

Anesthesia Information Management Systems: How to Choose and How to Use

David L. Reich, M.D.

New York, New York

How to Choose an Anesthesia Information Management System

There are many commercial products that are marketed as anesthesia information management systems (AIMS) in the United States (U.S.) and worldwide. The overwhelming majority of anesthesiology departments that use AIMS choose commercial products, although a small number have chosen custom programming solutions. The penetration of AIMS in the U.S. market is growing, but is probably much greater in academic departments. A survey of U.S. academic anesthesia indicated that 44% have installed or are currently installing AIMS; commonly cited reasons for lack of installation were cost, perceived medicolegal risk, and inertia.¹ Muravchik summarized the obstacles to more widespread AIMS adoption as more behavioral and financial, rather than technical.² In a survey of 294 European university-affiliated hospitals' AIMS usage, 29% responded. Of the respondents, 51% (15% of the total sample) were considered AIMS adopters because they were already using (n=15), implementing (n=13) or selecting an AIMS (n=16). The main barrier identified by AIMS non-adopters in Europe was lack of funds.³ Considering the changing U.S. healthcare environment, it is likely that many anesthesiology departments will be implementing AIMS in the near future.

A detailed summary of the process of choosing and implementing an AIMS was the subject of a recent multi-center publication by Muravchik et al.⁴ With some modification, the process is described in Table 1.

Table 1. AIMS Purchase and Implementation Plan Outline

1. Justifying the Purchase Expense	
a.	Return on investment (ROI) analysis examples <ul style="list-style-type: none"> i. OR efficiency; drug expenditure tracking; electronic billing revenue cycle enhancement; charge capture/completion facilitation, manual process labor savings; pay-for-performance measures, such as Physician Quality Reporting Initiatives; severity-of-illness grading for hospital charges; electronic health record incentive programs.
b.	Regulatory mandate examples <ul style="list-style-type: none"> i. Increased accuracy, legibility and retrievability of records; Surgical Care Improvement Program reporting; templates consistent with the Joint Commission standards
c.	Patient safety benefit examples <ul style="list-style-type: none"> i. Quality assurance/performance improvement program documentation; capture of co-morbid diseases; risk adjustment of mortality data
2. Product Selection and Implementation	
a.	Needs identification <ul style="list-style-type: none"> i. Define departmental needs; specify personnel and capital and operating budget resources required for implementation and maintenance.
b.	Assign leadership roles <ul style="list-style-type: none"> i. Executive sponsor (anesthesia chairperson or chief information officer) ii. Information technology project manager iii. Anesthesia clinician champion (technology-savvy anesthesiologist or CRNA) iv. System administrator (information technology resource assigned to support system)
c.	Create project folder <ul style="list-style-type: none"> i. Facilitates institutional capital budgeting and approval process ii. Basis for request-for-proposal (RFP) to AIMS vendors
d.	Comparative analysis <ul style="list-style-type: none"> i. Demonstrations on-site ii. Visits to other hospitals with similar size and workflow iii. Consider fixed workstation, mobile workstation, network, and non-OR anesthesia functionality of products specific to needs of anesthesiology department
e.	Contracting <ul style="list-style-type: none"> i. Specifies acceptance criteria and payment structure ii. Warranty and maintenance specifications and implementation and remote support from vendor iii. Business associate agreement for HIPAA compliance

- f. Software customization and configuration
 - i. Project manager, clinical champion, and system administrator effort allocation
 - ii. Creation of clinical templates consistent with local practices; imposing new template structures to facilitate quality measures/regulatory compliance by review/evolution from existing processes/forms
- g. Interfacing tasks for inbound data
 - i. Admission-discharge-transfer demographic system
 - ii. Laboratory information system
 - iii. Surgical scheduling system and “operation note” reporting system
 - iv. Hospital (enterprise) electronic medical record (EMR) for problem lists, medication lists, etc.
 - v. Clinical device outputs into AIMS
- h. Interfacing tasks for outbound data
 - i. Searchable patient database for quality, administration, and research.
 - ii. Network printing /paperless document (e.g., PDF) archive in hospital EMR system
 - iii. Professional charges
 - iv. Export to institutional data warehouse
 - v. Hospital patient tracking systems, materials management, and pharmacy systems
- i. Training
 - i. Clinicians trained using test system and/or in OR
 - ii. Network, server, and workstation support for information technology personnel
- j. Scheduling “Go-Live” process
 - i. Spectrum from gradual to rapid
 - ii. Parallel systems implementation

