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REVIEW ARTICLE/BRIEF REVIEW

Review article: The evolving role of information technology in perioperative patient safety

Article de synthèse : Le rôle en évolution de l'informatique dans la sécurité périopératoire des patients

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Abstract

Purpose *The adoption of new technologies in medicine is frequently met with both enthusiasm and resistance. The universal adoption of health information technology (IT) and anesthesia information management systems (AIMS) remains low despite the potential benefits. Electronic medical records, and hence AIMS, are at the intersection of patient safety. This article highlights advantages and barriers to adoption and implementation of IT in general and AIMS in particular, with a focus on clinical decision support systems (CDSS) and computerized physician order entry (CPOE) as hallmarks that may lead to improvement in patient safety and quality in the perioperative setting.*

Principal findings *The advantages of health IT and AIMS include improved legibility of documentation; the ability to integrate new scientific evidence into practice; enhanced management and exchange of complex health information; the ability to standardize order sets, incorporate computerized physician order entry, and provide clinical decision support; and the ability to capture data for management, research, and quality monitoring and reporting. While not foolproof, AIMS have been shown to improve safety, quality, and patient outcomes. Barriers to the adoption of health IT and AIMS include costs, lack of truly interoperable AIMS components in health-system IT solutions, and lack of clinician involvement in implementation, planning, design, and installation of many IT or AIMS products.*

Conclusions *Health IT and AIMS are at the intersection of patient safety and technology. Anesthesiologists are perfectly positioned to be the physician leaders of adoption, design, implementation, and integration, not only for AIMS but also for health-system IT solutions in general.*

Résumé

Objectif *L'adoption de nouvelles technologies en médecine suscite souvent à la fois enthousiasme et résistance. L'adoption universelle de l'informatique pour les soins de santé et des systèmes de gestion de l'information en anesthésie (AIMS) demeure peu répandue malgré leurs avantages potentiels. Les dossiers médicaux électroniques, et donc les AIMS, sont au cœur de la sécurité des patients. Cet article souligne les avantages et les barrières à l'adoption et à la mise en œuvre de l'informatique en général et des AIMS en particulier, en se concentrant sur les systèmes de soutien à la décision clinique (CDSS) et à l'entrée informatisée des ordonnances du médecin (CPOE) en tant que percées qui pourraient entraîner des améliorations au niveau de la sécurité des patients et de la qualité dans le contexte périopératoire.*

Constatations principales *Les avantages de l'informatique dans les soins de santé et des AIMS comprennent une lisibilité améliorée de la documentation; la capacité d'intégrer de nouvelles données probantes scientifiques à la pratique; une meilleure gestion et un échange amélioré des informations de santé complexes; la capacité de normaliser des ensembles de modèles d'ordonnance, d'incorporer la saisie informatisée d'ordonnances de médecins, ainsi que de fournir un soutien à la décision clinique; et la capacité à saisir des données pour l'administration, la recherche, le suivi de la qualité et les rapports de qualité. Bien que les systèmes AIMS ne soient pas à toute épreuve, il a été démontré qu'ils amélioraient la sécurité,*

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la qualité et les pronostics des patients. Parmi les barrières à l'adoption de l'informatique dans les soins de santé et des systèmes AIMS, citons les coûts, l'absence de composantes d'AIMS véritablement intégrables dans les solutions informatiques des systèmes de santé, et le manque d'engagement des médecins dans la mise en œuvre, la planification, la conception et l'installation de nombreux produits informatiques et d'AIMS.

Conclusion *L'informatique dans les soins de santé et les systèmes AIMS se situent à l'intersection de la sécurité des patients et de la technologie. Les anesthésiologistes sont dans une situation idéale pour devenir les médecins chefs de file de l'adoption, de la conception, de la mise en œuvre et de l'intégration – non seulement des systèmes AIMS, mais également des solutions informatiques pour les systèmes de santé en général.*

"That it [the stethoscope] will ever come into general use, notwithstanding its value, I am extremely doubtful; because its beneficial application requires much time, and gives a good deal of trouble both to the patient and the practitioner; and because its whole hue and character is foreign, and opposed to all our habits and associations. It must be confessed that there is something even ludicrous in the picture of a grave physician formally listening through a long tube applied to the patient's thorax, as if the disease within were a living being that could communicate its condition to the sense without."
Sir John Forbes (1787-1861)

