedures in various locations [14–17].

Monitoring equipment typically sends data in a unique and proprietary format through its RS232 ports. Newer monitors adhere to a common standard (e.g., universal serial bus [USB]), and today's AIMS can collate and analyze data. Many of these physiologic monitors are linked via a network (e.g., local area network or intranet) to servers that retain backup copies of the data. Duplicate copies of data are required for the mission-critical function of the operating room.

Many AIMSs are compatible with Health Level 7 standards, such as ours at Mayo Clinic Jacksonville, and hope to offer seamless interfacing with other hospital systems such as the laboratory or billing departments. Unfortunately, many hospital systems continue to use older versions of software that are less capable of interfacing with newer AIMSs. In addition, many early EMR system vendors were small companies with limited resources that became overwhelmed with the complexity of the tasks generated by an AIMS. Thus, even the "best-of-breed" systems with great potential failed to fulfill the requirements of documenting anesthesia procedures, and companies had limited capital to continue upgrading products and providing support to clients. Today, only seven or eight companies are developing AIMSs. These companies are usually outgrowths of electronic monitoring companies or anesthesia equipment vendors. These companies produce proprietary systems that require the additional purchase of specific monitoring equipment or database systems. Moreover, integration with older anesthesia equipment is often time-consuming and costly and is discouraged in favor of purchasing newer products. Even with numerous refinements, complete interfacing among the medical center systems and the AIMS is difficult, and the level of communication with the central data repository of the hospital is often underestimated. These difficulties must be taken into consideration as hospitals incorporate the United States Institute of Medicine guidelines (described below) for developing and establishing health system-wide EMRs.

In the future, patients will hopefully be able to interact with the anesthesia department from remote locations by using securely encrypted Web sites. Physical examination findings and digital images of the patient's airway may be stored and easily retrieved during surgical preparation and these data will also ensure that the correct patient is undergoing the correct surgery. This system may reduce system-level errors and increase patient confidence [18].

The United States Institute of Medicine Guidelines for an electronic health record system

The Institute of Medicine in the United States issued a report in 2003 that detailed the key capabilities of an EMR system [1]. It should provide: (1) longitudinal

collection of patient data; (2) immediate access by authorized users; (3) information to aid in decision-making throughout the continuum of patient care; and (4) support for efficient healthcare delivery. The guidelines further divided the EMR into primary and secondary applications [1]. Patient care, management, support processes, financial and administrative processes, and patient self-management are considered primary applications. Secondary applications include education, regulation, research, public health, and policy support.

Primary application of an AIMS would omit patient self-management, but otherwise would comply with the guidelines described above. Similarly, secondary applications would also include education, regulation, and research. If an AIMS had a greater role, one could argue favorably about its role in public health and policy support. Both public policy and public health are affected by the issue of what types of providers administer anesthesia. Aspects of anesthesiology that are important to public health (for example, whether changes in the quality of care occur when anesthesia is administered by a physician, a nurse anesthetist, or a physician and nurse anesthetist as a team, as performed in the United States and some European countries) can be analyzed using data from an AIMS. Furthermore, the role of the anesthesiologist assistant is evolving, and an AIMS may help define it. The increased accuracy in documentation that would result from the use of an AIMS will be necessary to determine policy support of an anesthesia care team.

The Institute of Medicine has recommended time lines for the implementation of electronic medical record keeping [1]. Guidelines for implementing an electronic system to record health data, results management, and order entry, as well as improve electronic communication, decision support, patient support, administrative processes, and population health management reporting, are slated for completion by the year 2010. The United States government has also supported an aggressive time line. Will this happen? Or will skeptics still rule the playing field?

Advantages of an AIMS

The patient record is extremely important and must be carefully chronicled with every anesthetic procedure. The anesthetic record is used for patient care during anesthesia administration and in the postanesthesia care unit (PACU), the intensive care unit (ICU), and the postsurgical ward [4]. The recorded information is used for billing, tabulating patient statistics, and reviewing previous anesthetic procedures. Finally, advances in quality improvement methods assist in peer review and legal defense.

