Can anesthesia information management systems improve quality in the surgical suite?

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Current Opinion in Anaesthesiology 2009, 22:215–222

Purpose of review

To summarize developments related to the use of anesthesia information management systems (AIMS) and quality assurance and quality improvement.

Recent findings

A real challenge for AIMS is that the technology is too often seen as a solution. The reality is that the technology is simply a tool, which is increasingly being installed by hospitals to give anesthesiologists better capabilities for managing quality assurance programs, developing guidelines, facilitating computerized decision support, and standardizing care in the surgical suite so that every patient receives optimal care. Anesthesia groups will likely have to assign a dedicated biomedical team and programmer to fully realize the clinical and business benefits of AIMS.

Summary

Implementation of information technologies in anesthesia as well as in all aspects of healthcare redesigns how patients receive care. AIMS accurately measure, store, query, and recall vital sign data, and enable the systematic analysis of anesthesia-related perioperative data. Using AIMS, quality management programs will be able to study more incidents and analyze them more quickly. Ideally, decision-support systems with practice guidelines delivered via AIMS should help overcome the usual barriers to guideline adherence, and improve care and safety.

Keywords

adverse incidents, anesthesia information management system, computerized decision support, quality assurance, quality improvement

Curr Opin Anaesthesiol 22:215–222

0952-7907

Introduction

The definition of the term information technology depends in part on who you ask. The Information Technology Association of America states information technology is 'the study, design, development, implementation, support, or management of computer-based information systems, particularly software applications and computer hardware' (http://www.itaa.org/es/docs/Information%20Technology%20Definitions.pdf). The National Institutes of Health, on the contrary, defines information technology as 'any equipment or interconnected system or subsystem of equipment that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information' (http://oeo.od.nih.gov/PoliciesResources/508training/docs/glossary.htm).

In healthcare, information technology is often perceived as a transformative force bringing about a radical redesign of how patients receive care. This view suggests that adoption of computers and computer software to convert, store, protect, process, transmit, and securely retrieve information is fundamentally changing the practice of medicine [1]. Is this true for anesthesiology?

Examples of information technology that may affect surgical and anesthetic practice in the operating room include:

(1) Radiofrequency identification technology to track people, supplies, and equipment [2].
(2) Robotics to deliver supplies or to assist a surgeon (e.g. da Vinci surgical system).
(3) Smart beds to monitor patient movements and pressure sensors to reduce the incidence of bedsores.
(4) Personally controlled online health records, which gather a person's medical data from primary care facilities, laboratories, and hospitals into one storage system. The data owner, the patient, authorizes access to this information to others, including clinical providers, family members, and researchers [3].

Anesthesia information management systems (AIMS) are a good example of an information technology application in the surgical suite. AIMS are used as an electronic

anesthesia record keeper, and facilitate the collection and analysis of anesthesia-related perioperative data.

Historically, the challenge for hospitals looking to invest in AIMS was that the more sophisticated commercial AIMS products were stand-alone systems, not integrated modules of a facility-wide clinical information system [4]. The choice often then is between vendors producing systems that serve anesthesia well and vendors producing systems that cover more areas but may not perform the AIMS function as well.

Although the prevalence of AIMS in Europe and worldwide is unknown, initial estimates for the USA suggested that perhaps less than 10% of operating rooms had an AIMS [5]. This may be changing, as a recent study [6••] showed that at least 44% of the 140 US academic departments have already implemented, are planning to acquire, or are currently searching for an AIMS. The same study [6••] confirmed that AIMS adopters strongly value improved data collection for clinical, quality assurance, and safety purposes, and to support clinical research.