Introduction and purpose

As with the introduction of the stethoscope into medicine, the adoption of new technologies into medicine is frequently met with both enthusiasm and resistance.[1] The universal adoption of health information technology (IT) and electronic health records (EHRs) into medical practice remains low despite the potential benefits.[2] Information technology in both the perioperative setting as well as in the entire hospital has the potential to make the delivery of health care more effective, more efficient, and safer. Early adopter benchmark institutions have been reported to show the efficacy of IT through improvements in quality and efficiency, and high-quality hospitals have been found to have higher rates of adoption of EHR functions than low-quality hospitals.[3,4] This may suggest that high quality and the adoption of EHR functions are linked.

In anesthesia practice, EHRs and IT are commonly referred to as "anesthesia information management systems" (AIMS). Although gaining popularity in the perioperative setting, the potential functions and advantages of AIMS may not yet be fully appreciated.[5] As with other EHR systems, the poorly planned installation of AIMS itself without active physician involvement in implementation strategies, design around workflow, and staff "buy-in" may lead to failed implementation and lack of acceptance of the system.[6] Without real-time clinical decision support systems (CDSS) or further data analysis, AIMS may not necessarily improve quality or safety.[7]

The purpose of this article is to highlight advantages and barriers to the adoption and implementation of IT in general and AIMS in particular, with a focus on CDSS and computerized physician order entry (CPOE) as hallmarks that may lead to improvement in patient safety and quality in the perioperative setting.

Principle findings

Health IT, EHRs, and AIMS

In 2009, the US Congress enacted the Health Information Technology for Economic and Clinical Health (HITECH) Act to promote the adoption and meaningful use of health IT.[8] Incentives (estimated to be 14-27 billion dollars) were implemented to support the adoption of EHRs by hospitals and health care professionals. Despite these incentives and the potential advantages of EHRs, the adoption of health-system IT and AIMS has remained low.[2,3,9-12] From a survey of 5,000 anesthesiologists as recently as 2011, Trentman *et al.* reported that only 50% of the respondents were currently using, installing, planning to install, or searching for an AIMS. Challenges exist for anesthesiologists when considering implementation of an AIMS. "Meaningful use", defined by the Centers for Medicare and Medicaid Services, may still be unclear as it relates to payment for anesthesia services and the relationship to AIMS.[9]

The Anesthesia Patient Safety Foundation (APSF) has long advocated for the use of technology in clinical practice to improve safety and reduce complications. The APSF has endorsed the use of AIMS as a means to collect data, and it has recognized the need for aggregate databases in outcomes research.[13] Recommendations to reduce clinically significant drug-induced respiratory depression in the postoperative period, first addressed in 2006 and again in 2011, include the addition of technological developments that may facilitate more effective utilization of continuous monitoring of oxygenation and ventilation.[14] Recommendations on medication safety include the use of technology at every anesthetizing location in order to identify medications before they are drawn up or administered (bar code

reader) and to provide a mechanism for feedback, decision support, and documentation (AIMS).[15]

The Institute of Medicine characterizes EHR systems as having eight functionalities. The core functionalities considered integral to EHRs include the ability to collect and store patient data, to supply information to providers, to permit physicians to enter orders on a computer (CPOE), and to provide clinicians with advice for making decisions for individual patients (CDSS). Patient and administrative support, electronic communication and connectivity, and the ability to report/analyze population health information are considered additional functions of an EHR.[16]

Advantages of EHRs and AIMS

The limitations of paper-based information management are inherently obvious. From some of the earliest reports of anesthetic misadventures in the early 1980s to today, most error analysis in anesthesia has been largely through review of paper records and incident reports. Craig and Wilson reported a review of more than 8,000 incidents, and they found the rate of any mishap was 1:694 anesthetics;[17] however, it was not until 2001 that Webster *et al.* first reported the rate of medication error during anesthesia.[18] Five reports from around the globe over the next 11 years reported similar results.[19-23] These large-scale studies, some retrospective and others prospective, relied on paper-based technology. While these paper-based systems did show opportunities for improvement, the resources involved with reviewing paper records and incident reports have taken over 30 years to establish a baseline from which to assess the effect of intervention strategies on the rate of medication errors in anesthesia.

