II. ANESTHESIA INFORMATION MANAGEMENT SYSTEMS

HOW TO SELECT AN AIMS FOR OPTIMAL DATA SHARING

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The concept of automated anesthesia recordkeeping, initially proposed almost three decades ago has now evolved into the reality of the electronic anesthesia information management system (AIMS). Given the complexity of even routine physiological monitoring in contemporary surgical practice, only digital systems can collect the entire volume of perioperative patient information needed for surgical and critically ill patients. An AIMS automatically creates a clinical anesthesia record, generates specialized patient-specific reports for clinical care and billing, and builds an electronic database and searchable repository of physiological and demographic data.

An AIMS makes it possible for anesthesiologists and institutions to meet the increasing demands for legible, comprehensive, secure, and shareable perioperative clinical documents. The Joint Commission mandates that legible and retrievable records be maintained for every perioperative patient encounter. Compliance with this and other requirements becomes a large, often unmanageable burden if handwritten anesthetic records are used. In addition, an AIMS can

generate time-stamped confirmation of a physician's physical presence during clinical procedures, which appears to be an evolving requirement for physician compensation that cannot be met using traditional handwritten records.

General Considerations

An AIMS uses electronic connections between physiological monitoring devices, health system databases, and local input devices to collect, organize, display, archive, and retrieve perioperative surgical patient care information. The two basic components of an AIMS are an automated anesthesia record (AAR) and a perioperative database (PD). A comprehensive AIMS will also include a preanesthesia evaluation (PAE) system as well as the ability to generate an electronic data warehouse (EDW), in which accumulated data in the PD are stripped of federal Health Insurance Portability and Accountability Act (HIPAA)–designated patient identifiers and stored anonymously for clinical research and sharing with other institutions or professional organizations.

Despite the plethora of proprietary and custom software systems designed for this purpose, no universal or turn-key solution for electronic anesthesia record-keeping and perioperative information management exists that will meet every institution's needs. Each AIMS will be installed in a unique and complex physical and technological environment; thus, even an off-the-shelf AIMS, no matter how sophisticated and mature at the time of sale, will require reconfiguration and customization to be compatible with the customer's established administrative and clinical workflow. Therefore, to be successful, the AIMS implementation process must identify a designated clinical leader who can accurately anticipate the extent to

which the vendor's software must be modified to suit the users, as well as to what extent administrators and clinicians must be asked to change their workflow patterns to accommodate the capabilities, features, and limitations of the AIMS itself.

Hardware

AIMS hardware consists entirely of generic computer and network components that are widely available from multiple sources. Some institutions may prefer to purchase all AIMS hardware directly from their current suppliers to take advantage of existing preferred vendor discounts, while others may choose to have the AIMS vendor bundle the hardware, software, and installation into a single contractual implementation agreement. In either case, AIMS vendors must provide customers with detailed specifications regarding the system requirements for each hardware component: workstation and server processor power, memory, and storage capacity; supported display and input devices; and communication standards. These specifications will permit the institution to assume local technical support and to budget for and build an inventory of replacement parts for the inevitable wear and tear that will occur once the initial AIMS implementation has been successfully completed.

The estimated cost of workstation hardware will depend primarily on the number of clinical anesthetizing locations to be included in the AIMS and the number of administrative and billing workstations needed. Hardware costs also reflect the exact physical installation requirements, as determined during the vendor's hardware survey, for items such as mounting arms, brackets, uninterruptible power supplies, cables, and network routers. At every workstation location, it is essential to catalog precisely which monitoring equipment is in use, device data

output port availability and configurations, and proximity of electrical power and network connectivity. The existence of AIMS driver software (digital data interfaces) cannot be assumed but must be confirmed for every input device and physiological monitor to be used at each anesthetizing location. The servers that support the AIMS must be sized with regard to both computational speed and data storage to meet not only current clinical demands but also increases anticipated in the near future. Is a single server adequate, or will multiple servers be needed for testing, interface, database, and reporting functions? A process and schedule for PD backup must be established, and redundancy at the server level is essential to avoid AIMS downtime because both server software and hardware are subject to episodic upgrades, maintenance, and replacement.

