

Correlation between provider computer experience and accuracy of electronic anesthesia

charting – A pilot study and performance improvement project

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Approximately 33 percent of anesthesia practices reporting to a national outcomes registry use anesthesia information management systems (AIMS), a subset of electronic medical records (EMR) (Stonemetz & Dutton, 2014). By contrast, about 75 percent of anesthesia departments in academic institutions use AIMS (Anderson & Merry, 2015). However, less than 15 percent had capability to exchange such information with other practices and hospitals. While most American hospitals use at least a basic form of electronic charting (Office of the National Coordinator for Health Information Technology, 2015), increasing Medicare reimbursement penalties over the next few years will likely spur an increase in the number of practice settings using a form of electronic health record (Office of the National Coordinator for Health Information Technology, 2013).

Accuracy of these records is an important consideration as more of these systems are put to use (Kohli & See-Lin Tan, 2016). Incomplete or inaccurate information is a factor in adverse events (Kohli & See-Lin Tan, 2016). Studies have demonstrated that adverse events lead to longer hospital stays (Forster, Kyremanteng, Hooper, Shojania, & van Walraven, 2008) and may lead to increased mortality of patients (Han et al., 2005), although these analyses did not involve anesthesia charting, but electronic records in general.

Ideally, according to Moore and Richardson (2015), an AIMS must be free of error, as much as possible, and readable. The user interface (UI) should not steal attention from rendering care. Its usefulness should include automation of inventory and charges for equipment and services. The aggregate of patient data generated should be of a quality to improve care, decrease adverse incidents, and enhance research. Use of AIMS should improve day-to-day and long-term

organization of staff. Finally, monitoring AIMS records should improve adherence to medical-legal requirements and submissions to government monitoring agencies.

Recent studies of AIMS accuracy (Anderson & Merry, 2015; Avidan & Weissman, 2012; Davis, Green, Colquhoun, Hage, & Biddle, 2012; Lamer et al., 2015; Simpao, Pruitt, Cook-Sather, Gurnaney, & Rehman, 2012; Wilbanks, 2014; Wilbanks, Moss, & Berner, 2013) relied on early efforts in healthcare IT from the 1970s through 1990s to compare electronic records with handwritten charts. These were studies such as *Differences between handwritten and automatic blood pressure records* (Cook, McDonald, & Nunziata, 1989), *Automated charting of physiological variables in anesthesia: A quantitative comparison of automated versus handwritten anesthesia records* (Lerou, Dirksen, van Daele, Nijhuis, & Crul, 1988), and *Are automated anesthesia records better?* (Thrush, 1992), among many others. Earlier analyses primarily focused on establishing that AIMS were accurate, or at least as much as paper records, and on provider vigilance. Generally, electronic charting was found to be accurate, but in need of improvement and centered on analysis of recording physiological information from anesthesia monitors (Wilbanks, 2014). For example, one early electronic system recorded blood pressure measurements 20-30 mmHg higher, and more accurate, than those charted simultaneously on paper (Shibutani, Subhedar, Shirasaki, Sakata, & Ogawa, 1992).

In anesthesia documentation, accuracy and completeness are equally important. However, a record might be accurate in physiological readings (e.g., vital signs of heart and respiratory rate, blood pressure, pulse oximetry) but incomplete by professional standards (e.g., vital signs documented at least every five minutes, notation of type of anesthesia and procedures performed). In such a case, the chart is accurate, but incomplete. Likewise, a record might be complete if it contains the required data points, but inaccurate if significant time markers are

incorrectly documented (e.g., the antibiotic was entered by a pre-programmed template as being administered 10 minutes prior to entry into the operating room, but was actually administered much earlier). Such a record is complete, but inaccurate. This theme of accuracy and completeness is inherent in meeting the anesthesia standard of care for documentation (American Association of Nurse Anesthetists, 1991; American Society of Anesthesiologists Committee of Quality Management and Departmental Administration, 2013).

Purpose

This performance improve project and pilot study was intended to examine one aspect of automated charting, that of automatic insertion of events into an anesthesia record file. This common practice is performed to help anesthesia providers remember to include all important events of a case. However, the inserted entries must be changed by the provider to reflect the actual occurrences and times of these events during each case. Examining whether or not providers were doing this, and who was doing this, was the purpose of this project.

Synthesis

Recent studies listed in the review of literature focused on accuracy to examine usability – ease of use – and effectiveness of electronic charts. These questions focus more on functionality and achieving a complete record (Wilbanks et al., 2013). Three themes emerging from these studies are *correctness*, *usability*, and *developing technologies*, discussed as follows.

Correctness

The concept of correctness, which included accuracy, here denoting correct entry of data content, time stamps and similar information, either by the provider or automatically from the AIMS, was a term put forth by Wilbanks (2014). Wilbanks et al. (2013) specifically noted that

completeness and ease of use in electronic charting was greatly increased by programmed entries in templates. However, accuracy sometimes suffered as a result of human fallibility.

Incorrectness by omission, incompleteness. Another concept of completeness referred to reporting of all events, parameters, procedures, and drugs during an anesthetic, their inclusion being necessary to comprise a full record of a case. As the signatory of the record, a provider is responsible for its integrity (Kohli & See-Lin Tan, 2016). However, Wilbanks et al. (2013) demonstrated that human omission was the most frequent cause of incorrect records. Likewise, Ehrenfeld, Epstein, Bader, Kheterpal, and Sandberg (2011) noted that when automated data collection was incomplete, or inaccurate for some reason, it was incumbent on the provider to notate the error and make corrections regarding which interventions were lacking. Thus, completeness evolved as a subset of the theme of correctness. The comprehensive reporting of all appropriate events during an anesthetic was lacking, and human error was primarily to blame (Avidan & Weissman, 2012; Ehrenfeld et al., 2011; Simpao et al., 2012; Wilbanks et al., 2013).

Several reasons might explain why charts are incomplete, such as forgetfulness while charting after the fact following a critical period or event (Ehrenfeld et al., 2011). Anderson and Merry (2015) noted that data quality suitable for pooling of patient information, for care or research, would be difficult to generate from an AIMS with an inefficient, challenging user interface, as such UIs contributed to inaccurate, incomplete data. The observers in the Wilbanks et al. (2013) research noted a high degree of accuracy, but fallible provider input with the use of case templates to populate appropriate events to a chart, which must then be fine-tuned to match reality. Anderson and Merry (2015) highlighted templates as the cause of errors, making AIMS less reliable and emphasizing the responsibility of providers to ensure records were complete and correct. This was not necessarily seen in early, basic AIMS versions, when providers had to

generate manual entries without the aid of automatic entry of events by pre-programmed templates. The same study specified poor interface design as a primary cause of inadequate or incorrect data, lessening its value for forensic use (Anderson & Merry, 2015).

Detecting and correcting inaccurate records. In order to detect error, it must be observed. Researching the accuracy of records was accomplished in several different ways. Researchers approached the problem with post-hoc observation and concurrent observation. When they attempted to correct, in addition to detecting, the problems, they used active, real-time intervention, or after-the-fact alteration of records.

Post-hoc observation. Lamer et al. (2015) and Marian, Bayman, Gillett, Hadder, and Todd (2016) reviewed finished records though only Lamer and colleagues sought to correct them. In the French, Lamer et al. study, patient records were altered in the AIMS database, with no discussion of the implications of such action in the context of U.S. FDA regulations. In the Iowa study by Marian et al., alarms were triggered by the observation that university hospital patients in the year following AIMS installation showed a 6.1-percent increase in perioperative acuity scores without a change in patient population. Correction of the AIMS returned the university health system to values in keeping with U.S. national averages.