How to Use an AIMS

Educating and Converting Skeptical Clinicians to Dedicated Users

People are often resistant to change, and an AIMS represents a substantial change compared to a handwritten anesthetic record. This is why one of the most important aspects of success with an AIMS is a local champion who is both motivated and empowered to overcome the many organizational and technical barriers to AIMS implementation. Such effort is rewarded, however, since clinicians eventually acknowledge that an AIMS improves the quality of their practice and rarely ask to switch back to manual/handwritten anesthesia records.⁴

The medicolegal fears about AIMS arise from concern that data that would have been omitted from a handwritten record are automatically recorded in an AIMS-generated one, even if it is factitious/artifactual or transient. A survey addressing this issue, however, demonstrated that AIMS records either had a beneficial effect, or no effect, on outcomes of malpractice cases. No cases were hindered by the AIMS record and the majority of respondents would recommend an AIMS as part of a risk management strategy.⁵ However, at least one case has been reported where a monitoring gap in an AIMS record caused by a technical failure, combined with additional data, showed that an attestation about the presence of an attending anesthesiologist at the time of extubation was entered prior to that event. This information was used to discredit the anesthesiologist and led to a settlement. That group’s AIMS software was later modified to show an alert when the data stream from patient monitors is unexpectedly missing, and they also created a reporting system that discouraged premature attestations.⁶

Improving Clinical Documentation

Several investigators have assessed the impact of an AIMS on the quality of clinical documentation. One study comparing AIMS-produced records to completely handwritten records showed that AIMS records required less practitioner time (both absolute time and percentage of case time), recorded more vital signs and clinical notes, had a similar number of artifacts, and fewer illegible entries.⁷ Another study concluded that missing or erroneous data occurred more frequently in handwritten records, especially during the first 15 minutes and last 10 minutes of a case, when greater attention to patient care is typically required which detracts from attention to documentation.⁸ Accuracy of physiologic (i.e., vital sign) data was also found to be more accurate (or at least more variable) in AIMS records compared with manual records.⁹

AIMS records are still imperfect. Additional studies have shown that information may be incomplete even in an AIMS record due to dependence on free text remarks, an inability to automatically present entries in logical

sequences consistent with workflow, and because practitioners deliberately smooth variability and extreme values in automatically acquired physiologic data in AIMS records.^{10,11} Overall, the improvement realized after AIMS implementation is supported by several surveys that showed that the majority of users, both in OR and obstetric settings, were satisfied with their AIMS and would not want to return to a manual system.^{12,13,14,15}

Enhancing Performance Improvement and Patient Safety

In addition to providing better documentation of clinical care, AIMS have the potential to improve quality of care. Several studies using simple reminders in an AIMS showed that these interventions significantly improved compliance with prophylactic antibiotic administration timing.^{16,17,18} Another group used a computer-generated reminder to enhance rates of re-dosing of antibiotics.¹⁹ Data from AIMS may be extracted and analyzed to generate daily reminders for US Physician Quality Reporting Initiative reports and other communications to improve practitioner performance.

An AIMS-based algorithm that alerted the clinician if a patient had multiple risk factors for postoperative nausea/vomiting nearly doubled the use of antiemetic prophylaxis for these high-risk patients.²⁰ Using an AIMS to screen for intraoperative markers of complications may also be helpful in identifying cases for quality assurance reviews. Electronic screening yielded many more cases of interest than voluntary reporting by clinicians.^{21,22} While the scientific evidence of outcome benefits is still emerging, public reporting of quality measures and pay-for-performance incentives are providing impetus to create AIMS-related systems that help anesthesia practitioners adhere to quality measures and guidelines.

Technologies in common use in other industries are also beginning to be used in healthcare and integrated into AIMS. Use of barcodes on medication labels in conjunction with a special scanning device may decrease medication errors and improve documentation.^{23,24,25} Barcodes and radiofrequency identification tags can also be used to verify patient identity, locate patients and vital equipment, and ensure blood product compatibility.

