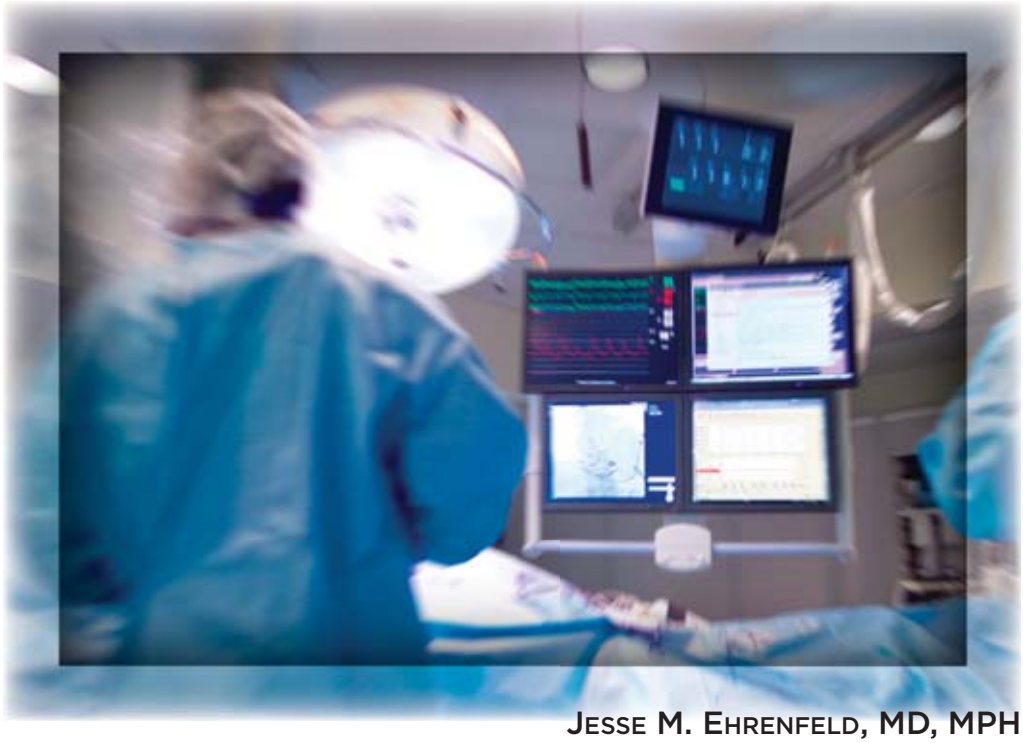
Anesthesia Information Management Systems

Clinical and Operational Impact



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Anesthesia information management systems (AIMS) are rapidly increasing in both their adoption and overall functionality. A previous article reviewed the basic features of an AIMS, and considerations for their purchase and installation.[1] This article discusses how AIMS can affect clinical practice in a variety of areas, including direct patient care, financial operations, and departmental management. When considering how an AIMS can impact your practice, keep in mind that the technology has become much more than a simple automated record keeper. It has been shown to improve patient care and patient outcomes, and, in some cases, impact the financial health of a department.

AIMS in Operation

AIMS are a specialized form of electronic health record (EHR) systems that facilitate the collection, storage, and presentation of patient data during the perioperative period. Multiple studies have found that AIMS can improve data collection relative to handwritten records, using a variety of metrics such as completeness and accuracy.[2-6] In addition to providing basic record-keeping functions, most AIMS also simplify a variety of management, billing, and quality assurance functions.

Table 1. Areas That May Be Impacted by Anesthesia Information Management Systems

Clinical practice/patient care
Clinical decision support
Enhance record keeping
Facilitate communication among providers
Improve availability of historical records
Financial operations
Improve billing efficiency
Enhance revenue capture
Facilitate participation in P4P programs
Operating room suite management
Track operational throughput
Manage drug/supply costs
Controlled substance accounting
Departmental management
Case tracking/assignment
Ensure compliance with regulatory guidelines
Facilitate provider credentialing
Staff recall in times of mass casualty/crises
Quality assurance/quality improvement
Track individual/aggregated provider performance
Highlight occult problematic practice patterns
Potential for enhanced legal protection

P4P, pay-for-performance

AIMS typically consist of a combination of hardware and software that interface with intraoperative monitors, and in many cases hospital clinical data repositories or EHRs. Although the primary role of an AIMS is to capture data during the intraoperative phase, most systems have expanded their functionality by also incorporating pre- and postoperative patient information. These data are housed in a robust relational database that can be accessed simultaneously by multiple users in different locations.

