Anesthesia information management systems (AIMS) are being increasingly used to assist the delivery and documentation of anesthesia services in the United States. The major benefits of AIMS cited in the literature are the ability to (1) reduce costs, (2) facilitate quality assurance and quality improvement processes, (3) increase the accuracy and completeness of the anesthesia record, and (4) improve adherence to recommended guidelines. The major drawback, especially for rural hospitals, is the cost. This article identifies 2 of the main elements of AIMS that exist in information technology and data systems already present in a hospital. In this project, the medication dispensing system was used to achieve a 70% reduction in drug costs, and a simple electronic database was created, which detected adverse events that were missed with the legacy quality assurance system. There was no additional cost to the hospital to realize these benefits because this project utilized technologies and data systems already in place and staff time was part of the normal workload. This project showed that it is possible to achieve 2 of the major benefits of an AIMS without the major cost of purchasing one.

**Keywords:** Anesthesia information management system, cost reduction, critical access hospital, quality assurance.

Electronic health records (EHRs) and anesthesia information management systems (AIMS) are increasingly used to assist the delivery and documentation of anesthesia services in the United States healthcare system. There are many benefits of AIMS, but the primary reason most rural hospitals have not adopted an AIMS is the cost.  

The 1,980 rural community hospitals in the United States serve the 20% of the US population that lives in rural areas and perform more than 4 million surgical procedures annually. Most of these anesthetic episodes are documented on a paper record; implementation of AIMS remains as low as 12% among rural hospitals. The population in rural communities tends to be composed of more elderly people, have a lower income level, a higher poverty rate, and a higher rate of individuals collecting disability. Members of rural communities are also more likely to be solely enrolled in public health insurance programs such as Medicare or Medicaid, which reimburse hospitals at a lower rate than do private insurance companies. The Institute of Medicine identified the lack of financial and information technology (IT) resources that many rural hospitals face in *Quality Through Collaboration: The Future of Rural Health Care.* Despite the benefits of AIMS, most rural critical access hospitals cannot afford the fixed startup costs of approximately $10,000 per anesthetizing location to install and operate an AIMS. Critical access hospitals do not have the ability of larger hospitals to spread out the cost of AIMS implementation among a large number of anesthetizing locations.

This article will discuss the benefits of AIMS, barriers to implementation, and ways for critical access hospitals to achieve 2 major benefits of an AIMS (a reduction of medication costs and improved quality assurance [QA]/quality improvement [QI] processes) using other information technologies already in existence at many hospitals.

### Benefits of Anesthesia Information Management Systems

Kadry et al list 7 key benefits of an AIMS: improved cost containment, improved operations management, improved reimbursement, improved quality of care, improved safety, improved translational research, and improved documentation. These benefits can be condensed into the 4 anesthesia-related goals most relevant to rural hospitals: (1) cost reduction; (2) facilitation of QA and QI processes; (3) increased accuracy and completeness of the anesthesia record; and (4) improved adherence to recommended guidelines.

Anesthesia information management systems can reduce costs by identifying overuse and waste of expensive medications in order to increase efficiency and reduce or eliminate waste. Another way AIMS can reduce costs is by identifying patterns of individual anesthesia providers who tend to use more expensive medications, and by assisting the development of workflows and procedures to reduce the use of the expensive medi-
Barriers to Implementation