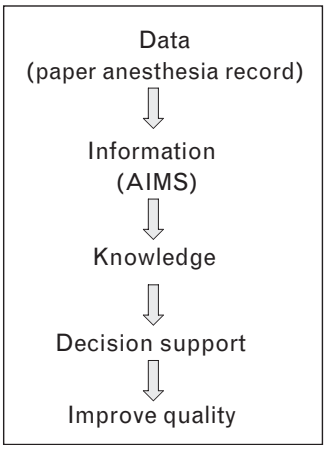
The first AIMS were only able to collect and store data streaming from perioperative monitors. The time course of the data flow with AIMS is seconds to minutes as compared with hours to weeks. This compressed time frame may be a key differentiator between AIMS and other electronic health record systems in primary care settings. To be commercially viable, AIMS need to produce more value beyond that of a legible and neat anesthesia record. In fact, if not properly configured, AIMS run the risk of increasing billing denials, medicare and medicaid noncompliance, security breeches, including medical identity theft (e.g. laptops with patient data being lost or stolen) and medical–legal defense difficulties.

A positive financial return on investment from AIMS can arise from reducing anesthetic-related drug costs, improving staff scheduling and reducing staffing costs, increasing anesthesia billing and capture of anesthesia-related charges, and increased hospital reimbursement through improved hospital coding [7].

Essential features of the AIMS include:

(1) collect and store data about patients,
(2) supply that information to providers on request,
(3) permit physicians to enter patient care orders,
(4) provide anesthesiologists with recommendations for healthcare decisions about individual patients,
(5) facilitate clinical research by allowing for querying of the AIMS database and using such results to change anesthesia practice.

Figure 1 The role of data and anesthesia information management systems for quality improvement



Anesthesia groups will likely have to assign a dedicated biomedical team and programmer to fully capture the potential quality improvements derived from AIMS data and decision support. AIMS, anesthesia information management systems.

Can AIMS improve the quality of care provided by anesthesiologists in the surgical suite? The issue at hand is how data becomes information and knowledge, and how that is used for quality improvement in anesthesia via practice guidelines (Fig. 1).

Anesthesiologists who have integrated AIMS into actual operating room practice often comment that anesthesia processes are not faster, but rather that AIMS change the workflow and time constraints. For short cases, for example, AIMS may actually consume additional time and delay throughput. Furthermore, AIMS data entry may distract from the core principle of continually focusing on the patient. The concern then is that the practitioner will spend more time interfacing with the computer than with the patient. We should consider such limitations and potential downsides of information technology applications in medicine [8•].

The clinician needs to make technologies such as AIMS work to improve patient care, by being involved in their development and deployment. An important insight is that the 'out of the box' AIMS products are often insufficient to fully deliver the potential value of AIMS [9••].

The goal of this review is to focus on potential ways that AIMS may improve quality in anesthesia, and to determine for which of these applications there is evidence to actually support its use.

Quality of care

If we are going to answer whether the use of AIMS can improve the quality of care provided by anesthesiologists,

Table 1 Defining quality: three general approaches from management science

Manufacturing	Structural characteristics (content)	Result (user based)
Adhering to the manufacturing protocol and steps yields a high-quality product	How well the product conforms to predetermined specifications	Degree to which the customer is satisfied
These established procedures result in an exact controlled process	Measurable product differences	Value oriented (performance at a reasonable price)

then a working definition of quality is necessary. In reviewing the management science literature, three approaches to defining quality can be outlined [10] (Table 1).

In fact, many industries believe that managing quality is the key to long-term growth in revenues. This may be especially true now in anesthesia with nonphysician providers delivering sedation and the increasing number of noninvasive cases that do not even require an anesthesiologist.

Some individuals relate quality directly to medical outcomes. The Institute of Medicine defines quality as 'the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge' [11]. Desired health outcomes refer to health outcomes that patients desire and highlight the crucial link between how care is delivered and how the care provided affects a patient's health. The achievement of a specified outcome is regarded as evidence that 'good' care was delivered. Quality measurement under this viewpoint acknowledges that process data may be more sensitive than outcome data because a poor anesthesia outcome does not occur every time there is poor care.