Although AIMS have existed in some form for the past 30 years, widespread adoption has been hindered by financial barriers and a perceived lack of value on the part of hospitals. As a result of these hurdles, only an estimated 5% of U.S. operating rooms (ORs) in 2006 had an AIMS.[7] Adoption has accelerated recently (44% of academic centers have implemented or are currently planning to implement an AIMS), driven primarily by a need to address increased regulatory reporting requirements and a desire to improve routine clinical documentation.[8]

Today, AIMS have the potential to affect virtually every function within an anesthesiology department. These areas include clinical practice and patient care, financial operations, management of the OR suite and department, and quality assurance/quality improvement (Table 1).

Clinical Practice and Patient Care

The most meaningful benefits of AIMS for both patients and front-line clinicians are likely to be the impact the technology can have on the provision of care. These benefits include opportunities to provide clinical decision support, enhanced record keeping, better communication among providers, and improved availability of historical records.

Clinical Decision Support

Clinical decision support, or the provision of tools that allow end users to more effectively accomplish a particular task, is the fastest-growing area within AIMS product development. The overall objective is to assist the clinician in making the best decision possible for the patient, and in following the recommended practices throughout the course of treatment. Although the availability of this feature varies from vendor to vendor, decision support can facilitate both improvements in the quality, and reductions in the cost, of care.

The most basic clinical decision support tools offer passive guidance. Examples include support around medication administration, such as providing drug-dosing calculations based on a patient's weight, age, or creatinine clearance; checking for potential drug interactions based on a patient's home or inpatient medication list; and reviewing the medical history for known drug allergies.

More complex decision support features are designed to actively manage provider behavior by using on-screen pop-up displays or integrated links to a hospital's paging system. Examples include simple reminders to dose medications (ie, administer antibiotics prior to surgical incision) or re-dose medications (ie, cefazolin after 6 hours), apply physiologic monitors (ie, place a temperature probe when no temperature data are present), or measure finger-stick glucose values in diabetic patients with no blood sugar concentrations recorded. Much work has been done around enhancing the usability and efficacy of various notification systems, leading to vast improvements over first-generation alerts that often made the AIMS workstation unusable.

Several studies in the peer-reviewed literature have evaluated and shown the ability of AIMS clinical decision support systems to positively impact patient care in a variety of different areas. Specific examples include a workaround improving prophylactic antibiotic administration rates,[9,10] adherence to prescribing guidelines for postoperative nausea prophylaxis,[11] proper use of monitor alarm systems,[12] and applying appropriate physiologic monitoring during surgery.[13,14]

A number of groups are developing advanced algorithms to provide point-of-care assistance during critical intraoperative events. For example, in the event of a chaotic electrocardiogram or disappearance of a pulse oximeter waveform, one prototype system prompts the end user to consider ventricular fibrillation as a diagnostic possibility and then makes available on-screen the appropriate Advanced Cardiac Life Support algorithm. Other systems, which have been proposed but not yet implemented, aim to detect the presence of certain disease states, such as new-onset malignant hyperthermia, with a goal of helping the provider detect and respond to the event more quickly.

Enhanced Record Keeping

The core feature of all AIMS is their ability to accurately and reliably record intraoperative patient information, including vital signs and key events. This can allow an anesthesiologist to focus on the patient, rather than charting. Furthermore, because of their unflagging ability to faithfully capture physiologic events at high resolution, AIMS are able to facilitate more accurate recording of patient responses to anesthesia.[4,15] For example, the minute-by-minute changes shown in the case of an air embolus depicted in Figure 1 would never have been recorded accurately on a handwritten record.

