

***Real Time Checks for Clinical Care and Billing***

AIMS did not check for and detect loss of incoming data resulting in an incomplete record. The patient became quadriplegic during the period without data and the quality of the anesthetic was claimed to be poor. Because data were missing, quality of care could not be assessed.

Vigoda MM, Lubarsky DA. [Failure to recognize loss of incoming data in an anesthesia record-keeping system may have increased medical liability](#). *Anesthesia & Analgesia* 102: 1798-1802, 2006

AIMS can improve incidence of use of monitor alarm systems.

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](#). *Anesthesia & Analgesia* 108: 1203-1208, 2009

AIMS can reduce the incidence of inaccurately recorded hemodynamic data and gaps in measuring blood pressure. Manual invalidation of the automatically recorded data was done at one facility for 19% of cases. The edits resulted almost always in smoothing of the anesthesia record. The loss of information is insufficient for chart review to result in different clinical inference. Gaps of  $\geq 10$  minutes with no blood pressure checked occur in 1% to 7% of cases depending on monitor and AIMS configuration. Absence from manual records is an artifact of clinicians' manual smoothing. When comparing hospitals, the incidences of gaps should be measured, as well as the incidences of manual editing of automatically recorded vital signs.

Wax DB, Beilin Y, Hossain S, Lin HM, Reich DL. [Manual editing of automatically recorded data in an anesthesia information management system](#). *Anesthesiology* 109: 811-815, 2008

van Schalkwyk JM, Lowes D, Frampton C, Merry AF. [Does manual anaesthetic record capture remove clinically important data?](#) *British Journal of Anaesthesia* 107: 546-552, 2011

Epstein RH, Dexter F. [Mean arterial pressures bracketing prolonged monitoring interruptions have negligible systematic differences from matched controls without such gaps](#). *Anesthesia & Analgesia* 113: 267-271, 2011

Ehrenfeld JM, Epstein RH, Bader S, Kheterpal S, Sandberg WS. [Automatic notifications mediated by anesthesia information management systems reduce the frequency of prolonged gaps in blood pressure documentation](#). *Anesthesia & Analgesia* 113: 356-363, 2011

Lack of accuracy and completeness of handwritten anesthesia records are well known. Free text entry fields in electronic systems are also inaccurate (e.g., > 1/3<sup>rd</sup> of required fields not completed), resulting in bills not sent because of lack of required documentation. Alphanumeric pages and email sent automatically and repeated at least daily until documentation was completed increased billing. For example, if there was an invasive arterial blood pressure tracing present, there also had to be a corresponding procedure note. Subsequently, the process was revised for the anesthesia record to be scanned in real-time for missing documentation (e.g., patient allergy not listed within 15 min of the start of the anesthetic) and an alphanumeric page sent to the anesthesia provider, rather than after the case was completed.

Driscoll WD, Columbia MA, Peterfreund RA. [An observational study of anesthesia record completeness using an anesthesia information management system](#). *Anesthesia & Analgesia* 104: 1454-1461, 2007

Spring SF, Sandberg WS, Anupama S, Walsh JL, Driscoll WD, Raines DE. [Automated documentation error detection and notification improves anesthesia billing performance](#). *Anesthesiology* 106: 157-163, 2007

Kheterpal S, Gupta R, Blum JM, Tremper KK, O'Reilly M, Kazanjian PE. [Electronic reminders improve procedure documentation compliance and professional fee reimbursement](#). *Anesthesia & Analgesia* 104: 592-597, 2007

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](#). *Anesthesia & Analgesia* 106: 192-201, 2008

Prophylactic antibiotic received within 1 hr before surgical incision is a JCAHO core measure. Hospitals must report their rate of compliance. Automatic AIMS messages sent if the antibiotic was not administered resulted in increased compliance rate. Results depend on latency of the server and messaging. Near 100% compliance can be achieved when there is email feedback, summary reports by provider, and real-time alerts.