Hardware requirements and costs will also reflect decisions regarding what procedures will be used in the preoperative and postoperative areas for completing the PAE and consultations, how and where anesthesia records will be opened, and how the completed record will be handled at time of case closure. How will surgical patients be identified, and how will their account numbers be confirmed? Are optical barcode scanners needed to read encoded patient wristbands? Are they supported by the AIMS? Which AIMS workstations will be used for reviewing anesthesia records prior to case closure and entering missing data elements prior to record closure? Is a paper copy of the final anesthesia record needed by those who provide postoperative nursing care or by the institution? If so, where will the printers be located, how many are needed, and who will maintain them? How and where will the anesthesia record closure and printing process be handled for patients who do not return to the postanesthesia care unit but are transported directly to the surgical care unit, medical care unit, or other nursing units in the hospital? Can some printers and workstations be shared locally or via a network, or are

dedicated standalone installations always required? These questions must be addressed and answered to realistically estimate hardware costs.

Mobile units, or computers on wheels (COWS), may be a good choice for off-site anesthetizing locations where the delivery of anesthetic care often moves from one procedure room to the next or where a fixed AIMS workstation is simply not practical. They also offer great flexibility if surgical outpatient receiving areas are used for both preoperative assessment and, later in the day, for postoperative recovery, facilitating bedside record completion and recording of vital signs at the time of transfer of care. However, COWS are considerably more expensive than fixed workstations and work reliably only with robust high-speed wireless network access to the AIMS server. A fleet of COWS is also subject to considerable physical abuse and should have secure off-hours storage; responsibility for physical maintenance and the recharging and replacement of battery packs should be defined during the planning phase. In addition, the configuration of printer locations can be problematic when COWS are used in many areas.

Software and Configuration

When correctly configured to accept the digital data output from physiological monitors and anesthesia equipment, the AAR component of an AIMS will reliably and consistently generate objective documentation of intraoperative physiological variables and anesthesia delivery system parameters as well as any entries made by anesthesia providers themselves. In addition to legible and structured documentation of the anesthetic procedure, an AIMS can provide useful data to the anesthesiologist at the workstation. Most AIMSs can be configured to

automatically retrieve laboratory results obtained prior to and during surgery. A fully implemented AIMS will facilitate the process of acquisition, storage, and retrieval of archived information. Combining current PAE data with prior intraoperative data and archived medical and surgical information will reduce the time required for subsequent preoperative evaluations.

In addition to these and other functions already described, an AIMS may meet additional specific institutional needs such as the ability to schedule surgical procedures, track perioperative patient flow, monitor the use of pharmaceuticals and disposable supplies, and standardize perioperative documentation, especially with regard to physician attestations and statements of regulatory compliance. Many AIMS products also include quality-related capabilities, such as alerting anesthesia providers to risk factors such as patient-specific adverse medication reactions, comorbidity warnings, and difficult intubation or providing time-stamped documentation of the patient safety time-out that has become a standard of care.

For clinician end users, the AIMS must generate an electronic signature suitable for billing and compliance documentation. In academic centers where the relationship between the anesthesia provider and the institution determines reimbursement, the AIMS should be configured to delineate and distinguish between the responsibilities of residents and attending anesthesiologists. To meet the varied needs of departmental researchers, administrators, the billing office, and financial personnel, multiple levels of access to the PD, EDW, and report-generating software are also preferred. A list of authorized users and their privileges should be automatically generated and easily maintained. Tracking usernames, passwords, and expiration dates should occur within the AIMS itself, unless the validity of log-on credentials is established with an active user directory or other institutional security privilege database.