Concurrent observation. In several cases, researchers placed an observer in the operating room to record events for later comparison with the chart developed by the anesthesia provider (Davis et al., 2012; Simpao et al., 2012; Wilbanks et al., 2013). Others used the AIMS as the observer (Avidan & Weissman, 2012; Ehrenfeld et al., 2011). With the AIMS' real-time surveillance, researchers had installed preprogrammed interventions to enhance completeness of records. In the case of Avidan and Weissman, the researchers reprogrammed their AIMS to present context-sensitive, mandatory entry prompts to anesthesia providers, requiring completion

of all key items before proceeding (2012). It should be noted that some, but not all, AIMS software can be set up with required-entry fields, sometimes in a context-sensitive manner, but this varies widely depending upon each software developer. Further, as in the French study (Lamer et al., 2015), Avidan and Weissman (2012) had no need to address the implications of altering what would have been, in the United States, an FDA-approved medical device for their purposes. A nuanced, real-time intervention, without rewriting the AIMS, was applied by Ehrenfeld et al. (2011), in which electronic observation of more than 10-minute gaps in blood pressure readings triggered pager and text message notifications to the anesthesia providers, which prompted them to complete the chart.

Incompleteness of voluntary reporting. Another critical factor of completeness is reporting of events, especially critical events. Simpao et al. (2012) observed 995 cases to determine the extent providers recorded pediatric patient emesis on induction of anesthesia. Reporting of such events was low (three reports), and even lower for quality improvement reports (one report), although the event was rare enough (eight incidents observed) that it was difficult to analyze. They concluded that such critical events were not rigorously reported in anesthesia records, and even less so in quality improvement reports.

On a more common level, everyday charting of the details of key anesthetic events is inherent in accurate charting. For this, Avidan and Weissman (2012) chose four key forms and reprogrammed their AIMS to make those items mandatory. Changing the charting requirements from voluntary to mandatory raised the completion rate from the 59- to 92-percent range to 99.6 percent. Similarly, the active intervention of paging and texting when gaps in charting blood pressure were noted (Ehrenfeld et al., 2011) increased completeness from about 93 percent to 98.5 percent post-intervention.

Comparison of AIMS charts to handwritten. On the subject of accuracy, Anderson and Merry (2015) remarked on the precise recording of electronic data compared to handwritten charts. Researchers cited “smoothing” – the human tendency to avoid charting extremes of physiologic readings, called “railroad tracks” (see Appendix., top section). Electronic records showed the more realistic variability of readings such as blood pressure and heart rate noted during an anesthetic.

Furthermore, when filling in the gaps on a handwritten record, providers do not typically leave obvious blanks. This was illustrated by a natural experimental that served as a control group for Ehrenfeld et al. (2011). In their study of gaps in blood pressure documented in AIMS in three facilities, one hospital was temporarily unable to use the AIMS, which yielded 500 paper charts for comparison. The authors noted that none of the handwritten charts had any gaps in blood pressure readings.

Usability

This theme encompassed a broad aspect of AIMS use. One aspect is providers’ ability to efficiently use the software (Avidan & Weissman, 2012; Marian et al., 2016). In order to be defined as efficiently usable, they must be able to do so without loss of vigilance (Davis et al., 2012). Further, the records recorded must be correct (Anderson & Merry, 2015; Avidan & Weissman, 2012; Ehrenfeld et al., 2011; Kohli & See-Lin Tan, 2016; Lamer et al., 2015; Simpao et al., 2012; Wilbanks et al., 2013) and thus valid and available for future reference, research, and legal questions.

User interface complexity. The UI was cited as one of the most common enhancers or impediments to accurate charting (Avidan & Weissman, 2012; Davis et al., 2012; Ehrenfeld et

al., 2011; Kohli & See-Lin Tan, 2016; Lamer et al., 2015; Marian et al., 2016; Simpao et al., 2012; Wilbanks et al., 2013). In designing forms with fields that required an entry before moving on, Avidan and Weissman (2012) considered that overly complex and deep menus to be a significant reason why providers entered incorrect information, or simply left entries blank. Further, the required information presented had to be appropriate to the circumstances being charting, or context-sensitive. Davis et al. (2012) tested the concern that having to click through menus in order to chart would be distracting to providers. Both studies vindicated electronic charting as highly accurate, if AIMS were designed to be context sensitive, and no more distracting than paper charting, respectively. However, Marian et al. (2016) demonstrated that AIMS design does affect the accuracy of information recorded, in that an overly complex set of forms skewed preoperative assessment data. In that case, redesigning and simplifying the forms corrected the errors.

Templates. As previously discussed, relying upon voluntary reporting of all events during an anesthetic ensures that some information might be left out. An attempt to correct these omissions was the focus of Wilbanks et al. (2013) examination of the use of pre-programmed templates. With these, a set of events typically entered for a procedure is imported into a chart and the provider must adjust times and content to make them accurate. Automatic import greatly increased completeness of the chart, regarding inclusion of events appropriate to the context of the case. This study revealed human error was the most common cause of either omission of events, or failure to correct data from imported events to reflect reality for that case. If the context-sensitive templates were not changed, or were not applicable, such templates were worse than useless, as they introduced error into the record (Anderson & Merry, 2015; Lamer et al., 2015; Wilbanks et al., 2013).

Context-sensitive prompts. Imported, preprogrammed templates containing events particular to each type of case qualified as context-sensitive. However, Avidan and Weissman (2012) instead altered the UI on key forms to present only applicable fields for completion. For example, a page detailing a general anesthetic with endotracheal intubation did not include mandatory data prompts to detail a spinal anesthetic. In this way, provider satisfaction with and appropriate use of the AIMS was increased to nearly 100 percent.

Another aspect of the context-sensitive UI was automated provider alerts such as were developed by Ehrenfeld et al. (2011). Anderson and Merry (2015) listed utility of such alerts for critical events, such as hypotension, or best-practice guidelines, such as administration of perioperative beta blockers or antibiotics. Patient data was also used to trigger reminders regarding prevention of postoperative nausea and vomiting. Patient demographics, such as age, was used to present physiological alarms, such as for pediatric heart rate.

Controls and unintended consequences of AIMS. Spurious charting of data was demonstrated by Marian et al. (2016) to alter patient assessment data simply by virtue of an overly complex AIMS UI. In this case, the errors may have gone unnoticed except for an external administrative audit, which noted an increase in the American Society of Anesthesiologists Physical Status (ASA PS) scores for 6.1 percent of patients in a university health system, with no corresponding change in patient population. The errors corresponded with the installation, one year prior, of an AIMS. Controls to prevent such errors were installed to change the provider workflow, which addressed data entry. Visual presentation of the data item on the AIMS form enhanced communication between providers. However, prevention of spurious charting was not possible within the AIMS, and physical control of changes to the data

item was only achieved by implementing a policy that only anesthesia providers would chart the data item.

Controls to prevent errors within AIMS were theoretically achieved by comparison of large datasets of cases to establish probable norms for each type of anesthetic (Lamer et al., 2015). However, such a review achieved only the establishment a normal context, such as the finding that an event for induction of general anesthesia was typically followed by an event describing placement of an airway device. Outliers from the normal context may be the cases requiring scrutiny, and would necessarily fall outside the norm. This use of proxy events (e.g., intubation, extubation) by Lamer and colleagues (2015) allowed them to increase their completion rate to nearly 100 percent by generating events (*start-* and *end of anesthesia care*) previously left incomplete in 20 percent of their anesthetic records. The authors indicated that the lack of mandatory fields and a poor user interface were possible reasons for their poor completion rate. Improving the usability of their AIMS would improve completion rates and obviate or reduce the need for post-hoc control.

