

Anesthesia Information Management Case Study

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The advent of anesthesia information systems (AIMS) has created an excellent source of perioperative patient data. Most of the information is highly accurate^{1,2,3} and retrievable, in contrast to the difficult task of acquiring data from handwritten anesthesia records. This presentation will summarize the issues that are involved in using data from AIMS for quality improvement or research purposes with the goal of conducting evidence-based medical research and improving patient safety.

The Mount Sinai Medical Center began using an anesthesia information management system (AIMS) (CompuRecord®, Philips Medical Systems, Andover MA) for electronic intraoperative anesthesia recordkeeping in 1991 in cardiothoracic and liver transplant operating rooms. The AIMS was extended to all ORs by 1998, and to the labor and delivery (L&D) suite in 2006. Currently, approximately 40,000 anesthetic records are created annually and it is presently used in approximately 50 ORs, 16 L&D rooms, and 10 non-OR procedural areas. Use of an AIMS for intraoperative recordkeeping has been associated with numerous benefits when compared with handwritten paper records, including improved capture of physiologic data, increased legibility, less time requirement, and stronger legal defensibility.⁴

In addition to intraoperative recordkeeping, our AIMS includes a generic form-management module that is flexible and can be adapted to many uses. Forms that have been developed include postoperative evaluations, pain management notes for both consultations and procedures, and critical care progress and procedure notes.

The proprietary AIMS software is the core system upon which we have created custom applications using departmental and medical center information technology resources. These custom applications fall under the general categories of performance improvement, departmental administration (billing and physician compensation), patient tracking, perioperative administration, regulatory/compliance reporting, and research. Thus, the term AIMS refers to a multitude of linked information systems that support the needs of the department and the institution.

The basic function of the AIMS is to acquire physiological data from the patient-based monitors, and information regarding medical history, perioperative procedures, and drug and fluid therapy from the practitioners or links to hospital systems. Completely objective and numerical data can often be acquired electronically, such as blood pressure and digital pulse oximetry readings, whereas subjective data, such as equal bilateral breath sounds following tracheal intubation, are entered as database fields (often done as 'check-off' boxes) or as free-form text entries. Various vendors of AIMS design their systems differently, and the configuration may differ from hospital to hospital within the same AIMS vendor's installations.

RESEARCH

The vast amount of clinical information stored in our AIMS provides a valuable resource for retrospective research efforts since large amounts of data can be mined to answer clinical questions and to test hypotheses. The AIMS data structure can also be modified to include additional variables of interest that will facilitate future retrospective 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 still be accomplished with manual mapping of variables between each system.⁵

Whenever possible, data should be acquired from anesthesia practitioners in the database format. Although it may be easier for the practitioner to enter the operation performed as a free text field rather than choosing from a long list of CPT or ICD-10 codes, the quality improvement and research task 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. For US practice surgical CPT codes are preferable to anesthesia CPT codes for many reasons, but mainly because it is possible to map one or more surgical CPT codes to a single anesthesia code using the American Society of Anesthesiologists Crosswalk Program (American Society of Anesthesiologists, Chicago, IL), but the reverse is not possible.

External Databases

One of the greatest challenges in information management 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 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

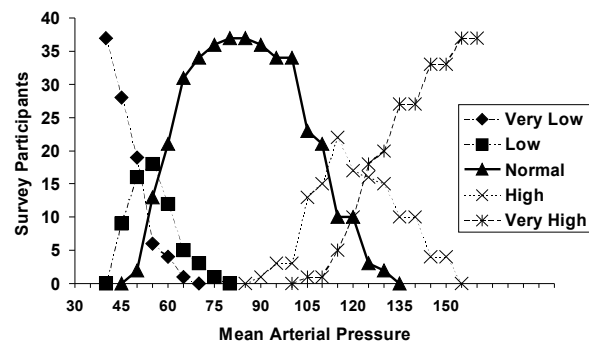
For many operational analyses of patient outcomes data, a formal statistical analysis is not undertaken. Clinicians and administrators use their judgment to assess the importance of the differences between groups. In the example provided in Table 1, data from the AIMS was merged with data from the PACU 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 very skewed. 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 similarly best suited to looking for differences between groups when ordinal data (e.g., ASA physical status classification) or skewed data are analyzed.