Attestation statements of participation in resident teaching or supervision of medical procedures can be customized and reviewed by institutional regulatory compliance officers and configured to specifications by governmental and commercial payers. Compliance with Medicare billing rules also requires specific documentation by anesthesiologists working with certified registered nurse anesthetists or anesthesia assistants within the anesthesia care team model. Generating an electronic professional services report via an AIMS completely eliminates reliance on handwritten billing vouchers. Billing information can be transmitted electronically to the billing office immediately upon case closure, rather than a day or two after the procedure has been completed. An AIMS can be configured to alert anesthesiologists and billing personnel for missing or inadequately documented information in the anesthesia record.

Automated billing with an AIMS requires real-time data exchange with surgical scheduling software and the institution's admission, discharge, and transfer (ADT) system. This functionality must be established using a carefully designed data exchange interface engine. Interfaces or database integration may already exist within the AIMS, may be available from the vendor as an add-on module, or may require custom coding and testing. Most medical data streams use some variety of the industry-standard Health Level 7 (HL7) Clinical Document Architecture (CDA) format, but it is essential to test the accuracy and reliability of data transfer for each element needed in the AIMS. Each interface should be configured to filter data flow to receive only those elements relevant to anesthetic management, eg, which preoperative laboratory results should be displayed for each patient and for what time period prior to surgery. Interfaces for essential time-sensitive data should be configured to function in real time, transmitting new data to the AIMS whenever a transaction occurs. Because processor and

memory requirements for real-time data exchange are substantial, some preoperative data can be batch processed during off hours when there is excess server capacity.

Data Sharing and the Electronic Data Warehouse

Every AIMS builds a searchable PD using proprietary reporting tools, a user-configurable structured query language database manager, or third-party report generation software. Appropriate database structure and intuitive, flexible search and report capabilities facilitate analysis of the large volumes of data associated with perioperative clinical care. However, maintaining data integrity and protecting patient privacy must be priorities. HIPAA defines protected health information (PHI) as individually identifiable health information created or received by a health care provider or health plan that relates to the past, present, or future physical or mental health or condition of a patient. HIPAA restricts to whom and for what purposes PHI may be disclosed. PHI is included within the PD and used for both clinical patient care and billing purposes. An AIMS may improve HIPAA compliance by eliminating the risk of accidental PHI exposure inherent with paper-based anesthesia documents. This requires controlled access to the AIMS workstations and server and to the information stored in the AIMS PD through secure log-on procedures and electronic signatures for the AAR. Even with secure AIMS access, it is easy to generate reports to assess the incidence of specific adverse perioperative events and correlate them with surgical procedure, patient demographics, surgeon, or even individual anesthesia care providers. Best practice parameters can be established, and both individual and group compliance with these guidelines can then be monitored by routine analysis of the data in the AIMS PD.

Data-sharing constraints imposed by HIPAA are removed if the PHI elements are stripped away from the physiological data stored in the AIMS PD to create an EDW. Clinical research and outcomes studies using pooled deidentified data from multiple institutions are ideal uses of AIMS-generated EDWs. The statistical power of these studies is greatly enhanced if data from thousands, rather than hundreds, of anesthesia procedures can be exported to a third-party program for statistical analysis. The volume and accuracy of the data extracted by this process far exceed those that can be obtained by visually scanning handwritten records. Assessing and comparing anesthesia outcomes, however, require consensus regarding the clinical metrics that best reflect the quality of clinical care.

However, pooling clinical data may be problematic as long as descriptive terminology differs. Consequently, the standardization of anesthesia-related data elements was undertaken by the Anesthesia Patient Safety Foundation (APSF)–sponsored Data Dictionary Task Force (DDTF), subsequently adopted as an official extension group by the Systematized Nomenclature of Medicine (SNOMED) developed by the College of American Pathologists. The DDTF merged with a similar European initiative in 2003 to form the International Organization for Terminology in Anesthesia (IOTA). The Canadian Anaesthetists Society, the Society for Technology in Anesthesia, and the American Society of Anesthesiologists are represented within IOTA, which is now creating the Anesthesia Subset of terms in SNOMED for use in the US and UK. This international effort to generate a consensus regarding AIMS terminology and data format has also generated the Special Interest Group for the Generation of Anesthesia Standards.