The fragmented nature of health care delivery, the large volume of transactions, the need to integrate new scientific evidence into practice, and other complex information management activities may make electronic information management systems more appropriate to address continuous quality improvements and patient safety initiatives.[24]

Vigoda *et al.* reported that the use of AIMS provided an epidemiological perspective which showed that gender disparities previously favouring men have diminished primarily as a result of women's increased use of beta-blockers, statins, acetylsalicylic acid, and antiplatelet medications.[25] Aggregating data using AIMS proved advantageous because the results showed that patients were being undertreated with standard medical therapies despite evidence supporting the use of risk reduction strategies. Without AIMS, they would not have identified an opportunity to improve quality and patient safety.

Classen *et al.* found a rate of 2.4 adverse drug events (ADEs)/100 admissions. Adverse drug events were associated with a 2.45% increase in mortality and increased costs of $2,262 (1997 US dollars), primarily due to a 1.9-day increase in hospital length of stay.[26] Merry *et al.* evaluated a multimodal system designed to reduce medication errors in anesthesia, and they found the system to be associated with fewer errors in the documentation and administration of drugs.[27] Technological innovations, including the use of bar codes and automated alerts, have been suggested as ways to reduce medication errors in patients undergoing anesthesia.[15,28]

In 2006, Chaudhry *et al.* found that only four institutions accounted for over 20% of the publications regarding health IT. These institutions reported findings with "home grown" internally developed EHRs that included CDSS and had capabilities added incrementally over many years.[3] Increased adherence to guidelines was achieved through CDSS in the form of computerized reminders. Preventive care initiatives, including influenza and pneumococcal vaccinations, were improved, and complications related to hospitalization (i.e., prevention of deep venous thrombosis, pulmonary embolism, and hospital-acquired pressure ulcers) were reduced. Information technology was found to offer an enhanced capacity to perform surveillance and an improved method to aggregate data with simpler processes than a paper-based system, and the incidence of medication errors was reduced.

Computerized physician order entry (CPOE)

While seemingly outside the scope of the anesthesiologist's practice, CPOE is an integral part of any health IT system. As perioperative physicians, anesthesiologists frequently enter preoperative and postoperative orders into the medical record. Computerized physician order entry replaces handwritten orders. There are potential opportunities with CPOE, including standardization, incorporation of CDSS, improved communication to facilitate patient transfers, and data capture for management, research, and quality monitoring.[29] An advantage of CPOE is the ability to notify all appropriate caregivers simultaneously to implement an order, which should result in less turnaround time and fewer transcription errors. Paper-based order entry cannot offer these advantages.

Computerized physician order entry does not alter the decision-making process; physicians still determine whether a patient needs a medical test or medication. It does not replace existing workflow, nor should it improve faulty or inefficient operations. Nevertheless, physician orders are legible and transparent to all stakeholders in real time, and transcription errors are minimized. Standardized order sets can be instituted, leading to minimal variation.

When using CPOE, physicians must verify orders, and this validation may lead to fewer errors. The potential to

reduce the turnaround time for carrying out orders also exists, and the implications for stat medication orders are obvious.

Computerized physician order entry allows analysis of adverse events. Bates *et al.* examined adverse events and showed a trend toward a decrease in events and a decrease in non-intercepted serious medication errors.[30] In a follow-up study after increasing the level of CDSS, the same research team found an 86% decrease in non-intercepted serious medication errors.[31]