Developing Technologies

With this theme, authors explored aspects of improvement in AIMS to achieve goals envisioned by a pinnacle system (Anderson & Merry, 2015; Kohli & See-Lin Tan, 2016; Wilbanks, 2014). The aspects include the mechanical functions of AIMS, specifically the user interface (Avidan & Weissman, 2012; Lamer et al., 2015; Marian et al., 2016). Augmentation of clinical decision support, cost containment, reduction of medication errors, improved administrative function, and automated billing from AIMS all lag behind their potential (Anderson & Merry, 2015; Kohli & See-Lin Tan, 2016). Easy, fast, widespread integration of data between AIMS and same-hospital EMRs, and among the community of AIMS, providers,

hospitals, and healthcare systems likewise require further development. They have been demonstrated in trials, but their use is not yet widespread in the many various AIMS. Finally, a significant facet of the theme of developing technologies was universality. Both Anderson and Merry (2015) and Kohli and See-Lin Tan (2016) noted that the hoped-for uses of large electronic datasets would not come to fruition unless a standardized method of communication between the various AIMS, government and private, was perfected.

Knowledge Gap

Currently, there is no standard across anesthesia records, much less all electronic medical records. A contemporary example of this problem is the difficulty experienced by the Veterans Administration health care system merging their records with those in the Department of Defense. Although ordered by Congress to complete the task years ago (Panangala & Jansen, 2013), it remains incomplete as of this writing, although a stopgap measure is in the process of being implemented. The International Organization for Terminology in Anesthesia, in cooperation with the International Health Terminology Standards Development Organisation and other entities, are at work to develop this common language (Hurrell et al., 2012). However, accuracy and completeness will likely suffer until this is perfected and adopted.

Evidence-based strategies

Although the premise of the Fort Benning project was not supported – at least in the low number of cases reviewed – by evidence with statistical significance, the review of literature on the subject of accuracy of electronic anesthesia records did reveal multiple strategies that are, or should be, undertaken by the community for improvement. Some of these strategies are as follows.

System-to-system communication. One of the hurdles described is the technical challenge of communication between systems with different file structures. Hurrell et al. (2012) described a technique already in common internet communication, called extensible markup language (XML). A prototype of such AIMS information sharing was a key demonstration by Walsh, Hurrell, Wu, Tomeh, and Monk (2009) using XML to send intraoperative data to the National Surgical Quality Improvement Program (NSQIP). These researchers developed an XML protocol to translate AIMS records into a file readable by another system. Additionally, to ensure validity of the information, they used nomenclature developed with EHR interoperability as a goal, including HL7 and SNOMED CT.

The Walsh et al. (2009) group succeeded in using XML to communicate accurately the anesthesia record data as intended, a strategy known as a “middleware” interface between systems. Anesthesiologist and informatics researcher Donald Voltz expressed hope that such interfaces would speed the pace of interoperability development. “No one is going to develop for 75 different EHR platforms when they come out with some sort of idea,” said Voltz. “But instead if we can develop into a system that then has its fingers or tentacles into all the different EHRs, then ... I’m accessing the patient data that I need” (Murphy, 2015).

While XML allows systems to talk in a common format, it lacks the common dictionary of healthcare-associated terms that would make it a complete solution for interoperability problems (Hurrell et al., 2012). Development of such a standard is underway with the HL7 clinical document architecture (CDA). Among other things, a CDA is a structure of common terminology that could be used in an XML information transfer between systems. This weakness leads into the second strategy for improving interoperability.

Person-to-person communication. Hurrell et al. (2012) described the use of the CDA as a method of improving interoperability. Again, a prototype was described (Hirai, 2009), which Hurrell and colleagues said was functional. The CDA file includes both person- and computer-readable and writable sections. They said the ability to restrict the content to a particular vocabulary suited it for use as an interoperability tool. However, it did not eliminate the possibility that the information might not be interpreted differently by different providers (Hurrell et al., 2012).

For this reason, Hurrell et al. (2012) described efforts by anesthesia providers and information technology experts to develop an overall anesthesia dictionary of terms. This would, theoretically, solve the problem of semantic interoperability. The IOTA group, among others, used online submissions to augment the SNOMED CT database of terms. Submissions included descriptions of processes and cases in anesthesia. Of importance was the inclusion of medical equipment communication standards, which would enable correlation of data for the same parameter that might differ between devices. The result was more than 5,000 anesthesia terms, processes, equipment, drugs, and other information brought into the previously anesthesia-generic SNOMED CT system.

The significance of this, according to Hurrell et al. (2012), was the change in the use of the middleware interface. Although the XML interface allowed file systems to exchange information, each system-to-system connection had to include an agreed-upon standard vocabulary. This had to be performed for each such interface in order for the information to be valid between the parties. With the development of an international standard, that vocabulary was already established. However, according to Kohli and See-Lin Tan (2016), the difficulty lies in bringing together all of the many different standards, both public and proprietary.

Furthermore, individual settings often have differing institutional priorities. When achieved, Hurrell et al. (2012) wrote, this would encompass semantic standards for anesthesia terminology and, importantly, physiological data shared between different medical devices.

Maintaining information infrastructure in a complex system. Because the healthcare information sector is complex, often proprietary, and comprised of both private and government efforts, the integration of systems still lags behind available technology, as Kohli and See-Lin Tan (2016) stated. Further, in a system as complex as healthcare, new developments ensure a constantly changing environment (Braa, Hanseth, Heywood, Woinshet, & Shaw, 2009). The theory to develop and maintain an information infrastructure in developing countries was also proposed as a strategy to face the complexity of health IT in developed countries. According to Braa and colleagues, the flexible standards system they described would apply, using complexity science as a theoretical underpinning. These researchers used complexity theory to develop a solution to their particular problem in electronic records. They proposed that their techniques and use of theory could be more broadly used.

Complexity theory. Kohli and See-Lin Tan (2016) described the flexible standard as allowing individual institutions or systems to maintain their own information infrastructure, but interface with others using middleware software. In this way, organizations could maintain their own nomenclature, and decide in which way they would adapt to wider standards. Braa et al. (2009) said complexity theory describes this as allowing standards, an information order, to emerge from below, rather than be dictated from top down in a way that might or might not fit the information standards of the lower echelons. In this way, standards would slowly evolve from below to be adopted, if appropriate, among a wider audience of systems. Braa and colleagues noted that intricate information networks will develop order, and that their differences

will mean that they work to develop common networks between each other and the wider information world, to evolve and adapt.

Developing an infrastructure from scratch. A concrete example of this theoretical system was described in the healthcare system of South Africa (Braa et al., 2009), which had (during apartheid) 17 health systems divided by racial and ethnic tribal black South Africa areas. Healthcare information standards were equally diverse and not interoperable. With democracy, a standard for health data became a political goal. To begin, two regions cooperated on a basic set of health data set, while the overseeing organization developed a software application to administer that data set. The problem, not just in South Africa, was that each system had different requirements. Also, each system had different, autonomous administrators and these had to permit admission of the new standards to their facilities. Braa and colleagues explained that the method around these problems was twofold. First, acknowledgement that there would never be 100-percent agreement allowed the participants to settle on at least a minimal set of standards that were acceptable to all. Secondly, each individual system was free to augment their data sets with as much additional information as they required. The authors said this hierarchy of standards was the key element of the South Africa standardization process.

After developing a basic set of 47 agreed-upon pieces of data, the set was successfully expanded for use in all of the regions and systems. Braa et al. (2009) said its success was partly because it was the first universal data set available to all in the system, which was an advantage for all to be able communicate information, at least at that very basic level. Also, the software application developed by the government health service provided a common system for working with the data set. It enabled local users to manage their own healthcare systems, which had previously not been available.