Facilitate Communication Among Providers

The ability of electronic systems to chart an anesthetic contemporaneously and legibly is another key feature that facilitates communication among providers. This ensures better communication among provider teams, and during transitions in care (ie, handoffs and breaks). Additionally, most AIMS allow end users to communicate with one another through built-in messaging functions that may be linked to hospital pagers, cell phones, and/or secure e-mail accounts.

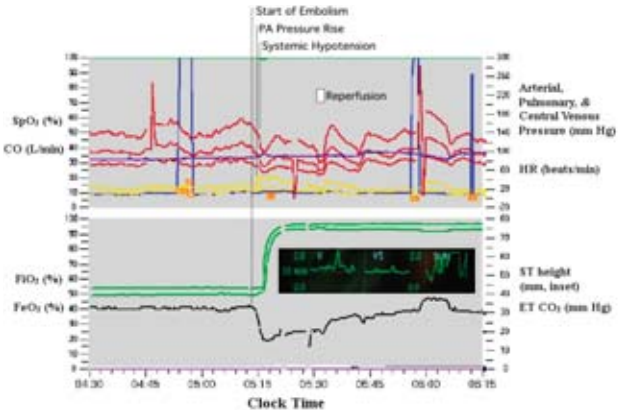

Figure 1. Physiologic events captured by an AIMS during an air embolus.

Improve Availability of Historical Records

Because AIMS create electronic records that can be accessed simultaneously by different users at multiple locations, they have the ability to improve the availability of historical records. This can be helpful during a number of circumstances. For instance, with a paper system, the original record for a patient who returns to the OR after an initial procedure for a subsequent operation may still be in billing/coding—making that information inaccessible to clinicians in the OR. With an AIMS, historical records can be viewed across multiple workstations obviating the need to search for or borrow old charts. This can greatly improve access to key information, such as a patient's prior airway management, or hemodynamic response to intraoperative agents.

Financial Operations

Although perhaps less meaningful to patients or at the point-of-care in the OR, the impact of an AIMS on the financial operations of a department can be significant. Although the initial direct and ongoing support costs associated with an AIMS installation can easily reach six figures,[1] even for a small department, there are a number of significant financial opportunities brought about by the installation of AIMS. Depending on the baseline financial performance of a group

Table 2. Impact of Anesthesia Information Management Systems on Financial Operations

Allow for clinician improvement on various performance metrics
Automatically extract data for billing
Enhance revenue capture
Ensure chart completion (required elements for billing)
Extract and report on P4P metrics (PQRI, etc)
Facilitate participation in P4P programs
Highlight charting errors (time sequence problems)
Improve billing efficiency
Provide notifications around missing documentation
Push data to third-party billing vendors
Reduce charge lag/accounts receivable
Reduce labor costs associated with billing operations

P4P, pay-for-performance; **PQRI,** Physician Quality Reporting Initiative

or hospital, over time these financial advantages may compensate for—or in some cases exceed—the costs associated with maintaining an AIMS. The specific impact on financial operations are summarized in Table 2 and described in depth below.

Improve Billing Efficiency

There are several ways in which AIMS are able to improve billing efficiency. AIMS can ensure that electronic charts contain all of the necessary elements that are required for billing. This might include the necessary attending physician attestation statements, required billing times (start and end of anesthesia care), and elements needed to calculate base units (anesthesia type, ASA physical status classification, age, etc). This can be accomplished by requiring fields be completed at various points during the case or providing automatic notifications of missing/erroneous information after case completion. This method has been shown to decrease the time cases remain in accounts receivable and the number of unbillable cases.[16]

In addition to reducing charge lag, AIMS can facilitate the billing process by automatically extracting elements needed to generate a bill (personnel, surgical procedure, patient demographics, anesthetics given, and relevant modifiers such as central line insertions or deliberate hypotension). Because the effort required to prepare data for external processing can be diminished by an AIMS, labor costs are reduced,[17] even in departments that contract with a professional billing service. Furthermore, AIMS can provide automatic concurrency checking to ensure that charts are compliant with all local and national regulatory requirements.