Despite the theoretical benefits of CPOE, few studies have shown an improvement in outcomes. Han *et al.* actually reported their findings after implementation of CPOE in a pediatric intensive care unit (ICU) for five months.[32] They examined interfacility transfers of 1,394 patients prior to CPOE implementation and 548 transfers afterwards. Approximately 60% of patients were transferred directly to the ICU. Prior to CPOE implementation, workflow patterns included radio contact from the medical transport team directly to the pediatric ICU fellow. This procedure facilitated ordering critical medications and diagnostic tests *prior* to the patient's arrival in the ICU. Following implementation of CPOE, no orders could be written until the patient arrived in the ICU and could be registered into the computer. In addition, no standardized order sets had been developed, which meant an average of ten screen clicks were required per order. Stabilization orders became time-consuming and frequently led to delays in the treatment of unstable patients. Further delays in treatment were reported because of a shift of medications from an ICU satellite pharmacy to a central pharmacy, and the change in workflow requiring physicians to order medications by computer then required nurses to activate the orders prior to dispensing. This often occurred at separate workstations, decreasing valuable physician-nurse interaction. While mortality may not best reflect the benefits of CPOE, Han *et al.* reported an increase from 2.8-6.57% in mortality. Computerized physician order entry led to a reduction in harmful ADEs; however, a direct association between CPOE and increased mortality among patients admitted through interfacility transport led the authors to suggest that surrogate outcome measurements, such as "medication error rate" or ADEs alone may be insufficient to determine CPOE efficacy.

Clinical decision support systems (CDSS)

Clinical systems that use population statistics and expert knowledge to offer real-time information to clinicians are known as CDSS. Patient management and consultation is aided through analysis of patient-specific information and comparison with an expert knowledge base.[33]

Clinical decision support systems in AIMS can alert the anesthesia provider to a number of important issues, including an existing allergy to the medication about to be administered; an inappropriate selection of vasoactive drugs based on the current blood pressure (BP) or hemodynamic variables; the need for an intervention to maintain appropriate BP and heart rate as determined by pre-set limits; the need for prompt prophylactic antibiotic administration and appropriate antibiotic selection based on the type of surgery or associated infectious process (if not documented prior to surgical incision); an indication for beta-blockers based on cardiac risk assessment; current and updated information regarding clinical guidelines (e.g., nil per os or the timing to discontinue anticoagulants prior to providing neuraxial anesthesia or following cardiac stenting); recommendations to delay surgery following recent transient ischemic attack or cerebrovascular accident; and an alert that forced-air warming may be indicated based on the patient's current temperature. There is also a host of other possible applications.

The basis behind CDSS is to help physicians manage the amount and evolving nature of information (e.g., antibiotic susceptibilities) presented to them, as it may overwhelm individual clinicians. More information may lead to better decision-making. At the health-system level, Evans *et al.* have shown that the appropriate antibiotic regimen was selected 94% of the time using a computer-based antibiotic consultant (CDSS) *vs* only 77% of the time using a physician-ordered regimen.[34] In a follow-up study by Evans *et al.*, they compared 545 patients treated in an ICU using the computer-based program *vs* 1,136 patients treated prior to implementation.[35] There was a significant decrease in ADEs, which was attributed to alerts of allergies and drug interactions. Interestingly, physicians followed the computer-suggested antimicrobial recommendation only 46% of the time; however, they followed dosing suggestions 93% of the time. This suggests that the physicians used the system as a decision support tool *vs* blindly following suggestions.

The key characteristic of a CDSS is its capacity to retain a huge amount of data that are essentially impossible for clinicians to master or keep updated.[36] Clinical decision support systems have the potential to make it easy for clinicians to do the right thing.

Anesthesia information management systems (AIMS)

Anesthesia information management systems are computer systems that capture data from the wide variety of monitors used in the operating room. The collected data can be used for management purposes and research analysis, and many

systems offer CDSS functions. Automated Anesthesia Record Keepers (AARKs), the precursors to AIMS, were implemented as early as the 1980s, and while they are invaluable for accurately collecting data, they are not classified as AIMS. The data they collect is not used for management purposes, and there is no CDSS; nevertheless, the recorded data is more accurate compared with handwritten records. Lerou *et al.* evaluated automated charting using the Ohmeda Modulus II^{TM} Anesthesia System *vs* handwritten records by comparing the acquisition of eight physiological variables in 30 elective eye surgeries.[37] Two records were compared for each patient, the handwritten record and that recorded by AARK. Anesthesiologists had two advantages; there was a centralized unit that displayed all eight variables on one screen, and they knew beforehand that their handwritten records would be compared with the automated record. Data were classified as either "missing" or "erroneous". Data were judged to be erroneous if there was more than a 20% variance between the handwritten record and the automated data. Results showed were more missing data than erroneous data. The "core" hemodynamic variables (systolic BP, diastolic BP, and heart rate) were recorded preferentially during induction of anesthesia and emergence, but they tended to be charted from memory and were often inaccurate. The anesthesiologist tended to fill in a preconceived diastolic BP derived from the systolic BP. While these variables were recorded by pen approximately ten times/hour, the less critically perceived variables, $ETCO_2$ and SaO_2, were recorded only three times/hour.