Complexity theory attractors and indicators. Subsequently, as black South Africa districts were developing this basic set, two white South Africa health systems were brought in, making the beginnings of the first national healthcare data set (Braa et al., 2009). These four startup programs became, in the language of complexity theory, *attractors*. Other districts, observing the successful example of gathering, disseminating, and using the new data sets for healthcare analytics for the first time, overcame resistance to participation. The attraction of at least a minimal information package, using common vocabulary, and having a common software system for analysis supported an administrative need. Three years after initiation, in June 2000, South Africa established a national data set of essential elements, and by 2005 included *indicators*, such as nationwide immunization rates, which are drawn from multiple data elements. All of the participants still maintained their own sets, expanded as fit their needs, but all gave the government at least those basic elements to be shared. Additional elements have since been developed and added.

Braa et al. (2009) said the constant debate over indicators in the national indicator dataset (NIDS) continues and, in fact, stimulates further change. An important facet of flexible standardization is that there is never a finished data set. Also, the common software tool simplifies information handling for the participants, making changes easier to develop and implement. Development of middleware, also called gateway, software has further supported expansion and adaptability of the data sets.

These three key studies – Walsh et al. (2009), Hurrell et al. (2012), and Braa et al. (2009) – outlined strategies to achieve interoperability, which means that the various different electronic medical record systems can communicate with each other. Walsh and colleagues' classic prototype AIMS communication standard proved that the technology already existed in 2009 to

accomplish interoperability, although the common vocabulary did not. Hurrell and colleagues described initial development of datasets for semantic interoperability as a basis for growth. Braa and colleagues described how a basic set of elements could become an information entity with the ability to evolve and adapt. But, they noted that the system change in the South African example was stimulated by a political shock with the fall of apartheid. Whether the elevation of user expectations for AIMS, and EHRs generally, described by Kohli and See-Lin Tan (2016) remains to be seen.

The question of accuracy of records cannot be separated from the question of completeness of records. Wilbanks (2014) noted one common usage of the terms to be “*accuracy* is the correctness of data, and *completeness* is the presence of data (2014, p. 56).” For this project, the theme of *correctness* included the topics *accuracy* and *completeness*, a slight variation of Wilbanks’ usage. The project hypothesis is that greater provider computer experience will make them more likely to change the preprogrammed chart for accuracy in timing, for example, and to add (or remove) events to reflect the actual events of the case. In December 2010, all Department of Defense (Army, Navy/Marine Corps, Air Force, and others) anesthesia departments began a mandated rollout of the Innovian Anesthesia AIMS software by Draeger Medical, Inc. For most providers at the Fort Benning institution, this was their first use of an AIMS.

Regarding the project hypothesis, several studies addressed AIMS usage. In related studies, Deshur and Levine (2015) theorized that providers’ comfort level with computers influenced the level of distraction caused by the anesthesia information management system (AIMS). Peterfreund et al. (2011) attributed their 92% increase in documentation of outcome events with use of AIMS, in part, to the relative youth and familiarity with technology in their

studied group of providers. Driscoll, Columbia, and Peterfreund (2007) attributed incomplete charting with AIMS to dependence upon free-text entries, something that preprogrammed templates are intended to avoid (but are not able to avoid with the Innovian system – free text is required). As early as 1997, one study (Gibby) identified a requirement that outcomes, events, and other data be standardized or accurate outcome studies, and risk/cost versus benefit analyses would not be possible. Sockolow, Weiner, Bowles, and Lehmann (2011) noted user satisfaction with new EMRs improved usage.

Wilbanks et al. (2013) identified several areas with common inaccuracies in AIMS. Among these was use of preprogrammed templates to chart events before they occur, intended to prompt anesthesia providers to enter all of the necessary events for a particular case. These investigators noted that use of the templates greatly increased the completeness of the AIMS charting, but created sources of inaccuracies (such as with time stamps and content). This evidence is the same as the thought process that began this process improvement project.

Method

The Innovian system at the Army community hospital on Fort Benning, Georgia, is integrated with six Draeger Apollo and two Draeger Fabius Tiro anesthesia machines and Philips Intellivue vital signs monitors. It is not integrated with other EMRs in use at that facility for charting outside of the anesthesia department. It is only accessible by the anesthesia service and, in a read-only mode, by any user with access to the finished anesthesia case files loaded into the general-use EMR (Essentris) at the end of each case. When the network is functioning, the cases are saved to a central database. When the network is down, cases are saved on the individual anesthesia workstations, then uploaded to the database when the network is reestablished. The Innovian AIMS workstations are located in all (six) main operating rooms, the labor and delivery

OR, urology OR, and one in the PACU for post-case charting and uploading the files to the Essentris EMR. The AIMS is not used in the endoscopy suite, interventional radiology, or other areas outside of the OR.

Standardized templates were developed from several hundred sample templates provided in January 2011 from the DoD testing facility, a naval station. At Fort Benning, a volunteer group of four CRNAs and anesthesiologists developed guidelines for the templates (“environments”) loaded into each case, pairing down to half a dozen, which were analyzed in this project. These were a an automatically loaded global template (which loaded items common to all cases), and one each loaded as appropriate by the provider for general endotracheal anesthesia, general with a laryngeal mask airway, caesarean section, pediatric general, or monitored anesthesia care. Each contained items and events thought likely to be used during one particular type of case. Excess items (drug entries and events) were intended to be deleted. Incorrect items were intended to be altered to fit each case. This was the basis for this project – were providers altering the templates to make their records reflect reality, and who was most likely to do so?

Participants

The database in the Fort Benning Army hospital provided a convenience sample of anesthesia providers who had used the system since installation of the AIMS in 2011. Most providers in the database had already transferred to other facilities, as is common in military service. Those currently working on Fort Benning, and those who still had an e-mail address in the DoD global contacts database were sent a recruitment letter explaining the project, a consent form explaining the project, and a survey developed to measure satisfaction with an EMR (Sockolow et al., 2011), altered with permission of the author. Of those, 17 returned the survey

and signed consent. Only one did not meet inclusion criteria because he had only 10 cases in the database. The author's cases were excluded from data analysis, although they were analyzed first to help develop the workflow for the data collection tool. This yielded a pool of 518 cases for analysis.

Of the 16 participants analyzed, they ranged in age from 32 to 63, 11 were male, and 12 were CRNAs. One had 30 years' experience with EMRs outside of Innovian, and one had 14 years' work with other AIMS; the rest of the providers had experience only with Innovian. Most, save two, had five years or less experience with Innovian. For 81 percent of the participants', their experience in anesthesia was eight years or less. Their self-rated computer knowledge was "average" for eight, "below average" for seven, and "above average" for one.

Design

A minimum of 30 cases were analyzed for each of 16 anesthesia providers in a retrospective records review. Participants completed a 23-question survey to assess their level of satisfaction with their use of the AIMS. The survey included demographic questions of birth year, gender, job title (CRNA or anesthesiologist), years of experience with AIMS other than Innovian (if any), years of experience with the Innovian AIMS, years of anesthesia work experience, and self-rated computer knowledge (minimal to advanced). The 23rd question was a free-text question, *What worked well or what are your concerns related to the system?* The 22 primary survey questions were answered on a Likert scale from *Strongly/moderately/mildly disagree* to *Strongly/moderately/mildly agree* with no neutral point. Per Sockolow et al. (2011), the survey evaluates provider opinions of EMR quality of design, logistics of data, processes, effects on quality of care, tangential effects, and the adoption process.