Enhance Revenue Capture

Another way that AIMS can impact the financial operations of a department is through their ability to enhance revenue capture. This is possible when an AIMS reminds a clinician to complete documentation that allows for complete billing and maximization of revenue opportunities. For example, when one hospital developed an alert that prompted the clinician to sign an arterial line placement attestation statement 15 minutes after the appearance of an arterial waveform in the electronic record, they demonstrated an ability to increase their professional billing by in excess of $40,000 per year because a large number of arterial lines that were not previously being billed for suddenly joined the department's revenue stream.[18] Similar logic is available for central lines, regional blocks, spinal drains, intraoperative echocardiograms, and all other procedures for which a department can bill and obtain reimbursement.

Facilitate Participation in Pay-for-Performance Programs

In order to participate in various pay-for-performance programs, such as the Centers for Medicare & Medicaid Services (CMS) Physician Quality Reporting Initiative (PQRI), hospitals must provide insurers with the relevant data highlighting the metrics in question. Two such measures that impact the OR in many hospitals are "Timely Administration of Antibiotic Prophylaxis" and "Maintenance of Perioperative Normothermia." In order to participate in these programs, which provide additional reimbursement when certain criteria are met, one must indicate which cases meet the specific criteria associated with the specific metric. For the "Timely Administration of Antibiotic Prophylaxis" PQRI metric, one must report the "percentage of surgical patients aged 18 and older who have an order for a parenteral antibiotic to be given within one hour (if fluoroquinolone or vancomycin, two hours) prior to the surgical incision (or start of procedure when no incision is required) for whom administration of prophylactic antibiotic has been initiated within one hour

(if fluoroquinolone or vancomycin, two hours) prior to the surgical incision (or start of procedure when no incision is required)."[a]

An AIMS can greatly simply obtaining these data, generating a list of compliant and noncompliant cases in a matter of a few minutes using little staff time. However, to gather these data from paper charts is an onerous task at best, and in many circumstances impossible.

In addition to facilitating participation in pay-for-performance programs by allowing seamless data extraction, AIMS can help physicians improve their compliance with certain metrics. For example, reminders to provide prophylactic antibiotics can increase compliance with the "Timely Administration" metric.[9,10] This is one example of how AIMS can provide the tools not only to track and measure performance, but also to allow clinicians to improve performance.

Operating Room Suite Management

In addition to serving as intraoperative record-keeping systems, AIMS have the potential to become useful tools to facilitate both OR workflow as well as management of the entire OR suite. A number of institutions have used AIMS to facilitate tracking of operational throughput and management of drug and supply costs, as well as accounting for controlled substances.

Tracking Operational Throughput

Many AIMS installations are accompanied by real-time status displays. Several different types of displays may be used, including passive status displays (eg, electronic whiteboards), active status displays (eg, notifications sent via text pager or short message service [SMS]), and command displays (eg, notifications that include automatic suggestions about how to proceed). Passive status displays often are located at OR control desks, but may also be placed in strategic locations around the OR (such as in anesthesia workrooms or physician lounges). In addition to providing continuously updated scheduling information, at least one study has shown that certain types of displays (command displays) are able to help managers make better decisions.[19]

At Massachusetts General Hospital (MGH), a custom display using AIMS data was designed and installed in the anesthesia workroom (Figure 2). This display allows anesthesia technicians to track the status of all 51 ORs, and has greatly helped facilitate a decrease in room turnover times. At MGH the technicians also receive automatic alert pages, generated by the AIMS, when cases are ending. Other hospitals have used their AIMS to send automatic notifications regarding patient flow to the OR team. Notifications have ranged from "patient arrived in holding area," to "patient ready for surgery," to "next scheduled case cancelled."

Figure 2. Real-time operating room status display.