Quality improvement

The difference between quality assurance and quality improvement may not be obvious to everyone [12]. With quality improvement, clinical processes are continually being evaluated, even if nothing adverse happens, because every process can be improved. For example, this typically starts with a data-gathering process to identify opportunities.

Characteristics of quality improvement:

(1) identifies most important customers,
(2) accurately defines the customers' requirements,
(3) monitors how well you are meeting those requirements,
(4) manifests itself as a reduction of unnecessary variability,
(5) aims to eliminate rework (e.g. asking the patient 'Do you have any allergies?' multiple times).

Data analyses are continually conducted by a quality management committee made up of clinicians. A carefully peer-reviewed process assesses the performance of clinicians as a group and the efficacy of per operative processes (http://www.asahq.org/quality/qmtemplate013105.pdf).

What quality-related variables should be included in AIMS is difficult to determine, in part because healthcare has various 'customers' evaluating its quality. For anesthesiologists, customers include surgeons, hospital administrators, nurses, the medical group, insurance companies, and patients [13]. Individuals in each of these groups use different criteria in determining a provider's 'quality'. Anesthesiologists will therefore have to track multiple quality indices.

Quality assurance

Traditionally, the term 'quality assurance' is a method utilized to determine how well a product meets specifications. Characteristics of quality assurance include that it is retrospective, relies on inspection, focuses on high profile, but low-frequency events, and does not allow changes in the system until after the event. Under this quality assurance philosophy, the quality of anesthesia care may be measured retrospectively as incidence of anesthesia-related events, outcomes, and human errors, as reported primarily by anesthesiologists, residents, and certified registered nurse anesthetists (CRNAs) by placing a checkmark on a quality assurance form for example.

In light of the increasing availability of AIMS, several questions arise. First, do AIMS, as electronic record keepers, collect data more accurately from anesthesia processes than handwritten records. Second, what is the role of AIMS in the quality management process? Can clinical practice guidelines be promoted via AIMS?

Do anesthesia information management systems collect better data than handwritten records?

The anesthetic record is by far the most detailed general physiological and pharmacological account available in routine clinical practice; however, the handwritten anesthetic record continues to show poor accuracy overall. Common problems include [14]:

(1) omission of abnormal values,
(2) lack or illegibility of normal values,

Table 2 Anesthesia information management systems as a better record keeper

Potential record-keeping benefits of AIMS	Study finding	Supported by literature (quality of evidence)[a]	Reference
More accurate data collection	SAP, DAP	II-2a	Cook *et al.* [15]
	SAP, DAP, HR, $EtCO_2$		Thrush [16]
	VT, RR, EtCO2, FiO2 – missing		Lerou *et al.* [17]
	SAP, DAP, HR – error		
	SAP, DAP, HR	II-2c	Reich *et al.* [18]
Won't lose record		Not supported	
Increased completeness and legibility	Significantly more vital signs recorded	II-2a	Edsall *et al.* [19]
Decreased anesthetic workload	Reduction in time spent on the documentation		
On time availability from many locations		Not supported	
Automated reminders to improve recorded documentation	Increase allergy field completion, sending automatic reminders	II-2b	Sandberg *et al.* [20]
Medical liability (problems related to AIMS, not seen in manual records)	Automatic alerts during system problems	IV	Vigoda and Lubarsky [21]
	Appropriate timing of documentation	II-2b	Vigoda and Lubarsky [22]

AIMS, anesthesia information management systems; DAP, diastolic arterial pressure; $EtCO_2$, end-tidal CO_2; FiO_2, inspiratory oxygen fraction; HR, heart rate; RR, respiratory rate; SAP, systolic arterial pressure; VT, tidal volume.
[a] Source: NHS Center for Review and Dissemination (1996) cited in Rittenhouse B. Use of models in economic evaluations of medicines and other health technologies. London: Office of Health Economics; 1996.

(3) smoothing or rounding of abnormal values to within the expected upper or lower physiologic limits,
(4) averaging of a number of measurements around an abnormal value.