There are many advantages of an AIMS, including (1) capturing data in real time; (2) alerting the anesthesia provider of deviations from preset physiologic limits; (3) communicating with various patient databases; and (4) generating an accurate, understandable record at the end of the procedure [19]. In certain instances, the EMR has enabled the identification of missing or incorrect data and thereby led to quality improvement [20]. A study of manual and automated documentation during anesthesia procedures showed that, with an AIMS, 18.7% of anesthesia administrations had recorded adverse events versus 5.7% of administrations documented manually [21]. Additional advantages of EMRs over manual records include immediate and simultaneous data access for authorized users, error checking, recovery of files from backup sources, definitions of billing and patient care for database entry, and integration of records into a searchable patient database [20]. Table 1 provides example functions of an AIMS. Moreover, an AIMS can overcome problems with illegible handwriting and transcription errors [19–21]. Nevertheless, electronic record-keeping systems do

Table 1. Functions of an anesthesia information management system

Automated collection of physiologic data from the operating room in flowsheet format (a time-honored format designed by Harvey Cushing, circa 1900s)
Mission-critical functionality
Emergency provisions for charting
Database for queries and analysis
Electronic billing
Cost analysis
Ability to print hard copies (black and white or color; 1- or 2-sided pages)
Electronic signature (e.g., authentication by biometric characteristic or password)
Secure data entry, storage, transfer, and access
Audit trails
Preoperative and postoperative documentation
Procedure documentation (e.g., central venous pressure, epidural anesthesia, spinal anesthesia, regional block anesthesia)
Ability to use in remote areas distant from the operating room (e.g., endoscopy suite, radiology suite, emergency department)
Full integration with other systems in the medical center (or well interfaced)

fail from time to time, although that frequency is not documented. Everyone must be prepared to document manually if the AIMS is unavailable.

Total integration of an AIMS into the hospital information network

Hospital administrators must consider merging an AIMS into the main body of the information network as a totally integrated system instead of an interfaced system. First, data should have seamless passage from one area or specialty to another. For example, after echocardiography is performed in the cardiology suite, images should be instantly accessible by the anesthesia provider evaluating the patient for surgery. Similarly, the anesthesia provider should be able to access laboratory data, consultations, pulmonary function test results, and patient history at any time.

Second, the resources required to support an integrated system are reduced when compared with maintaining an interfaced system because the information management team can be centralized with the mission to keep the whole system functioning. Otherwise, each proprietary system would require product-specific technology specialists for service. For AIMSs, which have a mission-critical function, the technical support staff would need to be available on a 24-h basis, resulting in high personnel costs.

Third, if a fully integrated medical system is supported by a large medical informatics vendor, future upgrades and improvements can reasonably be assured. Some vendors offer real-time data acquisition that can be integrated with other aspects of the hospital information system, but many vendors do not. However, if products from multiple vendors are used in a nonintegrated system, upgrades may be difficult or impossible. For example, a newly acquired piece of operating room equipment (e.g., a system to record and view radiographic studies or transesophageal echocardiography images) may be only partially supported by a company for integration into its monitoring system. The AIMS vendor would need to create a driver to help interpret the data recorded by this device or to import data. Ensuring timely access to data can be a concern, but such problems can be solved by sharing data within networks only on an intermittent basis. Networks currently are designed with a gigabit network bandwidth to ensure that data access is not compromised by the retrieval of information by others. Echocardiographic and other radiology studies are accessible through a separate network backbone. In both integrated platforms and interfaced platforms, a high-gigabit network bandwidth enables one to transfer data from elsewhere without interrupting data capture with AIMS.

Fourth, a fully integrated system provides the ability to analyze how the process of anesthesia and surgery fit into a medical center's overall mission. Benchmarks for data could be established, and the costs and resources needed could be determined. The whole process of healthcare delivery could be analyzed, and these data could be provided to state and government regulatory agencies or third-party payers (e.g., insurers). However, anesthesia departments often are fearful of how these data might be used and are concerned about potentially punitive outcomes. Nevertheless, in today's high-priced medical environment, if these crucial data are not provided, solutions to problems will ultimately be generated by administrators and chief executive officers with minimal or no knowledge of the anesthesia process [22].

Potential limitations

Acceptance

Certain departments may be somewhat reluctant to make electronic record-keeping the status quo. For example, smaller clinics might not welcome the change as a larger system might. Other factors can affect the degree of individual user acceptance. In particular, the quality of training required to convert from manual to electronic records may influence user satisfaction. In addition, the cost of implementation, demonstration of improved quality with electronic records, reluctance to give up manual records, hardware placement, and software features also have affected user acceptance [23]. Another study indicated the need to identify human factors (such as fear of computers) before the implementation of an EMR [24].