Table 1

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

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 subject to artifact 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 intra-arterial line data are acquired every 15 seconds, the median of systolic, diastolic, and mean blood pressure values over a 2-minute epoch (that includes 8 observations) is a very effective method of 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 the figure, a survey of 37



anesthesiologists at the author's 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 times that all 37 anesthesiologists agreed 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.

More complex analyses will require the services of a biostatistician and multivariate methods are commonly employed in database research. Database research is retrospective in nature. The major limitations of retrospective research are as follows: there is no prospective assignment to treatment groups; no randomization of therapy; and, therefore, no true control group. This is not necessarily a bad thing because many forms of research would be impractical or unethical in a prospective controlled fashion. An analysis that controls for these limitations is therefore required. Typically, multivariate logistic regression 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 here in Table 2, propofol induction of anesthesia is demonstrated to be an independent predictor of hypotension in the 10 minutes following induction of anesthesia, controlling for the effects of pre-induction hypotension, advanced age, fentanyl dosage, and ASA status. A biostatistician is crucial to the planning and execution of this effort.

Table 2

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

QUALITY AND PERFORMANCE IMPROVEMENT APPLICATIONS

There is evidence that AIMS can directly enhance patient safety. Wax et al. recently reported that a visual interactive antibiotic reminder in an AIMS resulted in higher rates of timely prophylactic antibiotic administration,⁶ and O'Reilly had similar findings using an AIMS-generated feedback system.⁷ Another group used a computer-generated reminder to enhance rates of re-dosing of antibiotics.⁸ Venous thromboembolism prophylaxis was improved at a center that used an expert system to insert reminders on the OR Schedule.⁹ Overall, the evidence in the literature is just emerging, but the trend towards pay-for-performance and other quality measurement efforts will provide further impetus to foster systems that help health care practitioners adhere to guidelines proven to enhance patient safety.

In addition to the contemporaneous reminders, data from our AIMS are extracted and analyzed to generate daily reminders for US Physician Quality Reporting Initiative reports and periodic 'report cards' that are sent to practitioners, thereby encouraging the staff to improve their performance.

Post-anesthesia evaluation forms allow documentation of postoperative findings and complications. Significant postoperative complications (e.g., neurologic injury, death) recorded in the AIMS trigger investigations by the Performance Improvement Committee. When appropriate, this process may result in educational efforts or policy changes to prevent recurrence.

ADMINISTRATION

Point-Of-Care Charge Capture

Although the health insurance industry has moved to electronic claims submission and back-office processing, only a minority of healthcare providers utilize electronic charge capture. This situation persists even though manual billing processes contain inherent sources of errors and omissions that may result in suboptimal reimbursement for providers or increased costs. To

optimize our collections, we use our AIMS as a point-of-care charge capture system to assemble all of the data necessary for the generation of electronic billing vouchers.¹⁰ Each billing worksheet is processed using business rules to ensure that all necessary information for a compliant bill is present. Any deficiencies (e.g., missing electronic signature, CPT code, or teaching rule attestation) are flagged, and the responsible practitioner is alerted. As the billing vouchers are completed, the prescreened bills are transmitted to the billing vendor for review and submission to payers. As a result of implementation of the point-of-care charge capture, the average charge lag decreased by 7.3 days following full implementation. There have been additional ongoing savings related to reduction of personnel and expenses related to paper charge voucher handling, as well as a likely reduction in missed/lost charges.

Compensation

Implementation of our AIMS for all clinical activities provided the necessary platform to add a productivity-based component to the faculty compensation system. We replaced a nearly fixed salary academic physician compensation model with a mission-based productivity model with the goal of improving attending anesthesiologist productivity. The supplemental pay structure was linked to AIMS records and a scheduling database to award points for clinical activity. The system accounts for participation of multiple attendings (e.g., relief by the on-call attending) and for faculty who are simultaneously directing medical care in multiple locations. This structure provides financial incentives for clinical productivity as well as completion of procedure, time, and modifier unit (i.e., ASA Relative Value Guide) documentation in our AIMS. To assist in monitoring personal productivity and billing compliance, a listing of all cases performed in the previous week is sent via electronic mail to each faculty member. This encourages faculty to scan for cases that may be missing or incomplete, and to identify and correct errors. This productivity-based compensation model has increased practitioner productivity and salaries with fewer clinical faculty relative to the number of daily anesthetizing locations.¹¹ Educational and academic output are incentivized separately.

