A systematic and comprehensive review of the scientific literature revealed 4 evidence-based methods that contribute to a positive return on investment from anesthesia information management systems (AIMS): reducing anesthetic-related drug costs, improving staff scheduling and reducing staffing costs, increasing anesthesia billing and capture of anesthesia-related charges, and increased hospital reimbursement through improved hospital coding. There were common features to these interventions. Whereas an AIMS may be the ideal choice to achieve these cost reductions and revenue increases, alternative existing systems may be satisfactory for the studied applications (ie, the incremental advantage to the AIMS may be less than predicted from applying each study to each facility). Savings are likely heterogeneous among institutions, making an internal survey using standard accounting methods necessary to perform a valid return on investment analysis. Financial advantages can be marked for the anesthesia providers, although hospitals are more likely to purchase the AIMS.

Key words: Anesthesia billing data, anesthesia information management system, automated anesthesia record, electronic medical record anesthesia billing data.

As the cost of healthcare in America eclipses $1.7 trillion and 15% of the gross domestic product, methods to reduce costs of care are being sought.¹ This article describes the evaluation of the proven role of anesthesia information management systems (AIMS) in reducing the costs of providing anesthesia services. For AIMS to be a good financial investment, they should produce a positive return on investment (ROI) for the hospital. This article adopts a broader societal perspective because AIMS may be more beneficial for society than for the corporations purchasing them. Thus, we also ask the question: Do AIMS produce net reductions in costs for the healthcare system?

Calculating the ROI is a method of analysis that business leaders use to decide what new technology to invest in for their companies. An ROI analysis can be applied to asset purchase decisions (eg, AIMS), “go/no-go” decisions for various programs (eg, opening an outpatient surgical center), and traditional investment decisions (eg, of hospital endowment).² Conceptually, an ROI calculation takes the difference of the “return” (marginal gain) from the action taken or investment made (marginal cost) and divides by the cost of that action or investment.² For example, a materials management system with a cost of $1 million in a 2-year period may result in a reduction in costs and increase in reimbursement of $3 million. The ROI would be slightly less than 200% adjusting for inflation and other changes in the value of money.

This article describes evaluation of methods by which AIMS can have a positive ROI. An AIMS can achieve a positive ROI by increasing revenue, decreasing costs, or a combination. It could achieve these goals by reducing costs related to delivering anesthesia and surgical care or by increasing reimbursement for the care that is delivered. The basic scenario evaluated in this article is the following. Suppose that an AIMS were placed in every operating room (OR) of a hospital, and managers were to make decisions to use the AIMS in the ways to reduce all possible costs with the AIMS and to increase all possible reimbursement related to surgery and anesthesia services. Then, what factors can contribute to a positive ROI? Knowing this is important because hospitals can then include those evidence-based factors in its ROI analysis.

Methods
A comprehensive literature search was completed in the MEDLINE electronic bibliographic database from 1966 through March 2005, using the OVID search engine. The search strategy was the following:
Literature review
The scientific literature described 4 factors that can contribute to a positive ROI from AIMS:

- Reducing anesthetic-related drug costs. Anesthetic practice guidelines developed with information compiled from an AIMS reduced anesthetic drug costs at an academic medical center by almost 50% in 1 year.\textsuperscript{13-15}

With the AIMS, clinicians were provided ongoing monthly feedback summarizing drug use that was not part of the pharmaceutical protocol for that type of patient and benchmarking use of expensive drugs relative to their peers. Feedback can be adjusted based on each clinician's drug and supply costs because the AIMS provides the necessary data for each patient to permit valid comparisons.\textsuperscript{21} The application of such guidelines nationally could reduce societal drug costs but would be unlikely to reduce costs at all institutions.

An institution should consider the following 4 arguments against achieving a substantive cost reduction when it performs an ROI analysis for an AIMS.

1. Cost reduction occurs from changes in anesthesia providers' behavior. When performing the ROI calculations, balance the forecasted potential cost reduction with the expectation that the institution will follow through when some clinicians balk at change.