A subsequent report by Devitt *et al.* reinforced the findings of Lerou.[38] Common problems of poor record-keeping included the omission of abnormal values, the smoothing or rounding of abnormal values to within the expected upper or lower limits, and the averaging of measurements around an abnormal value, thereby reducing the precision of a single abnormal value.

Demographic information, patient identifiers, and scheduling information can be captured automatically from the health-system IT admission/discharge/transfer data. Driscoll *et al.* reviewed 2,838 electronic anesthetic records and showed the progression of AIMS over a decade by revealing the breadth of physiologic data captured.[39] Temperature documentation was explicitly required in 2007 but was not noted in studies during the 1990s. Touch screen documentation for laryngoscopic grade of view had much higher completion rates compared with manual text entries for allergies (92% *vs* 64%, respectively), and 99.9% of records documented with AIMS met requirements for billing purposes. This was achieved with the support of other technology, such as a pager and E-mail messages. The value of a "hard-stop", a feature that prevents ending or closing a record if data are not entered, was apparent.

Anesthesia information management systems have shown benefits in seven key areas: cost containment, operations management, reimbursements, quality of care, safety, translational research, and documentation.[40] They can improve scheduling, staffing, and billing collections, and they may be more credible in medico-legal defense by their objective physiologic data documentation. The evolution of AIMS to address improved patient safety over the past decade is exemplified by recent additional functionality in the form of CDSS added to many AIMS products currently on the market. Following recommendations from APSF, more AIMS products have added bar code scanning features that not only document an administered medication but also offer CDSS alerts such as those described above. Merry *et al.* recently reported a prospective randomized trial using a multimodal AIMS with bar code reading capabilities and CDSS wherein the error rate of drug administration improved from 1:303 anesthetics to 1:625 anesthetics when implementing interventions, such as prefilled syringes and legible barcoded labels for syringes.[27] This represented a 21% reduction in the rate of drug errors.

The preoperative component of AIMS has the ability to collect, process, and disseminate data. Parker *et al.* described a pre-anesthetic computer program (Healthquest) used in conjunction with a Preoperative Anesthesia Consultation and Evaluation (PACE) clinic.[41] Patients completed an electronic questionnaire and were assigned a medical classification score by the computer program. The medical classification score was then combined with a surgical invasiveness score (based on invasiveness and potential blood loss). Patients with good Healthquest scores were considered low risk, bypassed PACE, and were seen the day of surgery. The computer-supported PACE clinic was shown to improve operations by decreasing cancellation rates, decreasing diagnostic testing and specialty consults, and improving perioperative outcomes.

Even with the limitations of AIMS, it is noteworthy that most AIMS qualify for "meaningful use" criteria as defined by the HITECH Act of 2009. The criteria specify that a certified electronic health record must be used in a meaningful manner (e.g., E-prescribing or CPOE), for electronic exchange of health information in order to improve quality of care, and for submission of clinical quality measures selected by the Secretary of Health and Human Services to qualify for financial incentives to hospitals and healthcare providers. The latter is an added value that may result in increased reimbursements (or decreased cuts) for anesthesia services in the future.

Barriers to adoption and implementation of EHRs and AIMS

Workflow and time pressures remain barriers to data entry, even with AIMS. The development and implementation of IT solutions may be easier when processes are ingrained into the workflow. Like CPOE, however, AIMS will not replace existing workflow or necessarily improve faulty or inefficient operations.

Criticisms of AIMS include discomfort with rapid documentation and electronic data entry during short or emergency procedures and inconvenient placement of the system at the anesthesia workstation.[42] Cost has been cited as a barrier as well as questions about legal status with missing or outlier data.[9,43] Documentation with AIMS is not foolproof, and data capture can be variable. Ehrenfeld *et al.* reported common gaps in BP documentation of equal to or greater than ten minutes; however, these gaps could be reduced by using CDSS real-time feedback to providers. These types of documentation errors with AIMS make some individuals hesitant to trust an electronic system.