AIMS MODULES

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AIMSs consist of several distinct modules. While some variation exists among systems, preoperative, intraoperative, and postoperative components are common to all AIMS. These three modules must interact as one seamless overall system, so ideally all three would be implemented together. If either budgets or time are constrained, however, it may be necessary to implement the modules individually. Although it may seem most natural to bring the modules on line sequentially (ie, first the preoperative component, then the intraoperative, followed by the postoperative module), when implementing them individually, expediency may dictate a different order.

For anesthesiologists, the key element of the AIMS is the intraoperative module. But, this module relies significantly on information that could, and should, be provided by the preoperative module. For example, one key function of the integrated system is to correctly identify the patient record with which the anesthesia information will be associated. This is best accomplished through a direct interface with either the ADT system or the surgical scheduling system. It is essential to avoid duplicate or incorrect patient identities before beginning an intraoperative anesthesia record. To correctly perform these functions and preserve continuity of

care, the preoperative module relies on information acquired from, or exchanged with, the electronic medical record (EMR) or the electronic health record.

In addition to interfaces with the preoperative module, interoperative modules depend on multiple interfaces with anesthesia and monitoring equipment, including the anesthesia machine, physiologic monitors (eg, electrocardiogram, blood pressure, pulse oximetry, CO_2 and other end-tidal gas monitors, etc), and other operating room equipment. Ideally the intraoperative module should also be able to receive data from the hospital laboratory, blood bank, and other departments. Because it is likely that the various pieces of equipment are from different manufacturers, it may be challenging to establish communication and information exchange protocols, but these are essential to ensuring successful implementation.

The postoperative module performs several important functions, including producing a summary of the intraoperative events, generating a report to the preexisting EMR, transmitting information to other hospital units to facilitate postoperative patient care, and providing details for anesthesia billing. The intraoperative module does not usually communicate directly with outside systems, leaving those functions to the postoperative module. Thus, it is advantageous to implement the postoperative module at the same time as the intraoperative.

When planning the order of implementation for the AIMS modules, one must take into consideration what systems are already in place and how well those systems can be interfaced. A standalone preoperative component is not nearly as effective as one with inputs from the patient's existing medical records. One the other hand, trying to run an intraoperative system without an operating preoperative piece requires much more manual entry at the beginning of the anesthetic case. The postoperative module is of little use without information from the

intraoperative system. When fully implemented, information from all of the modules should feed quality improvement and pay for performance monitoring systems.

The points of integration among AIMS modules and of the AIMS as a whole into the broader medical record system can be seen in Figure II-3.