Anesthesia outside the operating room

In the past 10 to 15 years, anesthesia providers have supplied services beyond the operating room, including the magnetic resonance imaging laboratory, the radiology department, the gastroenterology suite, and the emergency department. AIMS records can be easily kept in all these circumstances, with the exception of the magnetic resonance imaging area, because the magnet interferes with the computer. In that case, speech recognition may be a better option for electronic documentation [25]. Scheduling and logistics occasionally present problems for anesthesia administration in remote locations. Anesthesia providers may be able to assist with conscious sedation from distant sites, which could be practical in remote emergency situations.

Error reduction and patient safety

One tenet of the American Society of Anesthesiologists is vigilance. Documenting while administering anesthesia is difficult, regardless of whether the record is kept manually or electronically [26]. Some procedures, including transesophageal echocardiography, have been associated with increased workload and decreased vigilance [10]. What is needed is the documentation of precise data according to the system described by Gibby [27]. Simplifying data collection for quality assurance (e.g., by using a handheld device) [28] may help keep adverse-event data separate from discoverable data or data protected under rules set out by the United States Health Insurance Portability and Accountability Act. With an AIMS, provider vigilance may improve.

Error reduction and patient safety issues played weighty roles in the development of anesthesia record-keeping because anesthesia was one of the first specialties to develop concerns for safety matters. Documentation of adverse events is required to investigate safety questions, and an AIMS has been recognized as a superior means of documenting adverse events [21]. The system established by Benson et al. [29], which automatically chronicles adverse events during anesthesia, facilitates subsequent procedural reviews. As shown by Pronovost et al. [30], error reduction can be achieved with a medication reconciliation process. By incorporating a survey into an AIMS, medication errors in ICU discharge orders were virtually eliminated within 24 weeks. An AIMS could make similar safety nets possible in anesthesia. In particular, a real-time record will help pinpoint when errors occurred and help play a key role in their elimination [3].

Information technology can improve anesthesia patient safety by minimizing errors and adverse events, decreasing response time to an adverse event, and providing feedback for quality improvement [19,21]. Efficient information access, assistance with calculations, patient monitoring, decision support, and reduction in medication errors are part of the safety net provided by an AIMS [22].

Preoperative assessment

Most anesthesia providers feel that a thorough preoperative assessment is necessary to safely administer anesthesia [31,32]. Recording the patient's medical history, including problems during previous surgical procedures, is an important aspect of preoperative evaluation. An EMR can reduce the error rate on the preoperative assessment by as much as 46% [30].

Kopp [33] described a centralized preanesthesia clinic at the University of North Carolina. He reported a high rate of preanesthesia evaluation and a low rate of consent problems. Expansion plans include telemedicine and Internet-dependent processes.

An EMR can also be used for automated risk identification. Factors such as chronic alcohol consumption, hypertension, high body mass index, and emergency surgery could be associated with severe hypotensive complications during spinal anesthesia [34]. Prompt identification of risk factors on the basis of preoperative data could further reduce morbidity.

Despite optimism that automated record-keeping could solve the problems of preoperative evaluation, the electronic system has flaws. Although a hospital-wide electronic documentation system was in place at the University of Florida (Gainesville, Florida), preoperative assessment information was missing for a considerable number of their patients evaluated for surgery [27]. However, if anesthesia providers could receive complete and accurate patient information online, there is the potential to increase data accuracy and save time [4].

Intraoperative management

Anesthesia is the only medical specialty that requires dynamic documentation during the intraoperative portion of patient treatment. The provider must simultaneously be attentive to surgical procedures, administer the anesthetic, monitor the patient, and document the entire event. At the end of surgery, the patient is taken to the recovery room or ICU, and the physician prepares for the next patient. Anesthesiologists have little latitude for errors in documentation and little opportunity to correct records within the time frame allowed by law.

Weiss et al. [19] elegantly described what the ideal anesthesia record should accomplish in the operating room. Specifically, it should have four important capabilities: (1) capture and present data from monitors, anesthesia machines, and other devices such as infusion pumps; (2) use an algorithm-based method to identify deviations from the norm; (3) communicate with a patient database to transfer information from laboratory reports, radiology, and preoperative consultations; and (4) create an archival electronic record at the end of the procedure. To date, no commercial software package has been able to satisfy all these requirements.

Schwilk et al. [35] compared the information transferred from the operating room to the recovery room in a United States hospital and a German facility. In the United States hospital, vital signs had greater impor-

tance, whereas the German facility emphasized case history and evaluation of chronic health problems. The authors concluded that software developers could incorporate flexibility and customization into their products.