Managing Drug/Supply Costs

Because AIMS have the ability to capture all of the drugs and supplies used for a case, they can be used to calculate the cost of an anesthetic. In order to calculate the costs associated with each case, however, these systems also must have access to detailed pharmacy information systems that detail drug costs and vial sizes. This can allow the calculation of both case cost and wastage. When combined with the decision support capabilities of an AIMS, several centers have shown an ability to use AIMS as a cost-containment tool.[20] At MGH, a number of AIMS-based efforts have been put into place to guide providers toward using less-expensive intraoperative medications (eg, isoflurane instead of sevoflurane) with moderate success.[21]

Controlled Substance Accounting

All anesthesia departments need to account for controlled substances, and AIMS are able to assist with those efforts. Although there have been reports of discrepancies between medication entries in AIMS and pharmacy records,[22] at least one center has been able to develop a drug-diversion surveillance system that relies on AIMS data.[23] This type of controlled substance monitoring is important for a variety of regulatory reasons, as well as because a number of observational studies indicate that death is one of the most common presentations of controlled substance abuse by a resident physician.

Departmental Management

Beyond the OR suite itself, AIMS also can impact management functions at the departmental level.

[a] http://www.cms.gov/apps/QMIS/measure_details.asp?id=456

These functions include the ability to rationally assign and track cases, ensure compliance with regulatory guidelines, facilitate provider credentialing, and even manage staff in times of disaster or mass casualty.

Case Tracking/Assignment

Most AIMS can be used to help track and assign cases in a rational fashion for both trainees and staff. More than one study has shown the ability of an AIMS to help optimize anesthesia-staffing patterns and balance surgical workloads across anesthetizing locations.[24,25] This has allowed some centers to use their AIMS to better control resources across the department. In addition, AIMS have been used in several academic centers to facilitate both automatic reporting of resident case logs to the Accreditation Council for Graduate Medical Education, as well as daily case assignments to ensure that residents are assigned to cases that satisfy their educational needs. For example, at many residency programs, the AIMS is configured to provide a list to the program director of the total number of procedures, blocks, transplants, and so on that each resident has performed on a regular basis in order to facilitate rotation and case scheduling.

Ensure Compliance With Regulatory Guidelines

In addition to providing assistance with ensuring that charts are complete and billable in a timely fashion, many AIMS can assist with regulatory compliance. This can include system configuration to ensure all attestation statements are present, provide automatic concurrency checking, and many of the elements that might be necessary to comply with guidelines from the Joint Commission, CMS, and other regulatory agencies.[26] Some hospitals also use their AIMS to facilitate tracking of postoperative checks, immediate preoperative assessments, and other required elements of documentation.

Facilitate Provider Credentialing

The Joint Commission recently updated the requirements for the process of hospital physician credentialing requiring an Ongoing Professional Performance Evaluation (OPPE). Traditional methods of physician performance evaluation (simulated patients, direct observation, peer assessment) are time-consuming, expensive, and potentially biased. However, some centers, such as MGH, have employed AIMS data to satisfy the Joint Commission requirements for OPPEs.

By using AIMS data for credentialing, it is possible to allow physicians to track their performance, while letting those responsible for credentialing view the performance of the department as a whole. The flexibility associated with an AIMS installation also allows the adjustment of credentialing metrics based on clinical and administrative needs over time.[27]

The major advantage of using AIMS data for physician credentialing is that it requires no additional effort on behalf of the clinician being scrutinized, and reduces the modified behavior that an observer creates. It also has minimal costs to install and maintain, and is unbiased in its measurement of clinical behavior.

Staff Recall in Times of Mass Casualty/Crises

Despite the widespread availability of e-mail, many departments still rely on traditional telephone trees to rapidly communicate mission-critical information—such as a mass casualty incident. At least one center has used its AIMS to create an electronic staff recall system. In this particular center, the AIMS is used as a source of contact information, allowing SMS text messaging to send urgent recall messages to the department.[28]

Quality Assurance/Quality Improvement

Many AIMS provide several key quality assurance/quality improvement functions, and these features support a long tradition of ensuring patient safety and quality in anesthesiology. These areas include tracking individual and aggregated provider performance over time, highlighting occult or problematic practice patterns, and in some cases providing the potential for more prompt resolution of legal claims.