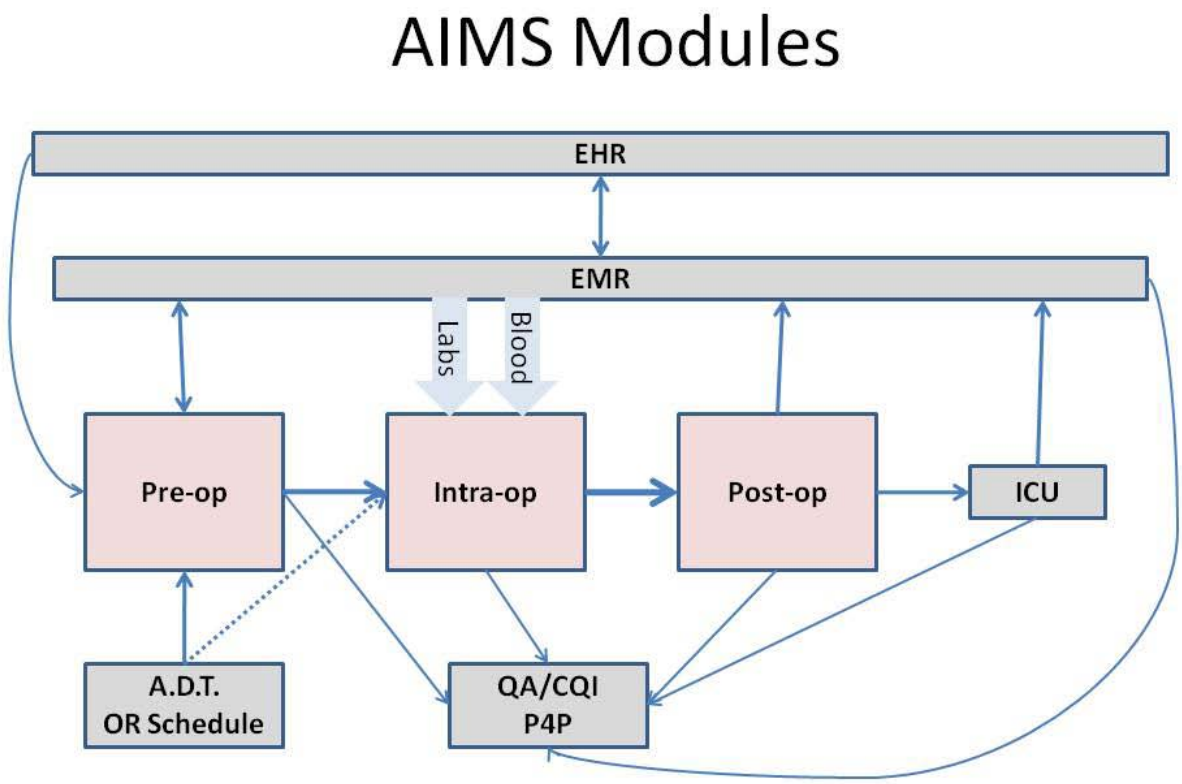

Figure II-1. Depiction of AIMS Modules with flow of data from external data sources.

INTEROPERABILITY

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One advantage of having an information management system is discovering that a plethora of people cannot live without your data; the downside is that every request for data requires the time and effort to query your system for the requested information or to build an interface between your system and the receiving system for intermittent or continuous data transmission as depicted in Figure II-2.