Some of these deficiencies may be explained because record keeping may frequently be perceived as a secondary task and is often completed after an event has occurred.

Several studies [15–22] have demonstrated the discrepancies between handwritten records and automatically generated records, most of them focusing on timing, magnitude, and direction (Table 2). Times of induction and emergence were the most commonly occurring recorded errors. This is often explained because induction and emergence are critical moments, which require full attention to patients, which then delays filling out the record.

By contrast, automated record keeping through AIMS increases the completeness of all physiological monitored data, improves legibility, and decreases time spent recording [19]. AIMS allow documenting a larger number of vital signs and events. Procedures performed by the anesthesiologist (e.g. airway management, invasive monitoring lines, regional anesthesia techniques) can also be documented more precisely with standardized entries. Furthermore, automated anesthesia records are less likely to be lost, should always be available, and can be accessed from many locations (with appropriate security), including access from home.

AIMS vital signs data can also be used by the operating room manager to remotely identify in real time when a patient enters and leaves a given operating room [23]. Such accurate data are needed to assess performance indicators related to how efficiently run an operating room suite is [24].

Improving anesthesia information management systems as a record keeper

In spite of the advantages of electronic anesthesia records there is still room for improvement. For example, electronic clinical anesthesia documentation still requires manual data entry, but is less likely to be completed if the clinician is required to generate free text [25]. Additional concerns raised include AIMS disconnection or failure [21] and inappropriate timing of documentation [22], which could affect medical liability.

To further improve anesthesia record documentation, mandatory data fields or reminders of missing data can be used. Mandatory data fields though may be too restrictive and interfere with the anesthesiologist's workflow, requiring the clinician to go back and forth from patient care and data entry. Custom software operating independently of the AIMS can identify missing data and inconsistencies in documentation and send reminders using pagers [20], text messages, e-mails, and pop-up AIMS messages. E-mails are less effective because the anesthesia care provider must actively access their mailbox prior to discharging the patient to the postanesthesia care unit (PACU). On the contrary, pagers and cell phone messages have the advantage that proximity to the operating room is not required.

Standardization of terminology in AIMS is required for benchmarking and comparisons in adverse events and other outcomes among hospitals on a national level. One barrier to this is that AIMS installation often includes the development of a customized set of terms and phrases for

that facility. This lack of standardization for terms in AIMS inhibits the sharing of data even with AIMS from the same vendor at different institutions.

What is the role of anesthesia information management systems in the quality management process?

As anesthetic mortality and serious morbidity are becoming exceedingly rare, a broader range of less severe and more frequent adverse events need to be monitored [26], many of which develop in the PACU [27]. Just as the specialty of anesthesiology was able to practically eliminate catastrophic events such as esophageal intubation, the challenge now is to similarly eliminate nausea and vomiting and severe pain after surgery.

Typically, a separate single-page form is used for such adverse event data entry, but with variable success, in part due to whether the process is anonymous, voluntary, or both. Unfortunately, few anesthesia groups have published their data, making benchmarking difficult. Thus, two barriers limit the usefulness of this manual process: the time and effort required to collect and analyze the data written on paper and the reliability of the data. Both barriers can partially be improved with the implementation of an AIMS.

When an AIMS is used to track events, completion may be voluntary or mandatory, self-reported or automated [28]. Collected data can be evaluated on a daily, monthly, or quarterly basis. AIMS have been used to change medical behaviors in an attempt to improve data reliability (Table 3 [28–32,33••,34,35]). For example, compliance with quality assurance increased from 48 to 78%, based on the dissemination of a departmental policy requiring quality assurance documentation. A different workflow did not allow the practitioner to enter 'no complications' until the patient was in the PACU or the ICU [28]. Individualized performance feedback was also provided.

In addition, AIMS can be used for automated detection of adverse events (e.g. hemodynamic instability or arrhythmias during anesthesia), which can also be cross-referenced with a hospital mortality database [29]. Then, such information could be useful in examining the relationship between critical events during anesthesia and surgery and patient morbidity and mortality.