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](#). *Anesthesia & Analgesia* 103: 908-912, 2006

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](#). *Anesthesia & Analgesia* 104: 1462-1466, 2007

Nair BG, Newman SF, Peterson GN, Wu WY, Schwid HA. [Feedback mechanisms including real-time electronic alerts to achieve near 100% timely prophylactic antibiotic administration in surgical cases](#). *Anesthesia & Analgesia* 111: 1293-1300, 2010

Schwann NM, Bretz KA, Eid S, Burger T, Fry D, Ackler F, Evans P, Romancheck D, Beck M, Ardire AJ, Lukens H, McLoughlin TM. [Point-of-care electronic prompts: an effective means of increasing compliance, demonstrating quality, and improving outcome](#). *Anesthesia & Analgesia* 113: 869-876, 2011

Quality assurance documentation is required of anesthesia groups. A hospital's completion rate did not meet benchmark standards. They changed the AIMS to open the QA form automatically if it had not yet been completed and the AIMS was accessed from a workstation in the PACU or ICU. Thus, to finish handoff of patient in the PACU or ICU, the QA form had to be completed. The paper shows that the sequence of AIMS forms should depend on the workstation location.

Vigoda MM, Gencorelli F, Lubarsky DA. [Changing medical group behaviors: increasing the rate of documentation of quality assurance events using an anesthesia information system](#). *Anesthesia & Analgesia* 103: 390-395, 2006

When reading, also see the following earlier article.

Feldman JM. [Do anesthesia information systems increase malpractice exposure? Results of a survey](#). *Anesthesia & Analgesia* 99: 840-843, 2004

Use of such a system substantially increased the number of adverse events captured.

Peterfreund RA, Driscoll WD, Walsh JL, Subramanian A, Anupama S, Weaver M, Morris T, Arnholz S, Zheng H, Pierce ET, Spring SF. [Evaluation of a mandatory quality assurance data capture in anesthesia: a secure electronic system to capture quality assurance information linked to an automated anesthesia record](#). *Anesthesia & Analgesia* 112: 1218-1225, 2011

Quality assurance documentation for intraoperative care can be automated based on tolerances of vital signs.

Grant C, Ludbrook G, Hampson EA, Semenov R, Willis R. [Adverse physiological events under anaesthesia and sedation: a pilot audit of electronic patient records](#). *Anaesthesia & Intensive Care* 36: 222-229, 2008

During the preanesthesia evaluation, each patient's risk for postoperative nausea and vomiting was calculated, and a message appeared as soon as the anesthetic plan was specified inquiring as to whether the anesthesiologist wanted to prescribe PONV prophylaxis. The rate of administration was increased for patients with the message, but not for those without. After discontinuation of the messages, prophylaxis use returned to baseline showing that it was the messaging itself that was helpful, not learning.

Kooij FO, Klok T, Hollmann MW, Kal JE. [Decision support increases guideline adherence for prescribing postoperative nausea and vomiting prophylaxis](#). *Anesthesia & Analgesia* 106: 893-898, 2008

### ***Real Time Management Calculations***

When AIMS are installed, they are often accompanied by status displays (e.g., at OR control desk and on computers). Anesthesiologists, OR nurses, and housekeepers were given nine simulated scenarios involving multiple ORs to study their decision-making based on AIMS real-time data. Participants were randomized to one of four groups, all with the hospital's current paper OR schedule: with/without command display and with/without passive status display. Participants making decisions without command displays performed no better than random chance in terms of increasing the predictability of work hours, reducing over-utilized OR time, and increasing OR efficiency. Status displays had no effect on these end-points, whereas command displays improved the quality of decisions.

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.](#) *Anesthesia and Analgesia* 105: 419-429, 2007

OR control desks use paper with colored pens or white boards with magnets. Installation of AIMS often involves creation of simple status displays. However, the anesthesia coordinators are using their multiple paper artifacts to link staff schedules, staff assignments, and case schedules in the presence of the frequent changes and updates. The marks communicate the linkages and bases for decisions asynchronously to the broad social audience.

Nemeth C, O'Connor M, Klock PA, Cook R. [Discovering healthcare cognition: the use of cognitive artifacts to reveal cognitive work.](#) *Organization Studies* 27: 1011-1035, 2006

Decision-support relies on matching patients to specific anesthetizing locations. Routine use of radiofrequency identification (RFID) was found to be impractical because the location of where each patient should be located had to be updated by clerks in real-time. For RFID and patient bar coding to be practical, there needs to be use of automated staff assignment software.

Egan MT, Sandberg WS. [Auto identification technology and its impact on patient safety in the Operating Room of the Future.](#) *Surgical Innovation* 14: 41-51, 2007

Automatic determination of when each patient has entered or left his/her OR can be determined automatically by real-time processing of networked S<sub>p</sub>O<sub>2</sub>, EKG heart rate, and temperature. This depends highly on the latency of updates on the server. If rapid, identification of patient in and out times can be as accurate as those recorded by staff on paper.