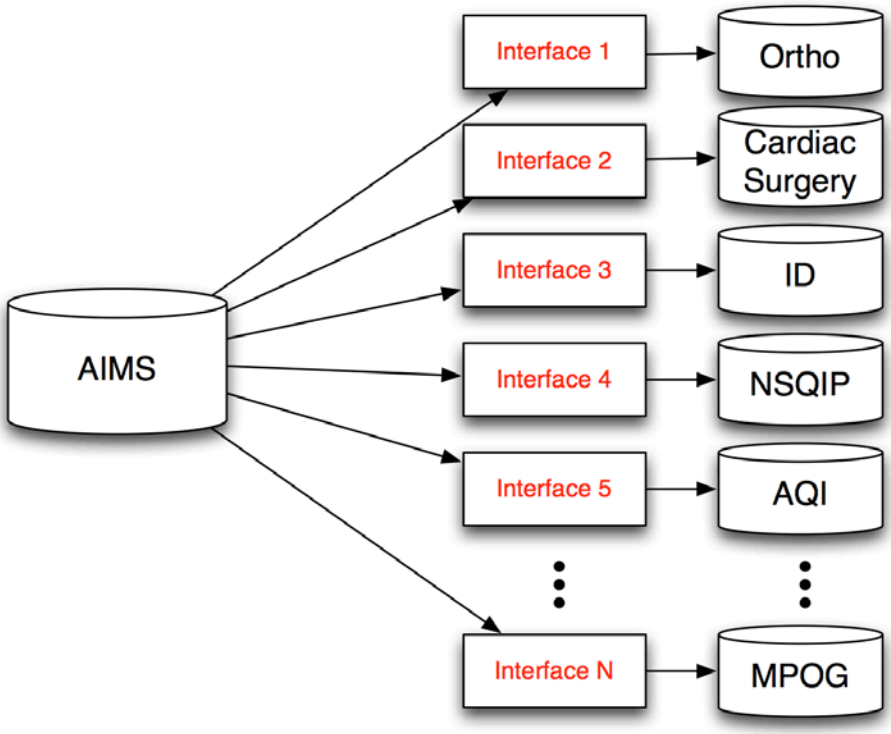

Figure II-2. The naïve way of interfacing an AIMS to data recipients. This solution requires writing an interface between the AIMS and each recipient. The recipients in this figure are representative of departments or organizations that might request the data: Ortho (Orthopedics), Cardiac Surgery, ID (Infectious Diseases), NSQIP (National Surgical Quality Improvement Program), AQI (Anesthesia Quality Institute), and MPOG (Multicenter Perioperative Outcomes Group).

At first glance, creating these interfaces appears to be a good investment of time for a great return (eg, earning goodwill points as a team player or collaborating on research projects with other centers). However, with time and the creation of an ever-increasing number of interfaces, this activity becomes a support nightmare. Every time one of your data recipients modifies a request, you have to rewrite your interface. Worse, every time you modify your database, you have to check all of your interfaces to make sure that you have not inadvertently

sabotaged them. At some point, you may have written so many interfaces that the burden of rewriting them compromises your willingness and/or ability to upgrade your own information system.

The burden of writing or rewriting interfaces would be nearly eliminated if all of the informaticians responsible for anesthesia records could agree on a common format for that information so that each of us is only tasked with writing one interface to get our data into the common format and one interface to receive data from the common format (Figure II-3). Therein lies the problem: “if [they] could agree.” The process by which agreement is achieved constitutes the development and adoption of standards. To maximize the acceptance of standards, their development should be held under the rules and procedures of an internationally recognized standards development organization (of which there are many).

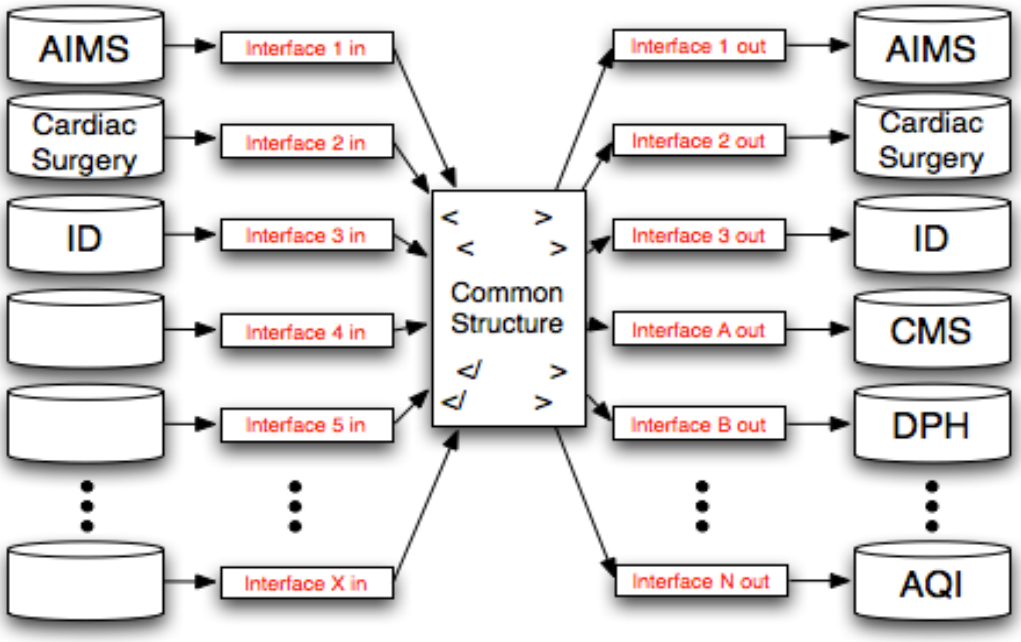

Figure II-3. The enlightened method of interfacing data sources with recipients. In the enlightened method, a data provider would need to write one interface to convert his or her data