The move to adopt a hospital or health-system IT solution that has an integrated and interoperable AIMS component is prevalent in today's healthcare environment. Nevertheless, off-the-shelf IT products designed for health-systems may not focus specifically on anesthesia workflow or be designed appropriately. Few AIMS on the market today are truly interoperable with the health-system or hospital IT system.[40] These barriers have the potential to lead to decreased provider satisfaction and user engagement, and they may decrease opportunities for additional CDSS.

While AIMS and health-system IT solutions have the potential to offer CDSS that may lead to improved patient safety, they only mirror or reinforce a safety culture. They do not substitute for one. The APSF has recommended the establishment of a safety culture for reporting errors, a safety culture that encourages discussions of lessons learned, that recognizes the benefits of standardization, technology, and pharmacy involvement (with prefilled or premixed medications), and that provides education, understanding, and accountability.[15] Cooper *et al.* suggested that a shift of organizational culture over the past decade that emphasizes safety rather than blame may have accounted for the increased rate of voluntary reporting of errors that were observed over previously published reports.[23] The establishment of non-threatening environments may encourage clinician "buy-in" to clinical solutions aimed at improving patient care. Buntin *et al.* found that the "human element" is critical to health IT implementation.[6] Provider satisfaction was associated with improved results during implementation, which highlights the importance of staff "buy-in" when purchasing, designing, installing, and implementing health IT systems and AIMS.

Friedman suggested that health IT is more about people than technology.[24] A person working in partnership with IT is better than that same person unassisted. Information technology can be any mechanism that supports completion of a task. Information technology and therefore AIMS must be people-centric to be effective. Information technology should offer decision support, interoperability, or electronic exchange of health information not readily available to the clinician with paper records. Poorly designed systems with little or no clinician input will typically lead to failure.[44]

Conclusion

Electronic health records and AIMS are at the intersection of patient safety and technology. As anesthesiologists are hospital-based physicians who are frequently organized into larger groups, they are perfectly positioned to be the physician leaders of adoption, design, implementation, and integration for AIMS and for health-system IT solutions in general. Lack of user engagement has been highlighted as a key contributing factor to failed EHR implementation. Involvement of physician and ancillary staff in selecting a system and customizing system functions to meet clinical needs is often overlooked, and this can lead to frustration and alienation.[44] The thoroughness and standardization of CPOE should improve the quality of patient care. A CDSS is a sophisticated tool that assists clinicians in decision-making, but is not a substitute for it. While the impetus for widespread adoption of AIMS comes from government agencies and regulatory bodies, it is unlikely to provide safety benefits unless there is a groundswell of physician support. The success of the Veterans Administration National Surgical Quality Improvement Program in improving surgical outcomes *vs* efforts by the Institute of Medicine (IOM) is exemplary. The latter was a top-down appeal from the government, and the former was a bottom-up implementation from surgeons. The lackluster performance of the IOM was, in part, a byproduct of poor physician engagement. Benchmark institutions succeeded because health IT and AIMS have been used as tools to improve existing safety cultures.

It is critical to frame health IT or AIMS as the *catalyst* for improving patient safety *vs* the *solution* to improving patient safety. Physicians and other clinicians are the solutions to improving patient safety; IT and AIMS are simply tools.

Key points

- The universal adoption of health information technology and anesthesia information management systems

remains low despite the potential to improve quality and safety.

- The Anesthesia Patient Safety Foundation has long advocated for technological solutions to improve patient safety.
- The fragmented nature of health care delivery, the large volume of transactions, the need to integrate new scientific evidence into practice, and other complex information management activities may make electronic information management systems more appropriate to address continuous quality improvements and patient safety initiatives.
- With computerized physician order entry and electronic health information technology, there are potential opportunities for standardization, incorporation of clinical decision support to alert clinicians of potential safety hazards, improved facilitation of patient transfers, and data capture for management, research, and quality monitoring.
- Anesthesia information management systems have shown benefits in seven key areas: cost containment, operations management, reimbursements, quality of care, safety, translational research, and documentation.
- Barriers to adoption include lack of clinician "buy-in" and the lack of truly interoperable health-system information technology solutions that focus specifically on or are designed appropriately for anesthesia workflow.

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