The Pearson product moment correlation was used to compare dependent, continuous variable of the count of total events changed with continuous, independent variables age, years of Innovian experience, years of AIMS experience, and years of anesthesia experience. The assumptions of the data for this parametric test included continuous variables, lack of outlying data points to skew findings, and a linear relationship (called “homoscedasticity”) (Statistics Solutions, 2016). The latter two assumptions could be considered, but not assumed true until data collection revealed the nature of the data.

Spearman’s Rank-Order correlation was used to compare the dependent continuous variable of the count of total events changed with the nominal and ordinal level in independent variables gender, job type, and self-rated computer knowledge (on a Likert scale). Assumptions of Spearman’s test variables include data on at least the ordinal level (Laerd Statistics, 2013). It is assumed that the relationship between the two variables compared increases and decreases in conjunction with each other. These assumptions seemed appropriate for the Likert variable of self-rated computer knowledge, but were not fulfilled for the nominal variables gender and job type, which were not central to the hypothesis.

Data Collection

The primary investigator began each review of a provider’s cases by recording the demographic information into an Excel spreadsheet, coded by the participant research identification number. Using the Innovian *Case Manager* application, the database was examined for the total number of cases the provider had conducted. Using the Innovian *Recorder* application, a picklist of cases was developed to exclude all since the date the provider was informed of the project and signed the consent. The first case encountered with that provider’s name in the staffing list was selected and examined to establish that they were the sole anesthesia

provider for that case, excluding short breaks. If so, the event summary for the entire case was examined for time entered, and whether content was changed. This summary was compared to the template of preprogrammed events for that environment (e.g., *Surgical time-out, SAB placed, Estimated blood loss, No untoward anesthesia outcomes noted for case, IV antibiotic prophylaxis administered*). If there was a difference in time or content, or both, a tick mark was made for each on the data collection sheet for that event. The tick mark was either vertical (“Yes”) or horizontal (“No”), in order to track that the number of tick marks matched the number of cases counted. After all of the events for that case were recorded, the record was closed and the picklist reopened to find that provider’s next case, or a random case by that provider. Each event of each of 518 cases (31 to 33 cases were counted for most providers) was documented in this manner. After recording each provider’s case-event changes, the totals were entered in an Excel spreadsheet. To complete data collection, all of the information – survey answers, demographics, case total, event totals – were transferred to SPSS version 24 for analysis. Totals of events were derived from the ratio of changed items-to-total events examined. Percentages of those changed totals were calculated for each provider, and for all providers as a whole.

Results

Survey of provider satisfaction with EMR

Anesthesia providers were generally positive about the Innovian AIMS EMR, reflected by most answers of *mildly-* to *strongly-agree* for questions framed in a positive manner. They felt Innovian was generally available, supported, and user friendly. It helped them in their work, was accurate, and contributed to patient safety. They felt it was worth the effort to learn to use, and that clinicians were satisfied with it.

Further, they generally answered *mildly-* to *strongly-disagree* for questions framed in the negative manner. These indicated that these anesthesia providers generally disagreed with statements that the system had frequent problems, patients had confidentiality concerns about it, the provider knew specifically that patient care had been negatively affected by its use, and that part of increasing healthcare costs were because of computers.

Test of the hypothesis

There were no significant correlations noted between the independent variables (age, gender, job title – CRNA or anesthesiologist – years of experience with AIMS software other than Innovian, years of experience with the Innovian AIMS, years of anesthesia work experience, and self-rated computer knowledge – minimal to advanced) and the number of events altered (Figures 1 and 2). Measurement using Pearson's r showed no correlation between the number of events altered (dependent variable) and any of the independent variables closer to significance than $p = .09$ level. The independent variables (Figure 1) were age ($p = .629$), experience with AIMS other than Innovian ($p = .09$), experience with Innovian AIMS ($p = .802$), and years of experience in anesthesia ($p = .973$). The hypothesis, that more experienced software and computer users would be more likely to change automated entries, was not statistically significant. There was a significant correlation ($r = .814$, $p < .001$) between independent variables *Age* and *ExpAnes* (years of experience working in anesthesia), as would be expected.

Most providers changed a limited number of key events from their pre-programmed settings, while others were infrequently or never changed (Figure 3). The data collection sheet included 70 events included in all of the pre-programmed templates. With a minimum of 30 cases analyzed per providers, a theoretical maximum of 2,100 events could be altered. The

number of events altered by the 16 providers participating ranged from a low of 238 to a high of 580, with a mean of 345.75.

The most commonly altered events are listed in Table 1. The percentages listed indicated the frequency with which anesthesia providers altered these events from their pre-programmed values for each template. The number of cases recorded of each template is listed, as is the number of events changed that generated the percentage listed. For example, 518 cases were review, thus all of these had all of the events from the *Global* template. However, only 46 cases of c/sections were reviewed, and 11 pediatric general anesthetic templates recorded. Thus, the percentage frequencies for altered events that were particular to these templates are based upon a much lower number of cases reviewed. The number of each type of template reviewed is recorded next to the percentage-changed listing.

Table 1

Template Events Changed

Event changed	Percentage of total altered	Template	# of cases, actual	# of cases, template
Baby delivered, time	99.2%	c/s	45	46
APGAR, 5-minute, time	96.6%	c/s	44	46
APGAR, 5-minute, value	96.6%	c/s	44	46
APGAR, 1-minute, time	96.6%	c/s	44	46
APGAR, 1-minute, value	96.6%	c/s	44	46
Spinal, in place, time	94.3%	c/s	43	46
Spinal, in place, note	94.3%	c/s	43	46
Antibiotics administered, type	93.4%	Global	484	518
IV in situ, time (Pedi GA)	92.9%	Pedi GA	10	11
IV in situ, type (Pedi GA)	92.9%	Pedi GA	10	11
Manual vitals, immediate postop, entry	90.7%	Global	470	518
Urine output, amounts	90.4%	Global	468	518
Uterine incision, time	90.4%	c/s	42	46
Oxygen administered, flow rate (MAC)	90.0%	MAC	38	42
Estimated blood loss, amounts	89.4%	Global	463	518
Oxygen administered, time (c/s)	84.0%	c/s	39	46
Oxygen administered, flow rate (c/s)	84.0%	c/s	39	46
Antibiotics administered, time	82.0%	Global	425	518
IV placed, time (MAC)	82.0%	MAC	34	42
IV placed, note (MAC)	82.0%	MAC	34	42
Pitocin, time administered	81.0%	c/s	37	46
Pitocin, amount added to bag	81.0%	c/s	37	46
Oxygen administered, time (MAC)	80.3%	MAC	34	42
Epidural, in place, time	80.1%	c/s	37	46
Epidural, in place, note	80.1%	c/s	37	46
IV placed, time (Pedi GA)	78.6%	Pedi GA	9	11
IV placed, note (Pedi GA)	78.6%	Pedi GA	9	11
IV in situ, type (Global)	72.3%	Global	375	518
Turnover to surgeon, time	71.3%	Global	369	518
Manual vitals, immediate postop, time	63.6%	Global	329	518
Estimated blood loss, times	61.9%	Global	321	518
LMA placed, time	60.5%	LMA GA	114	188
LMA placed, note	59.7%	LMA GA	112	188
LMA removed, time	56.5%	LMA GA	106	188
LMA removed, note	55.7%	LMA GA	105	188
Urine output, times	49.9%	Global	258	518
Foley catheter placement, time	45.2%	c/s	21	46
Placenta delivered, time	44.6%	c/s	21	46
Platelet count noted, value	44.5%	c/s	20	46
Allis test, note	38.7%	c/s	18	46