AIMS make it possible to track both individual and aggregated provider performance over time. Metrics may include items such as process measures (eg, on-time case starts), measures of clinical performance (eg, adequacy of neuromuscular reversal, or number of cases where blood pressure was not measured prior to induction of anesthesia), or indications of patient complications (eg unanticipated intensive care unit admissions or reintubations). Because AIMS can allow departmental quality managers to compare individual practice patterns with group performance over time, it is possible to quickly highlight problematic cases, providers, or practice patterns. This has the potential to allow a cycle of AIMS-facilitated continuous quality improvements, which might identify occult issues.

Several studies have shown that AIMS can increase patient care and safety,[9] enhance clinical quality improvement programs,[29] and support management of clinical risk.[30] Because of the improved intraoperative record-keeping quality provided by an AIMS,[4,15] they also offer the potential for more prompt resolution of legal claims brought against providers.

The Future of Information Technology In the Operating Room

Anesthesia information management systems have the potential to impact individual patients, OR suites, and even entire anesthesia departments. They are rapidly increasing in market penetration, and will become

more common across the country as hospitals and departments begin to understand the benefits of having an AIMS installation.

The lack of interconnectivity and seamless integration among systems is still a barrier that is not unique to AIMS, but a problem across many types of EHR systems. Although there is a growing movement toward national standards for data sharing and interconnectivity, we are still years away from having plug-and-play systems that can easily share data across systems—either within or outside of a given institution.

The provision of increasingly smart alarms will continue, as the algorithms that provide real-time clinical decision support improve. This is the most exciting area of AIMS development and will be helped by the development of more robust algorithms, faster processing times, and the accumulating experience of a number of centers working in this area. With the increased reliance on clinical decision support comes the need for both redundancy and backup systems—as providers begin to rely more and more on AIMS for their daily workflow.

Summary

AIMS clearly bring a number of benefits to anesthesiologists. These include the ability to provide clinical decision support, track and improve clinical performance, and potentially increase departmental revenue through the maximization of revenue opportunities. Although AIMS are not universally present in the OR, increasing pressure to provide more in-depth case-based details, such as to third-party payers or external quality improvement organizations, will continue to drive adoption nationwide. Key challenges include a lack of interoperability and a relatively immature market for these systems, with only a handful of vendors predominating.