The most comprehensive AIMS also include a preanesthesia evaluation component and an electronic data warehouse to organize data for outcomes research; however, the potential benefit of AIMS to facilitate clinical research may not be as straightforward as expected because of the need to consider regulatory requirements and institutional policies [36•]. Potential policy and configuration issues that need to be addressed prior to engaging in clinical research with AIMS are as follows:

(1) Can the investigator access all of the patient's data or just what is required for the study?
(2) Are there any changes to the Institutional Review Board review process or oversight requirements if a study is to use the AIMS for data collection, management, or extraction?
(3) For clinical studies with an external funding sponsor, are any additional data confidentiality restrictions required?
(4) What is the 'legal anesthesia record' when both clinical trial and standard-care data are mixed together?
(5) When study participants either complete a study or withdraw study consent, do their research data remain part of the permanent AIMS database?
(6) Are clinical trial data accessible to those clinicians not directly involved in the study?
(7) Can a clinician not officially designated as a study investigator change trial data that he or she feels are incorrect?
(8) Can the AIMS be used to manage randomization procedures?

Table 3 Anesthesia information management systems and quality management

Potential quality management benefits of AIMS	Study finding	Supported by literature (quality of evidence)[a]	Reference
Improved quality assurance	Increased report and reliability of adverse events Automated detection of adverse events by AIMS	II-2a	Vigoda *et al.* [28] Sanborn *et al.* [29], Benson *et al.* [30]
Adherence to guidelines	Timely administration of preoperative antibiotics	II-2b	Wax *et al.* [31], O'Reilly *et al.* [32]
Ability to provide computerized decision support	PONV prophylaxis in high-risk patients	II-1b	Kooij *et al.* [33••]
Decrease medication errors	Bar-code scanning provides automatic visual and auditory verification	IV	Merry *et al.* [34]
Reconcile discrepancies between dispensed and administered medications	Need electronic interface between AIMS and a medication dispensing system	?	Vigoda *et al.* [35]

AIMS, anesthesia information management systems; PONV, postoperative nausea and vomiting.
[a] Source: NHS Center for Review and Dissemination (1996) cited in Rittenhouse B. Use of models in economic evaluations of medicines and other health technologies. London: Office of Health Economics; 1996.

(9) Who funds the costs of research-related data management in AIMS?
(10) For budgetary purposes, how are the incremental additional hardware and software costs from research activities within AIMS identified?

Ideally, such querying of the AIMS databases would be used to assess anesthesia practice [37] and then make any changes to improve care. Even with AIMS, many adverse events need to be entered manually and there is always the voiced concern that artifacts could be interpreted as critical events in the presence of a bad outcome.

In 1993, the German Society of Anesthesia and Intensive Medicine defined incidents, events, and complications as situations that have or could have caused morbidity or mortality if the anesthesiologist had not intervened [38]. The importance of this definition lies in the need for an intervention by the provider, so, in this context, the presence of artifacts is negligible [30].

Can clinical decision support be promoted via anesthesia information management systems?

Clinical practice guidelines are consensus statements based on scientific evidence to assist care providers in making decisions for specific clinical situations. Their implementation should improve quality of care by decreasing inappropriate variation and expediting the application of effective advances to everyday practice [39]. In spite of their apparent utility, practice guidelines have a low level of adherence [40].

There are a variety of barriers to guideline adherence, which include a lack of awareness, a lack of familiarity, a lack of agreement, a lack of self-efficacy, a lack of outcome expectancy, the inertia of previous practice, and external barriers [41]. Several of these barriers may be resolved using AIMS. But to be widely accepted by practicing clinicians, computerized support systems for decision-making must be integrated into the clinical workflow. AIMS must present the right information, in the right format, at the right time, and without requiring special effort [42].