Event changed	Percentage of total altered	Template	# of cases, actual	# of cases, template
Surgical timeout, time	30.6%	Global	159	518
Temperature measured, values	29.8%	c/s	14	46
IV in situ, time (Global)	19.2%	Global	99	518
Airway suctioned before extubation, time (Pedi GA) ¹	16.7%	Pedi GA	2	11
Patient makes purposeful movement, note (Pedi GA) ¹	16.7%	Pedi GA	2	11
Bite block inserted before extubation, time (Pedi GA) ¹	16.7%	Pedi GA	2	11
Allis test, time	10.1%	c/s	5	46
Bite block inserted before extubation, type (Pedi GA) ¹	9.5%	Pedi GA	1	11
Airway suctioned before extubation, time (GA)	5.9%	GA	14	231
Bite block inserted before extubation, type (GA)	3.9%	GA	9	231
Bite block inserted before extubation, time (GA)	3.6%	GA	8	231
Anesthesia start, time	3.1%	Global	16	518
Patient makes purposeful movement, note (GA)	2.7%	GA	6	231
Anesthesia end, time	2.1%	Global	11	518
Patient spontaneously breathing, time	1.3%	Global	7	518
Anesthesia start, note	0.8%	Global	4	518
Patient makes purposeful movement, note	0.8%	LMA GA	2	188
Surgical timeout, note	0.6%	Global	3	518
Regional block assessed prior to incision, time	0.6%	c/s	0	46
Outcome occurrence, time	0.4%	Global	2	518
Outcome occurrence, note	0.2%	Global	1	518
Airway suctioned before extubation, time (c/s) ¹	0.0%	c/s	0	46
Patient makes purposeful movement, note (c/s) ¹	0.0%	c/s	0	46
Bite block inserted before extubation, time (c/s) ¹	0.0%	c/s	0	46
Bite block inserted before extubation, type (c/s) ¹	0.0%	c/s	0	46
Regional block assessed prior to incision, note	0.0%	c/s	0	46
Patient makes purposeful movement, note (MAC) ¹	0.0%	MAC	0	42
Bite block inserted before extubation, time (MAC) ¹	0.0%	MAC	0	42
Bite block inserted before extubation, type (MAC) ¹	0.0%	MAC	0	42
Airway suctioned before extubation, time (MAC) ¹	0.0%	MAC	0	42

Note: *Global* template events are entered into all cases. Listed also are pre-programmed events from the user-selectable templates. These are automatically entered into anesthesia charts depending upon while template is selected. Events are listed in descending order of those most frequently altered of all providers' entries, as a percentage of total cases for each template. Superscript notation ¹ indicates entries for general endotracheal anesthesia (purposeful movement, bite block usage, airway suctioning) in cases that would not typically involve GETA (c/section, MAC, or Pedi GA with a facemask anesthetic), which were included on the templates

to facilitate charting if such cases had to be converted to GETA. No such case conversions were noted during data collection.

		Age	ExpOutsideAIMSYears	ExpInnovianAIMS	ExpAnes	TotalEventsCount
Age	Pearson Correlation	1	.319	.086	.864**	-.131
	Sig. (2-tailed)		.228	.752	.000	.629
	N	16	16	16	16	16
ExpOutsideAIMSYears	Pearson Correlation	.319	1	-.272	.448	.438
	Sig. (2-tailed)	.228		.309	.082	.090
	N	16	16	16	16	16
ExpInnovianAIMS	Pearson Correlation	.086	-.272	1	-.105	-.068
	Sig. (2-tailed)	.752	.309		.699	.802
	N	16	16	16	16	16
ExpAnes	Pearson Correlation	.864**	.448	-.105	1	-.009
	Sig. (2-tailed)	.000	.082	.699		.973
	N	16	16	16	16	16
TotalEventsCount	Pearson Correlation	-.131	.438	-.068	-.009	1
	Sig. (2-tailed)	.629	.090	.802	.973	
	N	16	16	16	16	16

** . Correlation is significant at the 0.01 level (2-tailed).

Figure 1. Correlation significance table showing relationship between dependent variable (*TotalEventsCount*) and ratio-level independent variables (*Age*, *ExpOutsideAIMSYears*, *ExpInnovianAIMS*, *ExpAnes*). The only significant correlation was between anesthesia providers' age and their years of anesthesia experience (*ExpAnes*). Pearson's *r* test was used to analyze correlation between the parametric variables (Polit & Beck, 2012).

			TotalEventsC ount	Gender	Job	Self-rated computer knowledge
Spearman's rho	TotalEventsCount	Correlation Coefficient	1.000	.132	.125	.193
		Sig. (2-tailed)	.	.627	.644	.474
		N	16	16	16	16
	Gender	Correlation Coefficient	.132	1.000	.234	-.246
		Sig. (2-tailed)	.627	.	.384	.358
		N	16	16	16	16
	Job	Correlation Coefficient	.125	.234	1.000	.053
		Sig. (2-tailed)	.644	.384	.	.846
		N	16	16	16	16
	Self-rated computer knowledge	Correlation Coefficient	.193	-.246	.053	1.000
		Sig. (2-tailed)	.474	.358	.846	.
		N	16	16	16	16

Figure 2. Correlation significance table showing relationship between dependent variable (*TotalEventsCount*) and nominal/ordinal-level variables (*Gender, Job, Self-rated computer knowledge*). There were no significant correlations. Spearman's *rho* test was used to analyze correlation between the non-parametric variables (Polit & Beck, 2012).

Frequency distribution

Analysis of frequency distribution revealed some providers changed a limited number of key events from their pre-programmed settings (Figure 2). Specifically, more than 50 percent of the time providers changed the pre-programmed settings of the events: *IV in situ* (content), *TOTS* [Turned Over To Surgeon, a data point particular to military operating rooms] (time), *Intravenous perioperative antibiotics (Med, Dose / Declined)* (time and content), *Manual vital signs* [the institution's event for an immediately postoperative anesthesia note, entered in the PACU] (time and content), *Estimated blood loss* (time and content), *Urine output* (time and content), among others (Table 1; Figure 3). Providers altered the setting of the surgical "time out" safety pause about 30 percent of the time, from the programmed one minute prior to start of surgery setting, to the time it actually occurred during that case. About one in five providers altered the programmed time and content of laryngeal mask airway notes to remove the "[endotracheal tube] intubation" notation and leave the "supraglottic airway" event. Changes to other events occurred less than 10 percent of the time. Several events were never altered by providers, or altered so rarely as to be likely an anomalous occurrence or mistake.

