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Perioperative Information Systems: Opportunities to Improve Delivery of Care and Clinical Outcomes in Cardiac and Vascular Surgery

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Abstract

A variety of existing perioperative informatics tools offer clinicians and researchers the opportunity to improve the delivery of care and clinical outcomes for patients undergoing cardiac and vascular surgery. Many of these tools can be used to improve the reliability of the care delivery process through the application of clinical decision support tools and/or quality improvement methodologies at a number of junctures. In this review, the authors will offer a concise overview of the existing perioperative informatics literature, with a focus on tools considered to be of utility in confronting the unique challenges inherent to cardiac and vascular surgery. The authors also highlight areas that they believe are of interest for future targeted inquiry.

Keywords

clinical decision support; perioperative informatics; database research anesthesiology; information management systems

THE BOURGEONING FIELD of perioperative informatics offers an array of tools that have the potential to significantly improve the care of patients undergoing cardiac and vascular surgery. Unfortunately, few, if any, of these tools are specifically designed to be of use for cardiovascular care. The majority are designed for all forms of perioperative care, albeit with important potential applications in cardiac and vascular surgery. In this review, the authors outline essential elements of perioperative informatics and important developments in the field, with a focus on those with potential applications for patients undergoing cardiac and vascular surgical procedures.

Perioperative Informatics: Key Definitions

Clinical informatics is defined by the American Medical Informatics Association (AMIA) as “the application of informatics and information technology to deliver healthcare services.”¹

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Applications as diverse as clinical decision support, enhanced electronic health record (EHR) documentation, computerized provider order entry, and storage and organization of clinical images are all active areas of interest for clinical informaticians. Clinical informatics is an Accreditation Council for Graduate Medical Education and American Board of Medical Specialties recognized subspecialty, with a board exam administered by the American Board of Preventative Medicine and the American Board of Pathology.

Adapting the AMIA definition, perioperative informatics can be defined as the application of informatics and information technology to deliver healthcare services *in the perioperative period*. As the concept of the perioperative surgical home evolves, perioperative informatics is broadening further to include the informatics needs to support implementation of new, expanded models of care. Of note, the field of perioperative informatics includes both clinical and research applications of information technology.

EHR and AIMS-Derived Data

A wide number of data sources are available to perioperative clinical informaticians. The authors provide a list of common informatics-based data sources used for cardiovascular anesthesia research in Table 1. It is important to note that every data source has limitations and a thorough understanding of these limitations can significantly improve the quality of conclusions drawn from studying these data. To address this, informaticians are increasingly being tasked with normalizing data. This is a process in which data are organized to reduce redundancy and improve integrity. Normalization may involve merging data from 1 or more data sources, with the underlying assumption that the end, cleaned, normalized dataset will have fewer limitations than any one individual data source.

Many perioperative informatics projects rely on data derived in some fashion from the medical record. At many institutions, this is in the form of an EHR, which greatly facilitates the process of accessing and manipulating existing data. EHRs have been hypothesized to improve clinical care and, under the HiTech Act, have become a critical element in achieving so-called “meaningful use,” with associated financial implications through a variety of federal incentive programs.² In an EHR, once data are documented, they may be stored in consistent locations and with relatively standardized definitions. Informaticians can then readily access these data, most commonly using structured query language, to generate datasets for analysis. Data may be collected throughout the perioperative period, including in a preoperative assessment clinic, greatly facilitating structured assessment and optimization even before the day of surgery.³

During the intraoperative period, anesthesiologists have increasingly adopted one of several commonly employed Anesthesia Information Management Systems (AIMS). In fact, greater than 75% of academic anesthesiology departments in the United States currently use an AIMS, and adoption is estimated to increase to greater than 85% by 2020.⁴ An AIMS allows for the automated collection and storage of intraoperative data such as physiologic parameters, gas flows, and ventilator settings, thereby freeing up the anesthesia provider to focus on other tasks. Many AIMS may be accessed and monitored remotely, using hand-held devices, facilitating an anesthesiologist’s ability to monitor multiple anesthetizing locations.