One method to increase compliance with practice guidelines is using computerized reminders [31,32]. This seems straightforward when the guidelines are mandated (e.g. antibiotic administration within 60 min of incision) [43]. Timely administration of antibiotics is just the first in a series of proposed modifications in surgical work processes to reduce morbidity and cost. Other areas in which computerized decision support may be implemented include intraoperative glucose control, temperature control, β-blockade in high-risk cardiac patients undergoing noncardiac surgery, prevention of perioperative deep venous thrombosis and embolism, and postoperative nausea and vomiting (PONV) prophylaxis [33••]. The optimal method for clinical decision support may depend on the guideline, the percentage of eligible patients involved, and requires further scientific study.

Medication errors are another area in which AIMS may improve quality and safety [44]. A survey by the Canadian Anesthesiologists Society found that 85% of participants had experienced at least one drug error or 'near miss' [45]. AIMS developed with bar-code scanning can provide an automatic visual and auditory verification in an effort to reduce errors in drug administration and improve record keeping [34]. Moreover, linking AIMS with medication dispensing systems may alert users to medication entry errors [35].

A word of caution though; the processes appropriate for AIMS selection, installation, and implementation are quite complex, often learned at each site by trial and error [46••]. A real challenge for AIMS – or any information technology implementation – is that the technology is much too often seen as a solution. Hospital personnel may make the assumption that if a lot of resources are invested to address a 'problem' the result will be 'problem solved'. The reality is that technology is simply a tool and not a solution. Like any tool, the problem it is designed to solve must be defined to determine the potential utility of the tool. In the anesthesia situation, if the problem being addressed is to accurately measure, store, query, and recall vital signs then an AIMS is perfectly suited; however, other challenges may be better addressed with other tools. For example, if the problem is too many patients having severe pain after surgery, then AIMS may not be a solution unless decision support that is used everyday is installed in the AIMS.

To fully realize the potential benefits of AIMS, it is also important to address the role of vendors, and, in particular, how vendors themselves may be a barrier to technology interoperability. This is essential because many of the potential benefits depend on computer systems communicating with each other. Unless the anesthesia group is going to build its own system, the group is dependent on the vendor for a successful implementation. The irony is that the inefficiencies these vendors aim to eradicate may be limited by the fact that the proprietary software these vendors produce requires complex middleware to communicate with disparate information systems. The risk then becomes conversion of paper chaos to digital chaos. Traditionally, for vendors, a noninteroperable healthcare environment may be highly profitable in the short term. Of more concern, however, is that the complexities created by the vendor's product can even drive demand in the vendor's favor, and ultimately increase

AIMS costs. We have seen many examples in which the interwoven nature of technology vendors and providers is so intimate that clients may suffer greatly once they wish to disengage from a vendor. From a societal point of view, to truly profit from the benefits of a free market in favor of improved quality and decreased costs, consumers must have choice. Currently, choice is only available prior to the sale. Once sold, the cost of disengagement for all intents and purposes may be quite large. This may be a reason some medical centers are opting now for an integrated hospital and clinic-wide electronic solution. Often, however, AIMS products are quite unadavanced with such vendors.

Conclusion

Healthcare systems around the world are well behind other industries in the deployment of information technology. In the next few years, AIMS deployments will increase, as the value is becoming increasingly understood. Ideally, these AIMS will be integrated with the hospital information systems to provide a seamless and paperless flow of patient care. AIMS need to help make the clinician's job easier, faster, and safer such that they quickly become critical to the department's financial health and daily clinical activities. Automated anesthesia records are more accurate, contain more data, should never be lost, and are always available. Quality management programs will be able to study more incidents and analyze them more quickly. Finally, computerized decision-support systems with practice guidelines should help improve patient care and safety.

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This review should be read by any practitioner about to purchase and install an AIMS. Authors from multiple institutions that have installed AIMS summarize essential considerations for successful AIMS implementation, including product evaluation, assessment of information technology needs, resource availability, leadership roles, and training.