Lack of decision support is a major deficiency in the AIMS. Rather than advising the clinician about what to do, decision support alerts the provider to untoward events and provides prompts for remedial action. van der Walt et al. [36] proposed a monitoring system to alert providers to possible pediatric anesthesia complications. This would be invaluable in emergency situations when little patient history is available and also reduces the likelihood of overlooking important information. Krol and Reich [37] developed a decision support model for blood pressure monitoring during anesthesia. Decision support tools that consider a patient's health history, e.g., calculating the likelihood of adverse reactions to a given treatment [38,39], could also be incorporated into an AIMS.

Another feature of an EMR is its ability to assure that all aspects of anesthesia documentation are met. However, this is a dynamic form of documentation that not only requires verification of person but also of time [40]. Vigoda and Lubarsky [40] investigated the concept of emergence from anesthesia to see if this was being documented at the correct time. The authors were able to change the behavior of providers to document the correct time. They did this through the use of educational sessions, automated e-mail feedback, and personal communication.

Other data from AIMSs have been used to improve antibiotic administration [41]. The Surgical Infection Prevention Project in the United States has been tasked with improving the administration of antibiotics to prevent surgical infections [42]. An AIMS can generate guidelines and improve quality by providing feedback on the timeliness of antibiotic administration [41]. Likewise, an AIMS can improve prophylaxis for nausea and vomiting [43] and can improve operating room efficiency [44].

Speech recognition software would have an enormous impact on AIMSs. However, Jungk et al. [45] examined speech interaction with a patient monitor and concluded that current technology was not advanced enough to make speech recognition a feasible feature. They proposed that the primary features of a speech recognition system be based on physician needs rather than current technology measures.

Postoperative phase

An AIMS enables direct communication between patient databases and care providers. When a patient is admitted to the PACU or ICU, information such as vital signs, administered anesthetic agents, and details of adverse events during surgery must be readily available. By examining the anesthesia record before a patient arrives, caregivers can anticipate problems and individualize patient management. For example, if a patient has respiratory failure following extubation in the operating room, the ICU would prepare appropriate ventilator settings.

Administrative issues

An AIMS will expedite the processing of administrative data. Anesthesia billing is unique when compared with other forms of healthcare documentation because a legible record is essential for calculating anesthesia unit charges. If questions arise, the billing manager can immediately e-mail the provider to verify that the documentation is correct. Dexter [46] described the value of an AIMS in operating room management. Tables 2 and 3 list examples of how an AIMS improves surgical scheduling systems and improves efficiency of documentation for nurses.

AIMSs are valuable for risk management and the defense of malpractice lawsuits. A clear record is probably the best defense, but some providers may be wary of precise documentation for fear of giving too much information that could be used in malpractice suits. However, AIMS records can be used to reduce legal risks and help defend against malpractice litigation [47].

Table 2. Advantages of an anesthesia information management system for surgical scheduling systems

Maximization of operating room use
Surgical lists by procedure (i.e., instruments required, preferred operating room, special materials, valves, grafts, tissues)
Conflict checking (operating-room scheduling, instruments, peripheral equipment such as fluoroscopes, microscopes, or lasers)
Allocation of time (minutes) on the basis of actual surgeon case length
Waiting-list capability for add-on cases (to be scheduled in the most cost-efficient model)
Centralized material resource management
Outcome assessments
Integration with anesthesia scheduling
Personnel assignments

Table 3. Advantages of an anesthesia information management system for nurses

Patient allergies
Assessment of patient (special needs)
Length of time in surgery
Medical materials (antibiotics, surgical prosthesis model, and lot numbers)
Patient position, location of devices on the patient
Personnel in attendance
Instrument counts
Gauze, laparotomy pad, and needle counts
Procedural notes (emergencies, complications)
Equipment (X-ray machine, fluoroscope, microscope, implanted valves or pacemakers [lot and serial numbers])
Tourniquet use and time

The implementation of an AIMS can have setbacks. Costs, lack of resources, and resistance to change can pose problems. Eden et al. [48] showed that, with proper education, they were able to implement an AIMS in their anesthesia department with ease and acceptance by the providers. What has been shown is that guidelines [49] should be developed to help departments implement an AIMS.

Conclusion

AIMSs assuredly have a future role in the practice of anesthesia because they can only enhance provider vigilance. Quality improvement in patient care, billing, operating room management, and risk reduction will also be influenced by an AIMS. Clear and concise preoperative, intraoperative, and postoperative documentation can be provided by an AIMS. The challenge for the future is to develop a system that can be integrated across the rest of the hospital information network.

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