2. Partial cost reduction can be achieved without the use of an AIMS. For example, neuromuscular blocker drug costs can be reduced by having only protocol drugs available in each OR.\textsuperscript{22} Other neuromuscular blockers are maintained at a pharmacy OR substation and can be obtained after completion of a written form taking the time of and providing immediate feedback to the provider.\textsuperscript{22}

3. Anesthesia drug and supply costs contributed to 3% of inpatient surgical costs.\textsuperscript{23} A 50% reduction in drug costs may provide for an approximate reduction of just 1% in variable surgical costs. Furthermore, during the intervening decade since the 3% value was published, many anesthetic drugs have become generic, reducing costs.

4. The use of some anesthetic drugs can lead to reductions in OR and postanesthesia care unit (PACU) times. Drugs with higher acquisition costs can result in net cost saving for an institution because the drugs' pharmacokinetic and pharmacodynamic profiles affect the OR and PACU times. The impact of small changes in times on OR and PACU staffing costs depends on case mix, use of part-time staffing, PACU discharge policies, and daily workload.\textsuperscript{12,24}

There are also 2 arguments supporting achieving larger cost reductions from AIMS than described in the preceding text.

1. An AIMS can be combined effectively with bar-coded, medication-specific syringes and preadministration computer verification.\textsuperscript{17} Use of such a system may reduce drug administration errors, improve patient
safety, and reduce healthcare and medicolegal costs. Use of an AIMS may lead to the identification of best anesthetic practices and better outcomes. An institution with an AIMS has the ability to monitor adherence to best practices and take advantage of such advances in the science if they are obtained.

2. Decreased costs for medications can result if analysis of medication use (and waste) identifies that unit doses would reduce waste. Such findings may be most relevant to facilities caring for many children.

- Reducing anesthesia providers’ staffing costs and improving staff scheduling. Because costs for anesthesia staffing account for the majority of the anesthesia budget, the largest reductions in costs achievable from use of an AIMS are by adjusting staffing. For 9 of 11 facilities publishing results, achievable reductions exceeded 10% of anesthesia staffing costs. The AIMS are ideal sources of data for adjusting staffing because the activities of each provider are known almost completely without error by time of day, day of the week, and season of the year.

Although staffing cost reductions are a large source of savings, there are 5 reasons why achievable reductions attributable to the AIMS will be less at most institutions.

1. The cost reductions result from adjusting staffing on weekends, late afternoons, and evenings. Although hospitals may achieve such cost reductions because they have cases at those times, outpatient surgery centers are unlikely to accrue these benefits.

2. Adjusting staffing for weekends, afternoons, and evenings empirically based on existing workload can be easy to implement by an anesthesia department. Anesthesia staffing should have no effect on patients, surgeons, or nurses because case scheduling should be nearly completely unaffected. If less staffing were planned, then on busy days, people work late and vice versa. However, reducing staffing to achieve cost reduction during regular working hours (eg, Monday to Friday 7 AM to 3 PM) usually affects patients, surgeons, and nurses. Achieving such cost reductions requires major institutional change, particularly from its impact on the surgeons.

3. At some institutions, most anesthesia staffing costs are sustained by an anesthesia corporation separate from the hospital, whereas the latter pays for the AIMS. Thus, the AIMS investment is made by the hospital, but the return may be achieved by a separate corporation. This issue is irrelevant when considered from a societal perspective but can be significant for an individual hospital deciding whether to purchase an AIMS.

4. For staffing analyses, AIMS are essentially interchangeable with anesthesia billing information systems. For OR sites, they are interchangeable with OR information system data. The AIMS can provide the most insight if there are anesthesiologists present who are medically directing care. The AIMS can be used at institutions that do not bill for anesthesia services. Finally, AIMS are used at locations other than ORs (eg, magnetic resonance imaging), whereas OR information systems are not. Nevertheless, when considering the ROI, we recommend that institutions consider how many cases are performed outside of ORs in the late afternoons, evenings, and weekends. If most of the cost savings achievable are by fine-tuning staffing to actual workload in afternoons and weekends, almost all such workload is in ORs, and OR information system data are readily available, then the incremental reduction in costs from the AIMS may be low.