Additional data, such as the preoperative history and physical, intraoperative events, medication administration, and postoperative outcomes, are commonly stored in an AIMS and are readily accessible for use by clinical informaticians. In most instances, some knowledge of database programming is required to access data, although efforts are ongoing to simplify this process in many AIMS. Importantly, AIMS data can be easily integrated with other data sources when appropriately structured. As most informatics uses for AIMS data is very much a “secondary” use of the data, these data often need significant hand review and cleaning prior to analysis. A recent review by Gálvez et al outlines many of the benefits of AIMS adoption and may be consulted by those interested in additional information on this topic.²

Efforts to Centralize EHR and AIMS data

The Multicenter Perioperative Outcomes Group (MPOG) was formed in 2008, with the goal of facilitating multicenter research and overcoming obstacles relating to the regulatory and technical hurdles inherent to combining large datasets from multiple institutions and multiple AIMS vendors. Many of its quality and performance improvement efforts were later spun off into its sister organization, the Anesthesiology Performance Improvement and Reporting Exchange (ASPIRE), formed in collaboration with Blue Cross and Blue Shield of Michigan. Both ASPIRE and MPOG maintain large datasets that are available for analysis and use for members, provided member organizations approve the scientific merit of the proposed research. Although multiple publications have resulted from the MPOG collaboration none, to date, have focused specifically on cardiovascular surgery, although several projects are underway and are likely to appear in publication in the coming years. 5–10

A similar endeavor, the Anesthesia Quality Institute (AQI), was founded by the American Society of Anesthesiologists in 2008 as a vehicle to facilitate quality improvement and reporting to anesthesiologists of a variety of quality metrics.¹¹ Through improved reporting of quality metrics back to anesthesiologists, the AQI seeks to educate providers about evidence-based best practices and, in some instances, how individual providers may be outliers. Data reported to the AQI are stored in the National Anesthesia Clinical Outcomes Registry and are shared with such diverse entities as the Anesthesia Patient Safety Foundation, individual researchers, and the Joint Commission. Like the MPOG and ASPIRE initiatives, the authors would contend that the National Anesthesia Clinical Outcomes Registry and AQI have been relatively underutilized by the cardiovascular anesthesiology community, presenting a significant opportunity for interested investigators.

Perioperative Registries

Many perioperative registries have been implemented and used for numerous purposes, all with the overarching goal of improving perioperative care. Most involve data that have been manually collected. Each has unique strengths and weaknesses and in many, if not most, instances registry data is combined with other data sources to address these weaknesses.

The American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP) is one of the most widely used perioperative registries and has consistently been shown to offer high-quality data for analysis for research and quality improvement.¹² Trained reviewers manually enter data from selected surgeries, with efforts made to limit oversampling of common cases. Data are derived from the EHR, rather than claims data, thereby avoiding many of the inherent limitations of claims data. Patients are followed closely for a 30-day postoperative period, allowing for detection of relevant short-term postoperative complications after the index surgery. Consistent data definitions are used and rigorous efforts are maintained to ensure high-quality data are recorded. Inter-rater reliability, for example, has been measured at greater than 98%.^{13,14} Participation in the ACS- NSQIP and use of its benchmarking tools has been shown in several studies to result in improved patient outcomes, as well as decreased cost.^{15,16} Participating hospitals in the ACS- NSQIP collaborative are given access to the deidentified, HIPAA-compliant Participant Use Data File (PUDF), containing complete registry data from all participating hospitals. These data can be used for benchmarking, as well as research, purposes. When evaluating patients in the preoperative setting, data from the ACS-NSQIP collaborative have been used to create a free, online risk calculator (<http://riskcalculator.facs.org/RiskCalculator>), which may improve an anesthesiologist's ability to risk stratify patients prior to proceeding with surgery. Notably, there are significant potential uses for these data for cardiovascular anesthesiologists, given the ability to focus specifically on cardiac and vascular surgery patients in analysis of data.

The Society of Thoracic Surgeons National Database (STS) has been in existence for almost 30 years and, similar to the ACS-NSQIP, has been widely used for research, quality improvement, and patient safety initiatives.¹⁷⁻¹⁹ While ACS-NSQIP tracks data from a wide variety of surgical procedures, the STS database focuses specifically on cardiothoracic surgery, and collects data from over 1,000 participating centers, representing more than 90% of adult cardiac surgery hospitals in the United States.²⁰ Data from the STS database have been used to assess risk of a number of adverse events, including unanticipated conversion from off-pump to on-pump coronary artery bypass grafting.²¹ The STS has created an online risk calculator, which is freely available for providers (<http://riskcalc.sts.org>). Data collection modules have been developed for Adult Cardiac, General Thoracic, Congenital Heart, and Adult Cardiac Anesthesia care, allowing for improved data collection in these domains.²² According to the STS, significant effort is currently being made to enhance and develop the capabilities of the Adult Cardiac Anesthesia care module, to better track anesthesiology relevant metrics and outcomes.²³