The major barrier to AIMS utilization is the cost to acquire, implement, and maintain the AIMS.1-3,27 It is difficult to estimate a cost to implement an AIMS, because there are many variables that affect the cost (vendors, number of installed sites, education of providers, etc.). The direct cost to implement the AIMS includes, at a minimum; the software licenses, installation fee, cost to interface with existing anesthesia equipment and other hospital departments (laboratory, pharmacy, etc.), and the cost of all needed hardware such as additional computer stations.2 In large institutions, a generally accepted average cost per anesthetizing location to implement an AIMS is $10,000.9 The annual maintenance cost is estimated to be 20% of the initial cost of the software licenses.2 At a large hospital or medical center these costs can be minimized by spreading the fixed costs among the large number of ORs in which the AIMS is installed. In a rural critical access hospital, the cost per location to implement and maintain an AIMS is much higher because the number of installed sites is small and the fixed costs cannot be spread out. Our critical access hospital has 5 ORs: 3 primary ORs and 2 minor ORs. We provide anesthesia for a variety of cases in the 3 primary ORs and to patients with cataract in one of the minor ORs. The remaining minor OR is used for cases not involving an anesthesia provider. To implement an AIMS in 4 anesthetizing locations at our critical access hospital we estimated $26,000 per anesthetizing location (see Table) in contrast to the typically quoted $10,000 per anesthetizing location at larger medical centers.9

Maintenance costs, including software licenses/upgrades, interface maintenance, and ongoing IT support (from the AIMS vendor), was estimated at $14,000 annually for the 4 anesthetizing locations at our critical access hospital. This amount does not include the cost of local IT support, estimated at about $3,500 per year, or 10% of 1 full-time equivalent IT employee.28 Interestingly, the most frequently cited problem with AIMS was the unanticipated ongoing requirement for support from IT staff due to the complexity of the software and interfacing with legacy computer systems.1 Maintenance costs also need to include training additional staff and any agency or locum tenens anesthesia providers to use the AIMS.

Indirect costs are difficult to quantify because they include time spent training staff to use the AIMS as well as the decrease in productivity as the AIMS is being implemented.2 A large amount of time and money can be spent to train the staff to use an AIMS before implementation and annually or any time there are major upgrades made to the system or software. Installation and maintenance costs for an AIMS in 4 locations at a critical access hospital are summarized in the Table.

Despite the benefits that can be achieved with AIMS, the primary drawback is the expense. The Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 provides financial incentives to healthcare providers who have implemented EHRs under the Medicare and Medicaid EHR Incentive Programs.29 Most physicians and nonphysician primary care providers, such as nurse practitioners, are considered eligible professionals under the Medicare EHR Incentive Program. This means they are authorized to receive the incentive payments if they can demonstrate meaningful use of an EHR.30 Certified Registered Nurse Anesthetists (CRNAs) are not considered eligible professionals and
will neither receive a financial incentive for implementing an AIMS nor be subject to a financial penalty for failing to meet meaningful use criteria. Because CRNAs are not considered eligible professionals, critical access hospitals where CRNAs are the only anesthesia providers do not have the financial incentive provided by the Medicare EHR Incentive Program to install AIMS. This drawback may be adding to delayed implementation in many of these facilities.

Achieving Benefits of an Anesthesia Information Management System Without the Cost

Because of the high cost of implementation ($104,000) and annual maintenance ($21,000), alternatives were sought to achieve as many benefits of an AIMS as possible using existing resources at the hospital with minimal additional cost. The hospital does not have an institutional review board (IRB), so the ethics committee of the hospital approved this project. In addition, the IRB at Creighton University Medical Center in Omaha, Nebraska, was contacted and determined that this project was more of an institutional QA and QI project and would therefore be exempt from IRB approval.

• Achieving Cost Reduction. The medication dispensing system (Pyxis Anesthesia System, CareFusion) was used to determine the cost of all medications removed from each of the 3 primary anesthetizing locations over 1 year. It was discovered that 36% of medication costs, more than the next 3 drugs combined, were being spent on intravenous acetaminophen. Review by the pharmacist and one author (BAG) believed that much of this use was not indicated. An informational and educational in-service was conducted for the surgeons who were ordering and the CRNAs who were administering the acetaminophen. Cost information and a review of the literature on various alternative medications such as oral acetaminophen, gabapentin, oxycodone, celecoxib, and ketorolac was provided. The goal of the in-service was a reduction in the intraoperative utilization of intravenous acetaminophen.