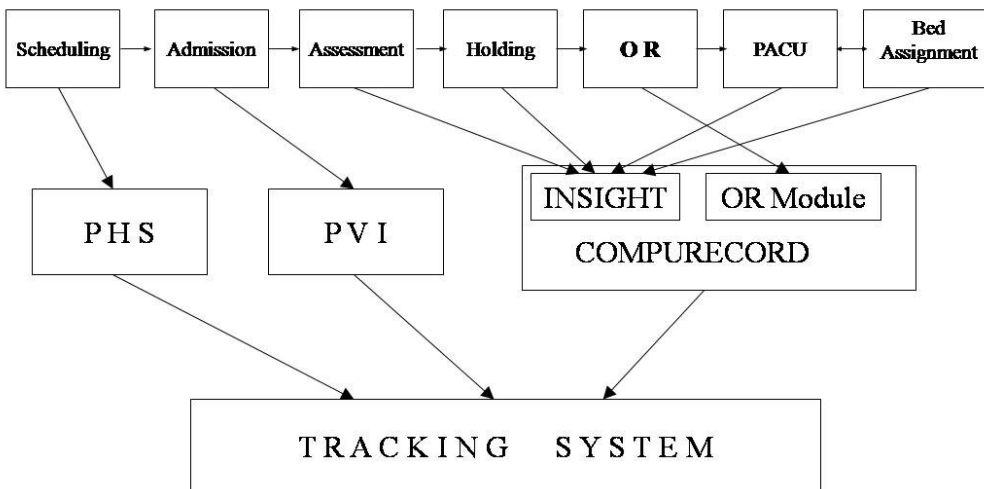
Operating Room Management Applications

We leveraged the information available in several hospital systems, including our AIMS, to create a custom 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. On the OR coordinators' 'big board', rooms that have been empty for prolonged periods of time and '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 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 can also be sent directly to clinicians via their text pagers or personal digital assistants (PDA), providing timely notification of events that can reduce delays. For example, both the surgical and anesthesia care teams can be notified as soon as a patient arrives in the holding area, thereby reducing turnover delay. The system diagram for the perioperative tracking system is reproduced in the figure.

Process Overview



Compliance Reporting

The Accreditation Council for Graduate Medical Education (ACGME) seeks to ensure that each trainee gains sufficient clinical experience during their training. Since most of the information needed for a case log is already stored in the AIMS, this reporting function has been automated to provide real-time tracking, thereby allowing more frequent review by the residency program director to assess and adjust trainee scheduling toward increasing exposure in areas that may be lacking. It also ensures the availability of necessary data for ACGME audits and frees the trainees of the burden of additional documentation.

Another ACGME goal is to provide for fair and uniform evaluation of trainees to ensure competency of graduates, provide timely feedback to trainees regarding their performance, and to help training programs improve their training methods. To accomplish this, we created a custom web-based trainee evaluation report that incorporates the six ACGME-designated core competencies.¹² Similarly, trainees have a mechanism by which to provide feedback to program directors regarding perceived strengths and weaknesses of the training program and its faculty.

Compliance with controlled substance regulations is enhanced by our custom application that extracts case records of controlled substance administration for pharmacy for reconciliation purposes. Similarly, antibiotic administration records are extracted and transmitted to our center's compliance group to merge with other SCIP-related data for monitoring and reporting.

CONCLUSION

The extensive functionality of our AIMS developed over many years. It began with the deployment of a standard commercial AIMS software package, which was then extensively configured to meet our departmental needs. This significant additional programming has been accomplished and supported mainly by our departmental team. Thus, full exploitation of the potential of an AIMS requires initiative and significant investment of resources. Command and control of extensive perioperative information resources is an intangible but real return on investment.

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