Xiao Y, Hu P, Hao H, Ho D, Dexter F, Mackenzie CF, Seagull FJ, Dutton R. [Algorithm for processing vital sign monitoring data to remotely identify operating room occupancy in real-time.](#) *Anesthesia & Analgesia* 101: 823-829, 2005

Upon AIMS implementation, listed anesthetic locations required to assess concurrency (i.e., for billing) were incorrect for 10% of cases. Most of these errors occurred 7 AM to 5 PM on workdays, when OR secretaries were present. A 1.5 yr effort of educating secretaries, formally reprimanding individuals, etc., resulted in a reduction in the percentage of cases moved after the start from 12% to 2%. However, this meant that the residual AIMS error rate was still 4% of cases. The hospital started to infer the actual location of cases for billing from the physical location of the workstation recording the majority of pulse oximetry saturations, achieving 99.9% accuracy. In real time, the anesthetic location was obtained using the workstation transmitting SpO<sub>2</sub>, EKG heart rate, and end tidal CO<sub>2</sub> partial pressures.

Epstein RH, Dexter F, Piotrowski E. [Automated correction of room location errors in anesthesia information management systems.](#) *Anesthesia & Analgesia* 107: 965-971, 2008

The system was combined with the use of historical case duration data to provide autonomous updating of OR whiteboards (status displays) with the times remaining in cases. The method is needed for decisions, because once a case scheduled for 2 h has been on-going for 1.5 h, the median time remaining is not 0.5 h but longer, and the amount longer differs substantially among procedures.

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.](#) *Anesthesia & Analgesia* 108: 929-940, 2009

The recommendations in decision-support systems driven by AIMS are sensitive to missing or delayed documentation and to the interval between successive queries (e.g., q 1 min or q 10 min on the server). For each automatic recommendation applied to each facility, the latency needs to be measured and its impact on the performance of the system's recommendations should be assessed. Appropriate statistical methods have been developed.

Epstein RH, Dexter F, Ehrenfeld JM, Sandberg WS. [Implications of event entry latency on anesthesia information management decision support system.](#) *Anesthesia & Analgesia* 108: 941-947, 2009

Ledolter J, Dexter F, Epstein RH. [Analysis of variance of communication latencies in anesthesia: Comparing means of multiple lognormal distributions.](#) *Anesthesia & Analgesia* 113: 888-896, 2011

### ***Calculations Made When an Anesthetic is Over***

The audit trail of time stamps events showed that attending physicians were documenting presence at emergence before emergence (i.e., there was an appearance of fraudulent billing). Automated email performance feedback with Cc of Chair corrected the behavior.

Vigoda MM, Lubarsky DA. [The medicolegal importance of enhancing timeliness of documentation when using an anesthesia information system and the response to automated feedback in an academic practice.](#) *Anesthesia & Analgesia* 103: 131-136, 2006

Multiple implementations of AIMS lack processes to validate attending physician attestations (e.g., both within cases and among cases to which the attending is assigned) – see preceding paper. They also lack process to annotate artifacts resulting in the false impression that they are absent because they do not appear in printouts.

Epstein RH, Vigoda MM, Feinstein DM. [Anesthesia information management systems: a survey of current implementation policies and practices](#). *Anesthesia & Analgesia* 105:405–411, 2007

To calculate costs for each case to a useful accuracy, AIMS must have detailed pharmacy information systems data (e.g., vial sizes are combined with amount of drug administered to estimate wastage). Daily AIMS feedback to clinicians resulted in reduced drug costs per case.

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* 86:1161–1169, 1997

Quarterly feedback was provided on compliance with postoperative nausea and vomiting prophylaxis guidelines, resulting in significant improvement in compliance rates. The accompanying editorial reviews regulatory requirements in developing real time versus delayed feedback to providers on clinical care.

Frenzel JC, Kee SS, Ensor JE, Riedel BJ, Ruiz JR. [Ongoing provision of individual clinician performance data improves practice behavior](#). *Anesthesia & Analgesia* 111:515-519, 2010

Epstein RH. [Postoperative nausea and vomiting, decision support, and regulatory oversight](#). *Anesthesia & Analgesia* 111: 270-271, 2010

Discrepancies in controlled substances were present in more than 10% of cases. Wastage check in pharmacy information system did not check total drug administration reported in AIMS. Some AIMS records had too little or much controlled substance reported. Thus, the running total of drug administered must be calculated and compared in real time to pharmacy system.