All medications dispensed 3 months before and after the in-service was obtained from the Pyxis system and entered into a spreadsheet (Microsoft Excel, Microsoft). The cost of each medication was obtained from the hospital pharmacist and entered into the spreadsheet. The pharmacist spent 1 hour and a CRNA spent 4 hours collecting and reviewing the Pyxis printouts for accuracy and creating the spreadsheet. Using average wages reported by the US Department of Labor, the total labor cost was $360.33. However, the time spent by both the pharmacist and the CRNA gathering and analyzing the data was completed during their normal daily duties and thus added no additional labor costs to the project. The amount of money spent on intravenous acetaminophen for the 3 months before the in-service was $1,031.04, whereas after the in-service it was reduced to $315.04, a nearly 70% reduction in cost. During the same period, the OR caseload dropped by 11%, which was not nearly enough to account for the 70% reduction in acetaminophen cost.

• Improving Quality Assurance and Improvement Processes. For the QA component of this project, a new quality assurance form (Figure) and a corresponding database (Microsoft Access, Microsoft) were created by the IT department in conjunction with the anesthesia department. The QA form was obtained from the Anesthesia Quality Institute (https://www.aqihq.org/) and modified for our institution. This new form was printed out and distributed with every anesthesia record to be completed by the CRNAs and recovery room nurses for a 3-month period. The forms were collected and returned to one of the authors (BAG). The information was then entered into the database. During the same 3 months, the previous QA process, which was administered by an OR

<table>
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<th>Table. Costs of Implementing an Anesthesia Information Management System in 4 Anesthetizing Locations (3 Primary and 1 Minor OR Site)</th>
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<tr>
<td>Abbreviations: IT, information technology; OR, operating room.</td>
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<tr>
<td>a Assumes the replacement of one of four computer stations per year.</td>
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<tr>
<td>b Support of an onsite information technology professional at 25% time for initial setup.</td>
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<tr>
<td>c Initial training assumes 1 full 8-hour day, using average wages reported by the US Department of Labor. 28 Maintenance training assumes 4 hours of reeducation annually.</td>
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<tr>
<th>Cost</th>
<th>Initial setup, US $</th>
<th>Annual maintenance, US $</th>
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<tr>
<td>Direct costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Software</td>
<td>85,000</td>
<td>14,000</td>
</tr>
<tr>
<td>Hardware</td>
<td>10,000</td>
<td>3,000&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>IT support</td>
<td>8,500&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3,500</td>
</tr>
<tr>
<td>Training costs (per provider)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>622</td>
<td>300</td>
</tr>
<tr>
<td>Total</td>
<td>104,122</td>
<td>20,800</td>
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<tr>
<td>Indirect costs</td>
<td></td>
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<tr>
<td>Decreased productivity—reduced or canceled OR days</td>
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<td>Training of relief/locums tenens providers</td>
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nurse who had performed this task for several years, was continued in the same patients. At the end of the investigation period, the number of adverse events recorded by each process was determined. This allowed the processes to be directly compared with each other because both were being completed in all the same patients.

During the investigation period (August-October 2014) there were 349 patients at the critical access hospital who received care from a CRNA. The new QA process detected 86 events in 67 different cases. The legacy QA process detected 10 events on those same patients during the investigation period. Not only were more events detected with the new process, they were entered into a database that can be queried in multiple ways (by

Figure. Anesthesia Quality Improvement
Abbreviations: ACEI/ARB, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; CRNA, Certified Registered Nurse Anesthetist; GA, general anesthesia; ICU, intensive care unit; MAC, monitored anesthesia care; N, no; PACU, postanesthesia care unit; PVC, premature ventricular contraction; req, requiring; SAB, subarachnoid block; VAS, visual analog scale; Y, yes. Note: Modified from the Intraoperative and PACU discharge forms retrieved from the Anesthesia Quality Institute (https://www.aqihq.org/).
surgeon, CRNA, event, date range, etc), facilitating future QI processes.