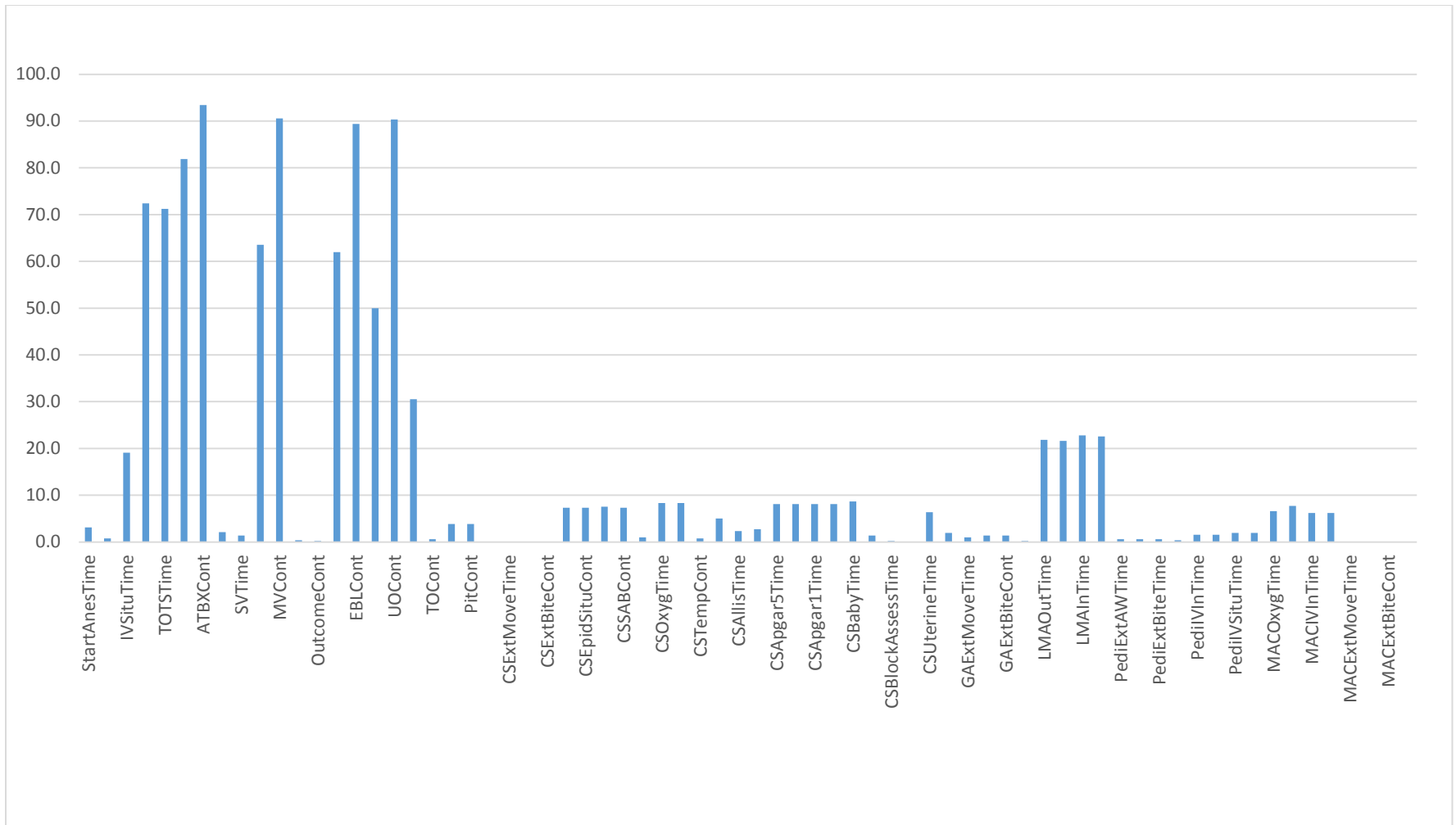


Figure 3. Events changed by providers as a percentage of cases counted. Percentages are on the y-axis. Events changed are on the x-axis.

Discussion

Current information on the accuracy of electronic anesthesia records is that, generally, they are more accurate than handwritten records, although methods to ensure complete and correct records are evolving, and further research is necessary. Because voluntary, manual reporting of critical incidents and outcomes lags behind in completeness, some sort of secondary audit is probably necessary (Anderson & Merry, 2015; Simpao et al., 2012). Furthermore, data from AIMS (and all EHRs) must be validated in order to be useful in outcomes research (Kadry, Feaster, Macario, & Ehrenfeld, 2012), because changing practice based upon incorrect data would be detrimental instead of helpful.

As noted in the survey results, Fort Benning providers tended to be positive about the accuracy and usability of their Innovian system. However, the results of the event counts show that providers tended to change only those events that were required (the antibiotic prophylaxis noted is mandated by the DoD), specific legal requirements (the “time out”), or anesthesia procedures, such as an intubation note. Stock events – those typically relegated to a checklist format on a paper form – were typically left in place. These included notations about the start of anesthesia care time, which is of importance in civilian-sector insurance billing, but less so in a military environment. Other items commonly left unchanged were automated charting of bite block insertion and airway suctioning prior to extubation.

Discussion with providers after data collection was completed yielded the idea that such items were not necessarily time critical, and therefore simply need to be in the chart, somewhere, as appropriate. Other items typically ignored or forgotten were documentation of outcomes, such as a laryngospasm. Critical events usually require all of the provider’s attention and energy, and charting is typically after-the-fact (Ehrenfeld et al., 2011). Frequently, this leads to a

reconstruction of the event from memory. In the case of Innovian and the DoD, outcome charting must be digitally signed by the provider. Signing a note requires calling up that menu item (at least one, possibly three mouse or key clicks), typing a prompt for the provider's name, and typing in a complex password of at least 16 digits, including upper and lower case characters, numbers, and special characters, which the DoD mandates be changed every 60 days. All of the requirements together, coupled with the patient-focused nature of the event, makes it unlikely that such charting is completed until after-the-fact.

The frequency distribution of events changed from the preprogrammed templates implies that providers as a professionally trained group place more importance on accurate charting of certain key events, than on keying standard entries usually relegated to a checklist on paper charts. The lack of distinction between age, experience, and practice implies that this importance is more of a standard in the community than a personal preference. One goal of presenting this hypothesis, regarding familiarity with computers, was the idea that electronic charting might be improved if provider felt comfortable in the digital environment. Several studies (Avidan & Weissman, 2012; Ehrenfeld et al., 2011; Simpao et al., 2012; Wilbanks et al., 2013) noted that, when comprehensive reporting of all events during an anesthetic was lacking, human error was primarily to blame. It was a premise of Avidan and Weissman (2012) that charting completeness was greatly improved by making data entry easier for the providers. This led to the question of: What if providers who were more facile with computers were better at charting electronically? It was this anecdotal observation that was the genesis for this project. During data collection, it was noted that some less computer savvy providers tended to chart these basics, and only these basics. However, because the overall pattern tended toward the same important events, and likely the low number of cases reviewed, there was no statistical distinction at this level. Wilbanks et

al. (2013) found near perfect compliance at 98.38 percent with providers charting according to the minimum requirement of the AANA standard by focusing on those minimum important standards. In that study, the primary source of inaccurate charting, at 45 percent, was altering the preprogrammed gas flows, which were not recorded by automation, to reflect reality. Again, at busy moments during a complex pediatric induction of anesthesia, providers perhaps had less (or felt they had less) time, and subsequently failed to return to the chart to correct their errors. In the Fort Benning project, automated templates ensured that all of the required data elements were on the chart, but could not ensure that the course of the anesthetic took place as specified, event by event, as it rests in the electronic record. To be fair, when paper charts are reconstructed after the fact, the same factors of memory, stress, and complexity would come into play (Shibutani, 1990). As suggested by (Ehrenfeld et al., 2011), many providers put aside charting in favor of focusing attention on the patient for some important activities.

The DoD attempts to standardize events in order to facilitate data mining of the large database generated by many facilities worldwide entering their cases into a common pool. Using a required item (such as for antibiotic prophylaxis or an outcome for reintubation of a surgical patient) would, theoretically, create a common label for these events, which could be referenced. However, the Innovian system still relies upon free-text comments for the details of these events. Further, the list of more than 500 events and outcomes is not searchable using context-sensitive terms, only by knowledge of the exact phrasing. Providers discussed this aspect of Innovian use, noting that they used only certain stock (preprogrammed by the template) events, and used free-text narrative comments for everything else. This defeats the intention of DoD to data mine these records and was, also, part of the reason for developing this project.

Ensuring validity of human-to-human transfer of information requires a common dictionary of definitions (Kohli & See-Lin Tan, 2016). Diagnoses, drug names, diseases, treatments, assessments – all medical terminology must have the same meaning for all participants in the system of standardization and sharing (Braa et al., 2009; Kohli & See-Lin Tan, 2016). Several standardization organizations have been developing the healthcare vocabulary for such communication, such as the Health Level Seven (HL7), which is used to import information from the surgical scheduling software each morning into the Innovian system.