Informatics Tools to Improve Timeouts

In 2004, the Joint Commission implemented the Universal Protocol (http://www.jointcommission.org/standards_information/up.aspx), in which organizations must perform a "timeout" prior to every procedure in order to decrease the incidence of preventable medical errors. Critical errors, so-called "never events," were identified by the National Quality Forum and, specific to surgery, include wrong patient, wrong procedure, and wrong site.²⁴⁻²⁶ Yet in spite of widespread implementation of the Universal Protocol, preventable medical errors continue to occur and present a significant risk to patients

undergoing surgery.²⁷ To help address this, informaticians have worked to develop tools to improve the quality and performance of timeouts. Given that miscommunication is commonly implemented as a root cause of these never events, this has been a key area identified for improvement.²⁵ Electronic whiteboards presenting data automatically derived from the EHR, for example, have become increasingly common in operating rooms to provide an extra safeguard against medical errors.²⁸ Structured handoffs and checklists, often integrated into the EHR and AIMS provide an additional layer of safety.²⁹ Given that cardiac and vascular surgery may be emergent and performed outside of “normal” hospital hours, they should be considered at particularly high risk for preventable medical errors.³⁰ Future studies will explore how informatics tools can help ensure adherence to the Universal Protocol in cardiac and vascular surgery.

Informatics Tools for Clinical Decision Support

One of the well-developed areas of perioperative informatics is clinical decision support. A large number of systems have been successfully designed and implemented, with demonstrable improvements in the delivery of anesthesia care in a variety of settings.³¹ Integrating alerts into the AIMS allows for real-time or near-real-time clinical decision support and has been shown to improve adherence to protocols, as well as billing performance.^{32,33} The authors provide a summary of clinical decision support tools with direct applicability to cardiovascular anesthesia in Table 2. Although an AIMS may improve the quality of anesthesia documentation, concerns, largely unsupported by the literature, persist among many practitioners that they may expose anesthesiologists to increased medicolegal liability.^{34–37} This concern has been heightened given documented instances of automated collection and recording of artefactual data in the AIMS.³⁸ Efforts to better detect and address these concerns are ongoing in the literature.

AIMS-based research has been employed to address many clinical concerns. Maintenance of normoglycemia, for example, has been a significant area of ongoing research focus in the anesthesia informatics field. Reminders to routinely check intraoperative glucose integrated into the AIMS and applied to high-risk patients have been shown to reduce surgical site infections—one of the few instances of demonstrating improved patient outcomes with AIMS-based clinical decision support, thus far.³⁹ Similarly, audiovisual alerting to remind providers to monitor glucose routinely has been shown to result in improved adherence to guidelines around maintenance of normoglycemia.⁴⁰ Alerts have been used as a reminder of laboratory values that may have resulted as abnormal prior to surgery, to ensure that providers are aware of these values and incorporate a knowledge of these values into perioperative planning.⁴¹

Given the complexity of hemodynamic monitoring and management in cardiovascular surgery, which may involve careful titration of vasoactive medications and anesthetic dosing, tools to improve the accuracy of medication dosing are of utility. An AIMS may facilitate documentation of this complex process, particularly through automated collection of data from patient monitors. Intraoperative drug infusion alarms have been employed to address this critical area of patient safety. Interestingly, however, few, if any, are derived from real-world usage data. Recently, however, Berman et al demonstrated a methodology that can be

applied to more accurately create and optimize AIMS-based alerts for drug dosing of infusions.⁴² This technique could reasonably be applied to any number of cardiovascular drugs, permitting cardiovascular anesthesiologists to more safely dose high-risk vasoactive medications.

Additional quality improvement and patient safety interventions have been employed using informatics-based clinical decision support. Improved documentation tied to quality metrics, such as the Surgical Care Improvement Project (SCIP) metrics, among others, has been an area of focus in several studies. In vascular surgery patients, SCIP metrics have appeared to have something of a mixed impact, with improvement in cardiovascular, thromboembolic, and infectious morbidity in only a handful of procedures.⁴³ A number of rationales have been offered for the mixed impact of the SCIP metrics.^{44,45} To better improve adherence to the SCIP metrics and postoperative outcomes, AIMS-based alerts have been implemented and shown to improve documentation of beta-blocker administration (SCIP-CARD-2),⁴⁶ antibiotic dosing (SCIP-INF-1 and 2),^{47,48} among others.⁴⁹ Although these studies have been shown to improve intermediate outcomes, most of which are procedural in nature, data continue to be lacking for improved clinical outcomes resulting from their implementation.