into the common format. To receive data, a recipient would only have to write one interface to extract data from the common format. An additional two representative data recipients have been added to those of Figure II-1: CMS (Center for Medicare and Medicaid Services) and DPH (Department of Public Health). Note that in the naïve approach, connecting X providers with N recipients would require X × N interfaces; in the enlightened method, only X + N interfaces would need to be written.

Structure

Two standards in the health informatics world compete to be the dominant standard for the structure of the electronic health care record. One is the American Society for the Testing and Materials Continuity of Care Record (CCR). The other is the American National Standards Institute HL7 CDA. Both standards implement their solutions in extensible markup language, a computer language that is "self-describing" and consequently fairly easy to understand by those not well-versed in programming. The two structures are to a great extent geared toward solving different problems: The CCR provides a snapshot of the patient's status, is good for communication between clinicians, and is probably more easily implemented; the CDA is more robust and provides a well-defined structure for the data. It is thus more appealing for sharing individual data elements, as would be required for feeding a data warehouse.

Since the CCR can be realized as a specific implementation of the CDA, the discussion that follows assumes the CDA as the standard for the common structure.

Terminology

When one specifies an information model, one has to specify not only the structure to be used but also the terms that reside in (bind with) the structure. This is analogous to describing a written language: in describing a language, one needs to specify not only the grammar (structure) of that language but the vocabulary as well. Reading English words in a German sentence structure would seem bizarre at best. The problem with terminology standards in health care and standards in general is that there are too many to choose from.

Two schools of thought exist regarding how to choose vocabularies to bind with the CDA. The first is to develop consensus about which vocabularies to use with which concepts, so that records would be mapped to a unique common model. The second is to allow the person generating the document to choose terms from any recognized standard and put the burden of sorting them on the receiver. Both of these options have their technical and political challenges: Consensus on a unique model is unlikely to occur in the near future; allowing permutations of standards *ad lib* effectively leads to having no standard at all.

The most likely solution is a balance of these approaches, where users are constrained as to which standards they may use in each section of their records, while receivers of the information accept that they will need to translate some of the information they receive into their preferred format. This is effectively what the US Department of Health and Human Services (HHS) did with their initial set of Standards, Implementation Specifications, and Certification Criteria and Certification Programs for Electronic Health Record Technology (45 CFR Part 170 Health Information Technology). For the summary record, the problem list should be populated by the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM)

or SNOMED-Clinical Terms (SNOMED-CT); the information related to procedures should come from ICD-9-CM or the American Medical Association Current Procedural Terminology, 4th Edition; medication codes may come from any drug vocabulary identified by the National Library of Medicine as an RxNorm source provider; laboratory values should be coded using the Logical Observation Identifiers Names and Codes.

As a starting point for anesthetic records, it would seem reasonable to bind the standards suggested in the final rule for summary records to the HL7 CDA to create an interoperable record. In addition, SNOMED-CT, maintained by the International Health Terminology Standards Development Organization, contains about 5,000 terms specific to anesthesia (submitted by the DDTF of the APSF). These terms should be used, if possible, to describe anesthesia-related events. Terms for data acquired by monitors are also specified in SNOMED-CT. Additionally, SNOMED-CT is one of the RxNorm source providers, and the SNOMED-CT medication terms might be considered if the goal is international collaboration. On the other hand, RxNorm, as opposed to its providers, appears to be the direction that HHS is headed in for medication terminology, so the decision on which medication terminology to use should be made with that caveat in mind.

With time, the preferred sets of standards will likely change, yet at the same time, more translators from one terminology to another will become available.