5. Significant cost reductions have been achieved from adjusting weekend staffing, not just by having fewer providers on call, but by having them available from home instead of scheduled in-house. Hospitals pressured to reduce costs may reduce weekend staffing in the absence of data so much as to result in a greater than 6% risk of being understaffed. Although analysis of AIMS data can identify opportunities to reduce staffing, it may also demonstrate a need to increase staffing.

- Increasing anesthesia billing and capture of anesthesia-related charges. Historically, anesthesia providers’ time charges were tabulated on paper by the provider, entered into a computer by a clerk, and processed by a billing department. This process allowed for manual errors when the sheets were tabulated and loss of the sheets before they were entered into the billing system. The AIMS result in significant reductions in such errors and corresponding increases in billing.

There are 3 arguments supporting large increases in anesthesia billing.

1. The time lag between performance of service and claim submission may be reduced with use of an AIMS. This would apply to hospitals and anesthesia corporations that purchase an AIMS with an electronic interface to the billing software.

2. An AIMS can be used to document discrepancies in materials used to provide anesthesia care vs hospital billing for these materials. An AIMS can be used to track the use of materials and ensure that materials and drugs billed are only those specifically used for each patient.

3. Institutional change is rarely needed when an AIMS promises to increase anesthesia billing. Achieving internal buy-in for increased reimbursement is usually not challenging.
Although advantages of AIMS can include increased anesthesia billing, there are 3 reasons why their influence on a positive ROI may be limited.

1. Increased billing is irrelevant from a societal perspective because no societal advantage has been achieved.

2. The increase in anesthesia provider billing may result in increased revenue for the anesthesia corporation, whereas the AIMS may be paid for by a hospital.

3. Many hospitals have a fixed annual budget and are paid a fixed fee based on patients’ preexisting conditions and/or numbers of surgical procedure(s). There may be no incremental payment for anesthesia drugs and supplies.

These 3 caveats are sufficiently important that the results at one institution are unlikely to apply to another. Consequently, each institution should perform an accounting survey when performing an ROI analysis for an AIMS relying at least in part on increases in collected charges.

• Increased hospital reimbursement through improved hospital coding. Although increased hospital billing may contribute to a positive ROI for an AIMS, this section is also irrelevant from a societal perspective because no societal benefit is provided.

This section relies on the electronic preanesthetic evaluation portion of an AIMS.

Hospitals in the United States and many other countries receive the majority of reimbursement based on the diagnosis-related groups (DRG) system or an equivalent. Rather than reimbursement being based on a line item basis, it is based on a fixed rate related to the service provided. In some healthcare systems, although incremental reimbursement may not be provided for each patient, the next year’s budget is based closely on the clinical care provided during the current year as quantified by the DRG-adjusted number of patients served. Regardless, correctly identifying each patient’s DRG is important financially.

Documenting coexisting patient illnesses of surgical patients is precisely the objective of the anesthesia providers’ completion of a preanesthetic evaluation. Whether documented automatically or manually by professional coders, the information in the preanesthetic evaluation can be used. At least 1 International Classification of Diseases, Ninth Revision, Clinical Modification diagnosis was added for 22 (12.2%) of 180 charts studied (95% confidence limits, 7.4%-16.7%). The hospital’s reimbursement was increased by 1.5%.

There are 3 significant caveats to this large increase in reimbursement.

1. As for anesthesia charges, the degree to which increased reimbursement can be obtained by improved coding is expected to vary substantially among hospitals. The variation will be particularly large because it likely will vary based on local billing practices, insurance contracts, and primary method of funding (eg, quite low for a Veteran’s Administration hospital). A survey is needed as part of the ROI process for the potential to improve coding and reimbursement.

2. An AIMS may not provide an incremental advantage. An interval survey should assess the extent to which the process would be enhanced by the use of an electronic preanesthetic evaluation system compared with use of the existing paper system by coders.

3. The preanesthetic evaluation portion of the AIMS must contain integrated International Classification of Diseases, Ninth Revision, Clinical Modification diagnostic coding as a required component of the patient assessment.