Real-time and near-real-time reminders also have been shown to improve billing performance. Automated electronic alerts to notify providers that they have likely incorrectly documented anesthesia start time, for example, significantly improved the accuracy of time-based documentation and resulted in improved reimbursement.⁵⁰

Although many of these interventions have not been tested specifically in cardiovascular anesthesia, they have clear implications and uses for this at-risk population. Future work will better identify and test areas for improvement specifically for cardiovascular anesthesia.

Informatics Tools for Operating Room Management

Given that modern day electronic health records grew out of rudimentary medical billing systems, it is not surprising that many EHRs provide tools and opportunities to improve practice and perioperative efficiency. Many AIMS have specific tools that can facilitate both evaluation and improvement of operating room staffing and scheduling approaches.^{51–55} Additionally, these systems have been used in academic centers to assist trainee education and case selection.⁵⁶ Finally, a number of AIMS have functionality that can support quality improvement efforts through their ability to capture and display large amounts of data at the provider level, allowing for targeted feedback and practice improvement.^{32,57,58}

Informatics Tools to Improve Transitions in Care

As transitions of care frequently occur in cardiovascular anesthesia, particularly from operating room to intensive care unit, there exists a significant opportunity to improve the quality of hand-off between teams. Inadequate hand-off between providers has been implicated as a root cause of many adverse events and has been commonly identified as a key area for improvement in a number of settings, including cardiovascular surgery and anesthesiology.^{59–62} Protocolized handovers, which may be greatly facilitated and improved through integration of the process into the AIMS and EMR, have been shown to be easily

implemented and may improve patient outcomes, particularly given evidence that verbally presented medical information is not optimally retained.^{63–65}

Improved Remote Monitoring Throughout the Perioperative Period Using Informatics Tools

An emerging field of study in clinical informatics has been the implementation of remote multisensor consumer monitoring devices, such as the Apple Watch (Apple, Cupertino, CA) to facilitate ongoing assessment of patient status. These devices may facilitate assessment of baseline and ongoing functional status, as well as energy expenditure, on an ongoing basis.^{66,67} As patients progress through the recovery process, it is hypothesized that remote monitoring using these commercially available consumer products may assist with detecting and addressing postoperative complications ranging from pain to delayed recovery of baseline functional status.⁶⁸

Conclusions

A wide variety of perioperative informatics tools have been developed, with demonstrable improvements in the delivery of anesthesia care. Many of these systems augment the ability of care teams to deliver care in a more consistent and reliable fashion. To date, the authors would contend that these tools have been underutilized by cardiovascular anesthesiologists and significant opportunities exist to test these tools in the cardiovascular setting. Future work in the field will continue to facilitate how cardiovascular anesthesiologists interact with patient data and better delineate how this improves clinically relevant patient outcomes.

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Table 1

Common Informatics-Based Data Sources for Cardiovascular Anesthesia Research

Source	Type	Primary Use
Electronic medical record	Single institution	Clinical
Anesthesia information management system	Single institution	Clinical
Multicenter perioperative outcomes group	Multicenter	Research
Anesthesiology performance improvement and reporting exchange	Multicenter	Quality improvement
National Anesthesia Clinical Outcomes Registry	Multicenter	Quality improvement
American College of Surgeons' National Surgical Quality Improvement Program	Multicenter	Quality improvement
Society of Thoracic Surgeons National Database	Multicenter	Quality improvement

Table 2

Common Decision Support Tools that Support Cardiovascular Anesthesia Care

Preoperative Alert	Intraoperative Alerts	Postoperative Alerts
Incomplete charting	Incomplete charting	Incomplete charting
PONV prophylaxis	Blood glucose monitoring	Patient status change/ deterioration
Lung protective ventilation strategy	Antibiotic redosing Heparin redosing Depth of anesthesia alerts Fresh gas flow alerts Temperature management	

Abbreviation: PONV, postoperative nausea and vomiting.