Other areas of potential improvement with AIMS include: (1) the capacity to retrieve records of prior anesthesia encounters to identify previous problems; (2) an improvement of summary documentation for transfer of care (i.e., handoffs); (3) guidance during emergencies (e.g., malignant hyperthermia or cardiac arrest); (4) laboratory data interfaces that report and record pertinent lab values when they become available; (5) “decision support system” alerts to worrisome trends in physiologic values beyond the simple limit alarms built into monitors, and (6) the ability to monitor cases remotely by accessing live AIMS records from a remote workstation or smartphone.

The possibility that an AIMS could actually jeopardize patient safety has been considered. With clinicians free of the need to record vital signs manually, there is potential for inattention to the vital signs that are both measured and recorded automatically. This issue was addressed in two studies that concluded that the use of an AIMS did not decrease vigilance.^{26,27}

Enhancing Professional Billing Metrics and Clinical Productivity

Use of an AIMS creates opportunities to improve the economics of practice. In addition to recording the clinical documentation that is needed to support billing, the AIMS can function as a point-of-care charge capture system as well. A complete AIMS record can contain all of the necessary patient information, procedure, time, and special technique information that, in combination with patient insurance information, can be used to generate professional charges. Using an AIMS can eliminate the need for paper billing vouchers and can reduce charge lag, clerical and processing costs, lost bills, days in accounts receivable, and practitioner paperwork burden.²⁸ Using automatic electronic mail and PDA alerts to practitioners about deficiencies in the AIMS record to facilitate early correction has also led to improved billing metrics.^{29,30}

AIMS can also increase revenue by helping to identify potentially reimbursable items. One study showed that screening AIMS records for presence of vital signs from an invasive monitor but without supporting documentation of placement of that monitor (necessary for billing) identified a significant source of missed revenue that could be corrected.³¹ Another study showed that use of an AIMS-based pre-operative evaluation system by hospital coders resulted in additional abstracted diagnoses that increased hospital revenue under the diagnosis-related-group (DRG) system.³²

AIMS may serve as a data source for both monitoring and incentivizing practitioner activities. AIMS serve as the basis of a productivity-based compensation system for faculty and house staff in an academic anesthesia practice.³³ An AIMS-based cost-analysis was helpful in implementation of practice guidelines regarding anesthetic drug usage, and lead to significant cost savings.³⁴ AIMS were also reported to assist in identifying practitioners who may be diverting controlled substances by monitoring dispensing behaviors³⁵ and medication reconciliation.³⁶

Enhancing OR Efficiency Using Custom Programming and AIMS Data

AIMS data are essential to a fully functional perioperative patient tracking system. Patient locations are updated and time-stamped as they move through various perioperative areas. Arrival in the OR is automatically documented, as is the progress of the case based on predefined events (e.g., tracheal intubation, procedure start, tracheal extubation). During the patient's post anesthesia care unit (PACU) stay, nurses document clinical progress and reasons for transfer delay (if any) after the patient is medically ready for discharge. The bed-management staff enter inpatient room assignments and the status (e.g., awaiting cleaning) for each same-day-admission patient. Administrative documentation of many other parameters, including personnel identity, patient readiness, expected recovery times, reasons for delayed discharges, and postoperative inpatient bed assignments can be created.

Tracking data are made available to staff with real-time reporting via a variety of modalities. Some of the information is displayed on large-screen monitors with color-coded patient status that is suited to each display location. For example, names of patients awaiting transport to holding areas are highlighted on the screen in the waiting area so that transporters can quickly tend to the patient. In the PACU, patients who are medically ready for discharge but remain in the PACU beyond that time are highlighted so that nurse managers can address the delays and minimize backups. OR coordinators have "big boards" that display OR's that have been empty for prolonged periods of time and on which "to-follow" patients who have not yet arrived are flagged. Tracking information is also available to authorized users at all hospital workstations through a patient-tracking report that can be used to locate patients based on patient name, surgeon name, OR, procedure, scheduled time, etc. A Health Insurance Portability and Accountability Act (HIPAA)-compliant tracking display of selected data is also provided in the family waiting area so that relatives and friends can see when surgery begins and ends. Tracking information is also sent directly to clinicians via their text pagers, email, or mobile phones, providing timely notification of events that can reduce delays. The anesthesia care team is notified as soon as a patient arrives in the holding area.