The time spent by the CRNA and IT department to create the new QA process was recorded and the associated cost calculated. A health information technology technician spent 4 hours and a CRNA spent 6 hours working on this project. Using average reported wages, the total cost for the CRNA and the health information technology technician was $532.92.28 As with the cost reduction portion of this project, the time spent by both the CRNA and the health information technology staff was part of the normal workday, so the cost was not passed on to the hospital in the form of additional labor costs. An improved QA process was demonstrated for no additional cost to the hospital.

Discussion
This project achieved 2 major benefits of an AIMS, a reduction of anesthesia drug costs and an improvement in the QA process, using technologies that are present in hospitals, without any additional costs to the hospital. Small hospitals have unique financial constraints, which make it more important for them to contain their costs. The primary downside to AIMS is the implementation and maintenance costs, which are magnified in small hospitals where economies of scale will not help defray these costs as they do in large medical centers with multiple anesthetizing locations.

Quality assurance programs can be improved with AIMS. This project demonstrated an improvement in the QA program without an AIMS. More than 8 times as many opportunities for improving the quality of anesthesia and surgical care were detected with the new QA program compared with the old. Catching and preventing these events is especially important at a critical access hospital because quality and safety initiatives are difficult to implement because of limited financial and human resources.32

• Angiotensin Axis Blockade. During the study period, a discussion about whether patients should take or hold their angiotensin axis blockade (AAB) medication the day of surgery commenced between providers. Before this project, some of our patients had experienced profound hypotension requiring vasopressor therapy during anesthesia after receiving an AAB medication on the day of surgery. Some research suggests that AAB should be held preoperatively, but this is not conclusive. The anesthesia providers requested that surgical patients hold their AAB medications on the day of surgery, especially patients who were likely to receive a spinal or general anesthetic. Despite this request, several patients continued to take AAB medications on the day of surgery, resulting in the CRNAs checking the box for “Failure to hold AABs” on the new QA form. During the first 2 months of the investigation period, the form captured 17 patients, 20% of the adverse events recorded, who took AAB medications on the day of surgery, prompting another discussion with the surgeons. A list of all AAB medications was sent to the surgeons and nursing staff members who call the patients with preoperative instructions the day before surgery. After these steps were taken, no patients took AAB medications on the day of surgery during the final month of the QA project. Although reducing the number of patients taking AAB medications was not an original aim of this project, there was an almost immediate improvement in the quality of care provided, which definitely was an aim of the project.

• Limitations. This project was a quasi-experimental institutional QI project. Medication cost reductions and improved QA and QI processes were achieved using existing computer systems. However, increased legibility and completeness of the anesthesia record and the benefits of a CDSS were not achieved without the implementation of an AIMS. It is highly unlikely that these benefits could be achieved without an AIMS, but these benefits were not considered sufficient enough to justify the additional cost for our facility to purchase an AIMS.

Conclusion
Although the benefits of AIMS have been demonstrated in the literature, the continued high cost makes their widespread implementation in critical access hospitals unaffordable at this time. This article demonstrates how a critical access hospital achieved the medication cost reduction and improved QA and QI functions of an AIMS without any additional costs using technologies that currently exist in many healthcare facilities. Focusing on the financial feasibility and support for small, rural, critical access hospitals to increase implementation of AIMS is a direction for future research and policy development.

REFERENCES
We refer to the image of one page of a document and the previously extracted raw textual content. The content pertains to the utilization and benefits of anesthesia information management systems (AIS). It highlights various studies and their findings, emphasizing the importance of AIS in improving compliance, demonstrating quality, and reducing errors. The text is a compilation of research articles discussing the impact of AIS on patient care, decision support, and quality assurance.

The page includes numerous references to studies and articles, each addressing different aspects of AIS. Some key points include:


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**DISCLOSURES**

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