Other possible benefits of AIMS
The preceding 4 sections reviewed the components to an evidence-based ROI for an AIMS. We have identified 3 other ways in which AIMS may allow for a positive ROI by reductions in costs:

• Reducing surgical site infections by more appropriately administering prophylactic antibiotics

• Reducing adverse cardiac events by more appropriately administering prophylactic β-blockers

• Reducing surgeon and patient waiting on the day of surgery

The focus is the societal perspective. The sections below are speculative.

• Reducing surgical site infection rates. In many surgical settings, the anesthesia provider administers the perioperative antibiotics. The AIMS could identify appropriate antibiotic prophylaxis for surgical patients according to the Centers for Disease Control and Prevention guidelines and prompt the anesthesia provider if needed. Proper administration of the appropriate antibiotic at the correct interval can reduce healthcare-associated infection rates and reduce direct and indirect medical care costs. Patients with surgical site infections are more likely to die, have longer hospitalizations, experience 6 times as many hospital readmissions, and accrue costs between $3,000 and $5,000 more per patient.

Clinical trials are needed to learn to what extent activities of anesthesia providers can modify the incidence of infections and the relative importance of the AIMS in changing anesthesia providers’ behavior accordingly.

• Reducing adverse cardiac events. Administration of
β-blockers to appropriate patients significantly reduces the rate of ischemic episodes and cardiac death during noncardiac surgery.\textsuperscript{31,35-38} The cost per event in Medicare charges (a surrogate for societal costs) is $12,500 to $15,000 per perioperative myocardial infarction in noncardiac surgery and $22,000 per patient who dies.\textsuperscript{35,36} Although β-blockers are of negligible cost, they are underused in the general population\textsuperscript{39,40} and most likely also in the perioperative period among patients with the known, specific risk criteria.\textsuperscript{38}

Clinical trials are needed to learn the relative importance of the AIMS in encouraging anesthesia providers’ appropriate administration of β-blockers and the resulting impact on hospital and societal costs.

- Reducing surgeon and patient waiting on the day of surgery. Managers in the OR try to reduce waiting past scheduled start times for elective cases to increase patient and surgeon satisfaction. When one surgeon follows another in the same OR on the same day and the first surgeon’s cases are running behind, the to-follow surgeon is frequently frustrated. How to make OR management decisions on the day before and the day of surgery to reduce waiting times is well understood.\textsuperscript{41} Relevant decisions include selecting the sequence of cases in each OR, scheduling delays between successive cases, determining when patients should be told to arrive and updating the choice, and moving cases among ORs.

However, scientific understanding of how to make the decisions has generally not translated into better decision making, in part because real-time information is needed on activities throughout surgical suites. The real-time vital sign information from an AIMS can be processed successfully for this purpose.\textsuperscript{42} For example, when there is an electrocardiogram signal, pulse oximetry signal, and temperature, then the odds are very high that there is a patient inside the OR. When there are no such vital sign signals, the odds are high that no patient is inside the OR. Because AIMS provide such data automatically, they are ideally suited for decision making on the day of surgery. Future studies are needed to learn to what extent reductions in patients’ and surgeons’ waiting on the day of surgery results in increased hospital and/or anesthesia professional group revenue.

**Discussion**

A systematic and comprehensive review of the scientific literature through March 2005 revealed 4 evidence-based methods that contribute to a positive ROI for AIMS:

- Reducing anesthetic-related drug costs\textsuperscript{11-15}
- Improving staff scheduling and reducing staffing costs\textsuperscript{16,17}
- Increasing anesthesia billing and capture of anesthesia-related charges\textsuperscript{11,18,19}
- Increased hospital reimbursement through improved hospital coding\textsuperscript{20}

There were several common features to these interventions. Savings are likely heterogeneous among institutions, making an internal survey using standard accounting methods necessary to perform a valid ROI analysis. Financial advantages can be marked for the anesthesia providers, although hospitals are more likely to need to purchase the system. Whereas an AIMS may be the ideal choice to achieve the cost reduction and revenue increase, alternative existing systems may be satisfactory (ie, the incremental advantage to the AIMS may be less than evident from applying each study to each institution).

**Note added before publication.** Since our paper was accepted in April 2005, 5 additional papers satisfying the study criteria were published.\textsuperscript{43-47} Conclusions are unchanged.

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