Dexter et al³⁷ implemented an automatic method to estimate the times remaining in OR cases. Instant message dialogs appearing on AIMS workstations were used to elicit estimates of times remaining from anesthesia providers, with acknowledgment occurring on average within 1.2 min. For cases taking nearly as long as or longer than scheduled, each 1 min progression of OR time reduced the median time remaining in a case by <1 min. Based upon historical surgeon performance, they demonstrated more accurate automated calculation of times remaining for every case occurring at a 29 OR hospital.

Conducting Clinical Research

Continued use of an AIMS leads to accumulation of large amounts of clinical data that can be used for research purposes. These data can be mined (extracted) and used to generate hypotheses prior to planning prospective studies, to study rare events, or questions that cannot be ethically or practically studied prospectively. There is also opportunity to combine the electronic records created by AIMS from multiple centers, allowing multicenter retrospective analyses. Such efforts are hindered, however, by the lack of standardization of structure and terminology in electronic medical records. Multiple efforts are underway to create such standards.³⁸ For prospective studies, an AIMS can be configured to collect necessary data elements, and an AIMS-based pre-operative evaluation can be used to screen patients for inclusion in research protocols.

The AIMS data structure can also be modified to include additional variables of interest that will facilitate future studies. Since the standards for controlled anesthesia terminologies have only begun to be incorporated by the AIMS vendors, there is very limited exchange of clinical data among AIMS in different institutions, though it can be still be accomplished with manual mapping of variables between each system.³⁹

Whenever possible, data should be acquired from anesthesia practitioners in a structured format. Although it is easier for practitioners to enter the operation performed as a free text field rather than choosing from a long list of current procedural terminology (CPT) or choosing diagnoses from International Classification of Diseases (ICD-9)

codes, the quality improvement and research tasks will be much simpler with the database-generated list. Free text fields are very difficult to search, and the variability of spacing, abbreviations, and misspellings greatly complicates the task, compared with the ease of searching across ranges of numerical codes.⁴⁰ For US practice, surgical CPT codes are preferable to anesthesia CPT codes for many reasons, but mainly because anesthesia CPT's do not specify the exact operation performed. It is possible map one or more surgical CPT codes to a single anesthesia code using the American Society of Anesthesiologists (ASA) Crosswalk Program (ASA, Park Ridge, IL), but the reverse is not possible.

External Databases

One of the greatest challenges in AIMS-based research is the merging of data from separate databases. In the process of conducting evidence-based patient safety research, it is inevitable that hospital, surgical, and governmental databases will be used at some point for collecting demographics, process and outcome variables that are not present in the anesthesiology database. For example, length of hospital stay and co-morbid conditions leading to prolonged hospital stays are data that are not routinely found in the anesthesiology database. In the reconciliation of databases, it is often critical to use multiple identifiers for patients, including medical record numbers, hospital account numbers that are specific to each hospital encounter, dates of surgery, etc. This is necessary in order to positively identify the data (e.g., a postoperative infection) that coincides with the hospital encounter of interest (e.g., an abdominal surgical operation).

Analyzing the Data

For many operational analyses of patient data, a formal statistical analysis is not undertaken. Clinicians and administrators use their judgment to assess the importance of the differences between groups. In the example provided in Table 2, data from the AIMS was merged with data from the PACU database to assess the effect of anesthetic technique upon PACU length of stay for ambulatory patients. Percentiles are displayed in addition to means and standard deviations. This is an important consideration because medical data are often skewed (i.e., are not normally distributed). For example, a few patients who stay overnight in a PACU will have drastic effects on the calculation of the average stay in PACU, whereas the median will be a more representative number. Non-parametric statistical approaches are best suited to looking for differences between groups when ordinal data (e.g., ASA physical status classification) or skewed data are analyzed.