References

1. Ehrenfeld J. Anesthesia Information Management Systems: A guide to the successful installation and use of AIMS. *Anesthesiology News.* 2009;35(9):1-8.
2. Sandberg WS, Sandberg EH, Seim AR, et al. Real-time checking of electronic anesthesia records for documentation errors and automatically text messaging clinicians improves quality of documentation. *Anesth Analg*. 2008;106(1):192-201.
3. Reich DL, Wood RK Jr, Mattar R. Arterial blood pressure and heart rate discrepancies between handwritten and computerized anesthesia records. *Anesth Analg*. 2000;91(3):612-616.
4. Cook RI, McDonald JS, Nunziata E. Differences between handwritten and automatic blood pressure records. *Anesthesiology*. 1989;71(3):385-390.
5. Thrush DN. Are automated anesthesia records better? *J Clin Anesth*. 1992;4(5):386-389.
6. Lerou JG, Dirksen R, van Daele M, Nijhuis GM, Crul JF. Automated charting of physiological variables in anesthesia: a quantitative comparison of automated versus handwritten anesthesia records. *J Clin Monit*. 1988;4(1):37-47.
7. Epstein RH, Vigoda MM, Feinstein DM. Anesthesia information management systems: a survey of current implementation policies and practices. *Anesth Analg*. 2007;105(2):405-411.
8. Egger Halbeis CB, Epstein RH, Macario A, Pearl RG, Grunwald Z. Adoption of anesthesia information management systems by academic departments in the United States. *Anesth Analg*. 2008; 107(4):1323-1329.
9. O'Reilly M, Talsma A, VanRiper S, Kheterpal S, Burney R. An anesthesia information system designed to provide physician-specific feedback improves timely administration of prophylactic antibiotics. *Anesth Analg*. 2006; 103(4):908-912.
10. Wax DB, Beilin Y, Levin M, Chadha N, Krol M, Reich DL. The effect of an interactive visual reminder in an anesthesia information management system on timeliness of prophylactic antibiotic administration. *Anesth Analg.* 2007;104(6):1462-1466.
11. Kooij FO, Klok T, Hollmann MW, Kal JE. Decision support increases guideline adherence for prescribing postoperative nausea and vomiting prophylaxis. *Anesth Analg*. 2008;106(3): 893-898.
12. Eden A, Pizov R, Toderis L, Kantor G, Perel A. The impact of an electronic reminder on the use of alarms after separation from cardiopulmonary bypass. *Anesth Analg*. 2009;108(4):1203-1208.
13. Ehrenfeld J, Sandberg, WS. Temperature monitoring and management practices in a large academic anesthesia department. *Anesthesiology*. 2007;107:A96.
14. Ehrenfeld JM, Sandberg WS. A novel method for creating alerts of intra-operative gaps in patient monitoring during anesthesia. *Anesth Analg*. 2008;106:S-110.
15. Devitt JH, Rapanos T, Kurrek M, Cohen MM, Shaw M. The anesthetic record: accuracy and completeness. *Can J Anesth*. 1999; 46(2):122-128.
16. Spring SF, Sandberg WS, Anupama S, Walsh JL, Driscoll WD, Raines DE. Automated documentation error detection and notification improves anesthesia billing performance. *Anesthesiology*. 2007;106(1):157-163.
17. Reich DL, Kahn RA, Wax D, Palvia T, Galati M, Krol M. Development of a module for point-of-care charge capture and submission using an anesthesia information management system. *Anesthesiology*. 2006;105(1):179-186.
18. Kheterpal S, Gupta R, Blum JM, Tremper KK, O'Reilly M, Kazanjian PE. Electronic reminders improve procedure documentation compliance and professional fee reimbursement. *Anesth Analg*. 2007;104(3):592-597.
19. Dexter F, Willemsen-Dunlap A, Lee JD. Operating room managerial decision-making on the day of surgery with and without computer recommendations and status displays. *Anesth Analg*. 2007;105(2):419-429.
20. Lubarsky DA, Sanderson IC, Gilbert WC, et al. Using an anesthesia information management system as a cost containment tool. Description and validation. *Anesthesiology*. 1997;86(5):1161-1169.
21. Sandberg WS, Spring FS, Xue F, Paul S, Ehrenfeld JM. Effective reduction of anesthesia drug costs: implementation & outcomes. *Anesthesiology*. 2009;109:27.
22. Vigoda MM, Gencorelli FJ, Lubarsky DA. Discrepancies in medication entries between anesthetic and pharmacy records using electronic databases. *Anesth Analg*. 2007;105(4):1061-1065.

23. Epstein RH, Gratch DM, Grunwald Z. Development of a scheduled drug diversion surveillance system based on an analysis of atypical drug transactions. *Anesth Analg*. 2007;105(4):1053-1060.

24. Dexter F, Epstein RH. Optimizing second shift OR staffing. *AORN J*. 2003;77(4):825-830.

25. Junger A, Benson M, Quinzio L, et al. An anesthesia information management system (AIMS) as a tool for controlling resource management of operating rooms. *Methods Inf Med*. 2002;41(4):81-85.

26. Muravchick S, Caldwell JE, Epstein RH, et al. Anesthesia information management system implementation: a practical guide. *Anesth Analg*. 2008;107(5):1598-1608.

27. Ehrenfeld J, Spring S, Pierce E, Peterfreund R, Forbes V, Sandberg W. Utilization of an anesthesia information management system for physician credentialing. *Anesth Analg*. 2009;107:S-78.

28. Epstein RH, Ekbatani A, Kaplan J, Shechter R, Grunwald Z. Development of a staff recall system for mass casualty incidents using cell phone text messaging. *Anesth Analg*. 2010;110(3):871-878.

29. Röhrig R, Junger A, Hartmann B, et al. The incidence and prediction of automatically detected intraoperative cardiovascular events in noncardiac surgery. *Anesth Analg*. 2004;98(3):569-577.

30. Feldman JM. Do anesthesia information systems increase malpractice exposure? Results of a survey. *Anesth Analg*. 2004;99(3):840-843.