Vigoda MM, Gencorelli FJ, Lubarsky DA. [Discrepancies in medication entries between anesthetic and pharmacy records using electronic databases](#). *Anesthesia & Analgesia* 105: 1061-1065, 2007

AIMS are used to monitor anesthesia providers' drug diversion by detecting (e.g., frequent checkout of drugs from dispensing systems in locations differing from where the anesthetic is performed and checkout far earlier or later than the start of cases). These rely on accuracy in the AIMS of the principal location of the case and tracking of all locations where the anesthetic was performed (e.g., holding area to block room to OR #1 to PACU).

Epstein RH, Gratch DM, Grunwald Z. [Development of a drug diversion surveillance system based on an analysis of atypical drug transactions](#). *Anesthesia & Analgesia* 105: 1053-1060, 2007

Tetzlaff J, Collins GB, Brown DL, Leak BC, Pollock G, Popa D. [A strategy to prevent substance abuse in an academic anesthesiology department](#). *Journal of Clinical Anesthesia* 22:143-150, 2010

Epstein RH, Gratch DM, McNulty S, Grunwald Z. [Validation of a system to detect scheduled drug diversion by anesthesia care providers](#). *Anesthesia & Analgesia* 113:160-164, 2011

Billing elements are extracted automatically from the AIMS record (e.g., personnel, relief to check concurrency, surgical procedure, patient information, anesthetics administered, modifiers such as deliberate hypotension, and procedures such as central line). There were significant reductions in charge lag, days in accounts receivables, and labor costs.

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* 105:179–186, 2006

Residents in anesthesia training programs throughout the world are required to document their clinical cases to help ensure that they receive adequate training. Case logs generated automatically from an AIMS can replace manual processes, improve accuracy, and decrease residents' clerical burden.

Simpao A, Heitz JW, McNulty SE, Chekemian B, Brenn BR, Epstein RH. [The design and implementation of an automated system for logging clinical experiences using an anesthesia information management system](#). *Anesthesia & Analgesia* 112:422-429, 2011

If choosing to monitor recovery times by using the AIMS record, the accurate end point to use is the percentage of times that are prolonged (e.g., > 15 minutes).

Dexter F, Bayman EO, Epstein RH. [Statistical modeling of average and variability of time to extubation for meta-analysis comparing desflurane to sevoflurane](#). *Anesthesia & Analgesia* 110: 570-580, 2010

### ***Other studies***

Automatic quality of care review was based on the vital signs from the AIMS.

Dexter F, Penning DH, Lubarsky DA, DeLong E, Sanderson I, Gilbert BC, Bell E, Reves JG. [Use of an automated anesthesia information system to determine reference limits for vital signs during cesarean section](#). *Journal of Clinical Monitoring and Computing* 14: 491-498, 1998

Anesthesia staffing calculated from AIMS are interchangeable with that calculated using OR information system data for locations with OR data. Since all locations in the AIMS, the results mean that the AIMS will generally be best for anesthesia decision-making. Surgical workload for each anesthetizing location can also be calculated using AIMS data.

Dexter F, Epstein R. [Optimizing second shift OR staffing](#). *AORN Journal* 77: 825-830, 2003

Junger A, Benson M, Quinzio L, Michel A, Sciuk G, Brammen D, Marquardt K, Hempelmann G. [An Anesthesia Information Management System as a tool for controlling resource management of operating rooms](#). *Methods of Information in Medicine* 41:81-85, 2002

Survey of US academic anesthesia departments revealed that 44% have installed or are installing an AIMS.

Egger Halbeis CB, Epstein RH, Macario A, Pearl RG, Grunwald Z. [Adoption of anesthesia information management systems by academic departments in the United States](#). *Anesthesia & Analgesia* 107: 1323-1329, 2008

This article summarizes the experiences of a large number of AIMS experts and highlights essential considerations for selection and implementation of an AIMS. Practical aspects of the process are emphasized.

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](#). *Anesthesia & Analgesia* 107: 1598-1608, 2008

Anesthesia group developed and tested a staff recall system using Short Message Service (SMS) text messaging. Their AIMS is used as the source for contact information and from which the messages are sent, making the process inexpensive and easy to implement.

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](#). *Anesthesia & Analgesia* 110: 871-878, 2010

Same group used the AIMS as a software platform for a computerized system to convey frequently used prerecorded phrases in the languages most often encountered in their patients.

Taicher BM, Alam RI, Berman J, Epstein RH. [Design, implementation, and evaluation of a computerized system to communicate with patients with limited native language proficiency in the perioperative period](#). *Anesthesia & Analgesia* 112:106-112, 2011