Table 2. Post-Anesthesia Care Unit Length of Stay Data by Type of Anesthetic

	General	MAC	Spinal	Non-Spinal Regional
Number of Patients	1266	553	84	87
5th Percentile (min)	40	30	76	47
25th Percentile (min)	80	55	134	75
50th Percentile (min)	115	80	181	95
75th Percentile (min)	168	110	264	140
95th Percentile (min)	298	190	408	214
Mean \pm SD (min)	135 \pm 89	205 \pm 2025	209 \pm 148	113 \pm 63

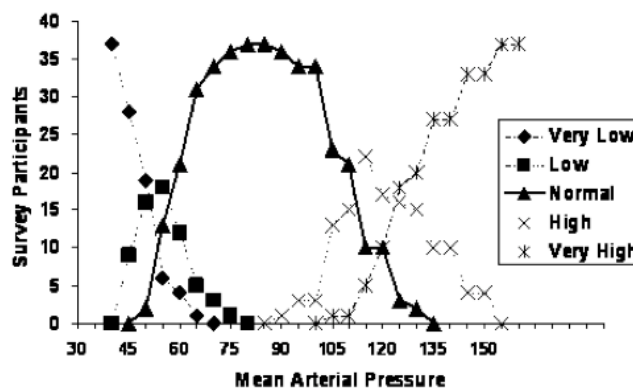
MAC = monitored anesthesia care

(unpublished data from author's institution)

The analysis of physiological data, such as blood pressure or heart rate, requires a method for removing artifact. With blood pressure for example, arterial lines are subjects to artifacts during flushing or blood sample withdrawal, and non-invasive blood pressure cuffs are subject to motion artifact. Just as in the analysis of skewed data, blood pressure artifacts are also best removed by determining the median of several observations over a period of time. For example, if intraarterial line data are acquired every 15 seconds, using the medians of systolic, diastolic, and mean blood pressure values over a 2 minute epoch (that includes 8 observations) is a very effective method for removing artifacts. It is more problematic with non-invasive blood pressure data that are usually collected less often. Median values over 5-minute epochs are useful in non-invasive blood pressure data artifact rejection. It is also possible to reject all values above and below certain limits of validity. For example, all mean arterial pressure less than 20 mm Hg or greater than 200 mm Hg can be rejected as being non-physiological and therefore artifact.

The problem with this is that all rules have exceptions, such as the blood pressures in certain pediatric patients and cardiac patients.

Another problem that remains is the definition of abnormalities during anesthesia. For example, the definitions of hypotension and hypertension in the anesthetized patient have never been established. While ranges of normal and abnormal BP must be adjusted for age and coexisting medical conditions, anesthesiologists have considerable inter-individual variability in defining abnormal BP. In the example presented in Figure 1, 37 anesthesiologists at the authors' institution were surveyed on criteria for defining very low, low, normal, high, and very high mean arterial pressure (MAP) in a healthy adult patient. The figure demonstrates that the only parameters that all 37 anesthesiologists agreed upon unanimously were the following: that a MAP of 40 was very low, that a MAP of 80-85 was normal, and that a MAP of 155-160 was very high. This classic demonstration of a fuzzy logic plot implies that our profession has yet to define what is abnormal despite our improved ability to measure and record exact physiological parameters using AIMS.⁴¹



More complex analyses will require the services of a biostatistician and multivariate methods are commonly employed in database research. The major limitations of retrospective database research are as follows: there is no prospective assignment to treatment groups; no randomization of therapy; and, therefore, no true control group. An analysis that controls for these limitations is therefore required. Typically, multivariate logistic regression, propensity analyses, or case-control methodology are used to control for the influence of demographic and perioperative variables that could influence the process or outcome variable being analyzed. In the example provided in Table 3, propofol induction of anesthesia was demonstrated to be an independent predictor of hypotension in the 10 minutes following induction of anesthesia, when the effects of pre-induction hypotension, advanced age, fentanyl dosage, and ASA status was controlled for.⁴² A biostatistician is crucial to the planning and execution of this effort.

Table 3. Predictors of Post-Anesthetic Induction Hypotension

Variable	OR [95% C.I.]	P-Value
Baseline MAP <70 mm Hg	5.00 [2.78–9.02]	<0.0001
Age ≥50 yrs	2.25 [1.75–2.89]	<0.0001
Propofol induction (vs. thiopental or etomidate)	3.94 [2.42–6.43]	<0.0001
Increasing fentanyl dosage*	1.32 [1.13–1.56]	0.0008
ASA 3-5 (vs. ASA 1-2)	1.55 [1.22-1.99]	0.0004

MAP = mean arterial pressure

ASA = American Society of Anesthesiologists Physical Status Classification

Modified from Reference 42.