Conclusion and Implications

Though the hypothesis of this particular project was not supported, research from the review of literature supports further development of AIMSs and EMRs to improve functionality, accuracy and completeness. A further pilot study of selected, clinically significant events, conducted with more providers and more cases (perhaps using automated, rather than manual, tallying for a more comprehensive analysis), and using more sensitive statistical tests, might yield significant correlation. A more important focus should be the development of more user-friendly, less time consuming graphical user interfaces (GUIs) – such as voice commands – to facilitate accurate, complete charting on electronic anesthesia records (Alapetite, 2008; Ehrenfeld et al., 2011). More research into usability, designs to facilitate better usability and completeness, examination of workflows and ergonomic processes required to enter data, and common processes and terminology to facilitate data sharing are necessary to advance this nascent field of medical informatics. The prospect of very large datasets could answer research questions previously too complex to address using randomized controlled trials or meta-analyses, and offer insight for improved quality control (Ehrenfeld, 2009; Hurrell et al., 2012). This opinion is supported by Anderson and Merry (2015); and Kohli and See-Lin Tan (2016). Lack of

completeness may invalidate the usefulness of these datasets in research. AIMS require more research in usability, design, workflows and ergonomics, and common terminology to facilitate data sharing. There is no standardized method to examine data quality (Weiskopf & Weng, 2013) or achieve interoperability between information systems (Hurrell et al., 2012; Kohli & See-Lin Tan, 2016). This lack will likely hinder further study of AIMS software. Furthermore, a lack of accuracy and completeness of these records calls into question their validity as a research tool (Anderson & Merry, 2015; Kohli & See-Lin Tan, 2016).

Three studies (Braa et al., 2009; Hurrell et al., 2012; Walsh et al., 2009) outline strategies to achieve AIMS EHR interoperability. The elements of interoperability described were system-to-system communication (syntactic), provider-to-provider communication (semantic), and flexible development of standardized data sets in an evolving healthcare environment. These strategies should be pursued by the healthcare informatics community and the industry that provides these products.

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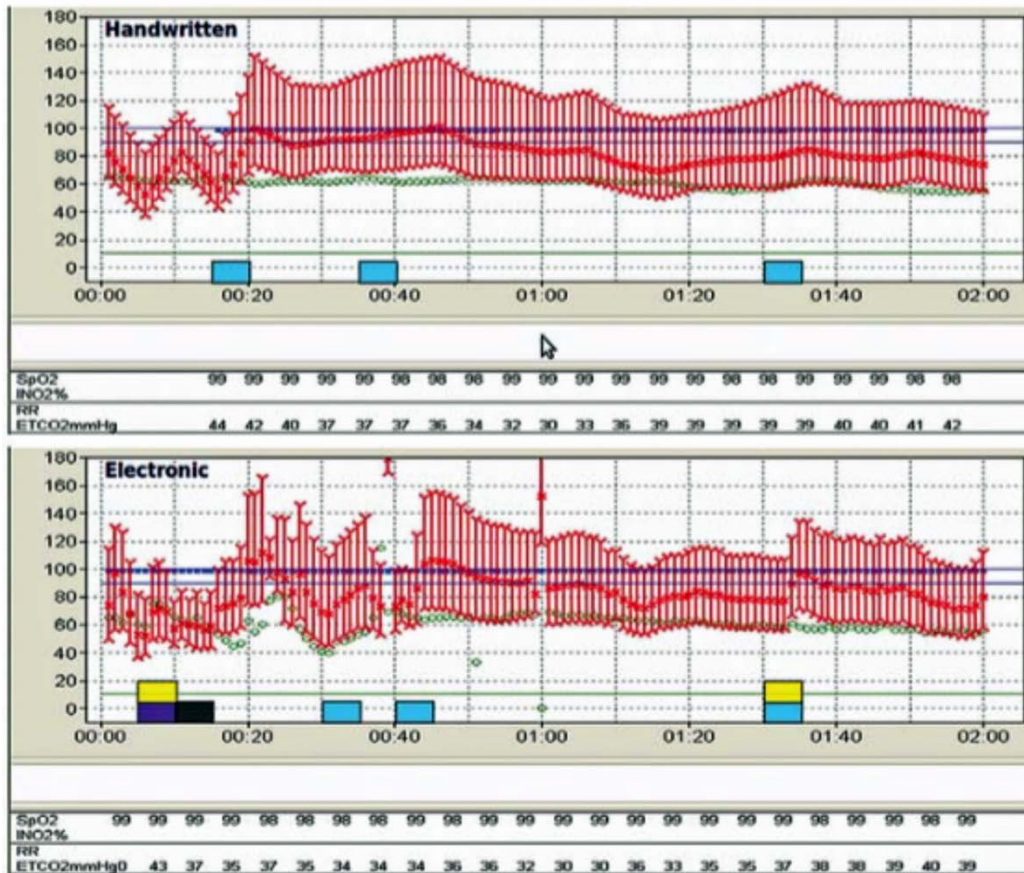
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Appendix



Comparison of physiologic variables charted in handwritten and electronic records (van Schalkwyk, Lowes, Frampton, & Merry, 2011).

IRB APPROVAL

Institutional Review Board for Human Use

Form 4: IRB Approval Form
 Identification and Certification of Research
 Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The Assurance number is FWA00005960 and it expires on January 24, 2017. The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56.

Principal Investigator: ZITZELBERGER, JOHN
 Co-Investigator(s): LOPEZ, FERNANDO
 Protocol Number: **X160120012**
 Protocol Title: *Correlation Between Provider Computer Experience and Accuracy of Electronic Anesthesia Charting - A Pilot Study and Performance Improvement Project*

The IRB reviewed and approved the above named project on 5-31-16. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.

IRB Approval Date: 5-31-16

Date IRB Approval Issued: 5-31-16

IRB Approval No Longer Valid On: 5-31-17

Expedited Reviewer

Member - Institutional Review Board
 for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.

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 HEADQUARTERS, DWIGHT DAVID EISENHOWER ARMY MEDICAL CENTER
 300 EAST HOSPITAL ROAD
 FORT GORDON, GEORGIA 30905-5650

Institutional Review Board (IRB) Notification

- a. Date: 31 May 16
- b. Principal Investigator: John Zitzelberger
- c. Project Title: Correlation between provider computer experience and accuracy of electronic anesthesia charting - A pilot study and performance improvement project (AIMSEMR)
- d. Project #: 1601008
- e. Project Risk Level: Minimal Risk (MR) IAW 32CFR219.102(i)
- f. IRB Review Level: Expedited IAW 32 CFR 219.110 Category(ies) 5 & 7
- g. Approval Period: 31 May 16 - 30 May 17
- h. Enrollment Limit: 30 Subjects
- i. Submission Type: Protocol (Application/Initial Review)
- j. IRB Action: Approved
- k. Effective Date: 31 May 16
- l. Informed Consent Process: Obtained and documented IAW 32CFR219.116(a)
- m. HIPAA Authorization: IAW 45CFR164.512(i)(1)(i)/DoD 6025.18R C7.9.1
 Psychotherapy Notes Authorization:
- n. Research Monitor (RM): Not Required
 (See RM appointment letter)
- o. Ombudsman: Not Required
 (See Ombudsman appointment letter)

Approved/acknowledged documents to support the project are:

- Protocol 5 Jan 16
- Site-Specific Protocol Addendum
- Informed Consent Form – Control Group
- Informed Consent Form – Experimental Group 15 May 16
- Informed Consent Form – Combined Control and Experimental Groups