Conclusion

The extensive functionality of AIMS and custom add-on systems in many of the “early adopter” centers have been developed over many years. Such systems are likely to be implemented more rapidly in the future by others. This process most often begins with the deployment of a standard commercial AIMS software package, which is then extensively configured to meet the individual departmental needs and integrated with the enterprise (hospital) electronic medical record. Programming resources and initiative are needed for a full exploitation of the potential of an AIMS. Control of extensive perioperative information resources is an intangible but real return on investment.

References

1. 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;107:1323-9.
2. Muravchick S. Anesthesia information management systems. *Curr Opin Anaesthesiol*. 2009;22:764-8.
3. Balust J, Egger Halbeis CB, Macario A. Prevalence of anaesthesia information management systems in university-affiliated hospitals in Europe. *Eur J Anaesthesiol*. 2010;27:202-8.
4. Muravchick S, Caldwell JE, Epstein RH, Galati M, Levy WJ, O'Reilly M, Plagenhoef JS, Rehman M, Reich DL, Vigoda MM. Anesthesia information management system implementation: a practical guide. *Anesth Analg*. 2008;107:1598-608.
5. Feldman JM. Do anesthesia information systems increase malpractice exposure? Results of a survey. *Anesth Analg*. 2004;99:840-3.
6. Vigoda MM, Lubarsky DA. Failure to recognize loss of incoming data in an anesthesia record-keeping system may have increased medical liability. *Anesth Analg*. 2006;102:1798-802.
7. Edsall DW, Deshane P, Giles C, Dick D, Sloan B, Farrow J. Computerized patient anesthesia records: less time and better quality than manually produced anesthesia records. *J Clin Anesth*. 1993;5:275-83.
8. 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;4:37-47.
9. Reich DL, Wood RK Jr, Mattar R, Krol M, Adams DC, Hossain S, Bodian CA. Arterial blood pressure and heart rate discrepancies between handwritten and computerized anesthesia records. *Anesth Analg*. 2000;91:612-6.
10. Driscoll WD, Columbia MA, Peterfreund RA. An observational study of anesthesia record completeness using an anesthesia information management system. *Anesth Analg*. 2007;104:1454-61.
11. Wax DB, Beilin Y, Hossain S, Lin HM, Reich DL. Manual editing of automatically recorded data in an anesthesia information management system. *Anesthesiology*. 2008;109:811-5.
12. Eden A, Grach M, Goldik Z, Shnaider I, Lazarovici H, Barnett-Griness O, Perel A, Pizov R. The implementation of an anesthesia information management system. *Eur J Anaesthesiol*. 2006;23:882-9.
13. Coleman RL, Stanley T 3rd, Gilbert WC, Sanderson IC, Moyer GA, Sibert KS, Reves JG. The implementation and acceptance of an intra-operative anesthesia information management system. *J Clin Monit*. 1997;13:121-8.
14. Quinzio L, Junger A, Gottwald B, Benson M, Hartmann B, Jost A, Banzhaf A, Hempelmann G. User acceptance of an anaesthesia information management system. *Eur J Anaesthesiol*. 2003;20:967-72.
15. Beilin Y, Wax D, Torrillo T, Mungall D, Guinn N, Henriquez J, Reich DL. A survey of anesthesiologists' and nurses' attitudes toward the implementation of an Anesthesia Information Management System on a labor and delivery floor. *Int J Obstet Anesth* 2009;18:22-7.
16. 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;103:908-12.
17. 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;104:1462-6.
18. St Jacques P, Sanders N, Patel N, Talbot TR, Deshpande JK, Higgins M. Improving timely surgical antibiotic prophylaxis redosing administration using computerized record prompts. *Surg Infect (Larchmt)*. 2005;6:215-21.
19. Zanetti G, Flanagan HL Jr, Cohn LH, Giardina R, Platt R. Improvement of intraoperative antibiotic prophylaxis in prolonged cardiac surgery by automated alerts in the operating room. *Infect Control Hosp Epidemiol*. 2003;24:13-6.
20. Kooij FO, Klok T, Hollmann MW, Kal JE. Decision support increases guideline adherence for prescribing postoperative nausea and vomiting prophylaxis. *Anesth Analg* 2008;106:893-8.
21. Sanborn KV, Castro J, Kuroda M, Thys DM. Detection of intraoperative incidents by electronic scanning of computerized anesthesia records. Comparison with voluntary reporting. *Anesthesiology*. 1996;85:977-87.
22. Benson M, Junger A, Fuchs C, Quinzio L, Böttger S, Jost A, Uphus D, Hempelmann G. Using an anesthesia information management system to prove a deficit in voluntary reporting of adverse events in a quality assurance program. *J Clin Monit Comput* 2000;16:211-7.
23. Merry AF, Webster CS, Mathew DJ. A new, safety-oriented, integrated drug administration and automated anesthesia record system. *Anesth Analg* 2001;93:385-90.

24. Webster CS, Merry AF, Gander PH, Mann NK. A prospective, randomised clinical evaluation of a new safety-orientated injectable drug administration system in comparison with conventional methods. *Anaesthesia*. 2004;59:80-7.
25. Nolen AL, Rodes WD 2nd. Bar-code medication administration system for anesthetics: effects on documentation and billing. *Am J Health Syst Pharm* 2008;65:655-9.
26. Allard J, Dzwonczyk R, Yablok D, Block FE Jr, McDonald JS. Effect of automatic record keeping on vigilance and record keeping time. *Br J Anaesth* 1995;74:619-26.
27. Loeb RG. Manual record keeping is not necessary for anesthesia vigilance. *J Clin Monit* 1995;11:5-8.
28. 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;105:179-86.
29. Spring SF, Sandberg WS, Anupama S, Walsh JL, Driscoll WD, Raines DE. Automated documentation error detection and notification improves anesthesia billing performance. *Anesthesiology* 2007;106:157-63.
30. Sandberg WS, Sandberg EH, Seim AR, Anupama S, Ehrenfeld JM, Spring SF, Walsh L. Real-time checking of electronic anesthesia records for documentation errors and automatically text messaging clinicians improves quality of documentation. *Anesth Analg* 106:192-201, 2008.
31. 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;104:592-7.
32. Gibby GL, Paulus DA, Sirota DJ, Treloar RW, Jackson KI, Gravenstein JS, van der Aa JJ. Computerized pre-anesthetic evaluation results in additional abstracted comorbidity diagnoses. *J Clin Monit* 1997;13:35-41.
33. Reich DL, Galati M, Krol M, Bodian CA, Kahn RA. A mission-based productivity compensation model for an academic anesthesiology department. *Anesth Analg* 2008;107:1981-8.
34. Lubarsky DA, Sanderson IC, Gilbert WC, King KP, Ginsberg B, Dear GL, Coleman RL, Pafford TD, Reves JG. Using an anesthesia information management system as a cost containment tool. Description and validation. *Anesthesiology* 1997;86:1161-9.
35. 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;105:1053-60.
36. Vigoda MM, Gencorelli FJ, Lubarsky DA. Discrepancies in medication entries between anesthetic and pharmacy records using electronic databases. *Anesth Analg* 2007;105:1061-5.
37. Dexter F, Epstein RH, Lee JD, Ledolter J. Automatic updating of times remaining in surgical cases using bayesian analysis of historical case duration data and "instant messaging" updates from anesthesia providers. *Anesth Analg* 2009;108:929-40. javascript:PopupMenu2_Set(Menu19224806);
38. Warner MA, Monk TG. The impact of lack of standardized definitions on the specialty. *Anesthesiology*. 2007;107:198-9.
39. Monk TG, Sanderson I. The development of an anesthesia lexicon. *Seminars in Anesthesia Perioperative Medicine and Pain*. 2004;23:93-8.
40. Levin MA, Krol M, Doshi AM, Reich DL. Extraction and mapping of drug names from free text to a standardized nomenclature. *AMIA Annu Symp Proc* 2007;11:438-42.
41. Reich DL, Krol M. Using AIMS data for quality improvement and research. *Seminars in Anesthesia, Perioperative Medicine and Pain* 2004;23:99-103.
42. Reich DL, Hossain S, Krol M, Baez B, Patel P, Bernstein A, Bodian CA. Predictors of hypotension after induction of general anesthesia. *Anesth Analg* 2005;101:622-8.

This speaker has indicated that he or she has no significant financial relationship with the manufacturer of a commercial product or provider of a commercial service that may be discussed in this presentation.