Information Technology in Anesthesiology

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Introduction

In the 1950s and 60s digital computers, in the form of mainframe systems, first made their way out of government laboratories and into the corporate world. They soon found their way into hospitals, generally as accounting tools. Over time, computer technology was offered as a solution to many real and perceived problems in the hospital, including medical record keeping, patient data analysis, and materials management to name just a few. In spite of the expenditure of significant resources, both monetary and personnel, few real clinical solutions were successfully introduced. This was disappointing to both investors and computer advocates. The reasons for these failures are many, but were often based on the fact that the proposed clinical solutions were more complex and demanding than was technically or fiscally feasible. Often the solution was far more expensive than the problem it was meant to solve.

The last decade has seen truly dramatic changes in computing. Desktop and server hardware are remarkably powerful. Advances in network technology allow for the integration of thousands of machines. Storage solutions make it possible to store and retrieve information stored on hundreds of gigabytes. The Internet has demonstrated that large amounts of information can be transmitted and displayed in new and creative ways. Finally, and most importantly, advances in computer science, particularly programming tools and computational theory now allow for the introduction of clinically important computing technology in the medical environment.

The Operating Suite

The operating suite is the most cost intensive area of most medical facilities. Costs can easily be greater than US$1,000/hour/operating room, excluding physician charges. The inefficient use of personnel and resources can turn what is traditionally a revenue center into a cost center. Computer-based tools are being used to more efficiently use the time, personnel, and resources in the operating suite to minimize costs and, hopefully, optimize the quality of patient care. These tools include:

- Display systems to rapidly inform personnel where they are needed
- Drug and supply tracking for
  - revenue capture
  - utilization review
  - outcomes analysis
- Integrated patient and blood product identification system

Embedded Computing Devices

One area that computer technology has been remarkably successful is inside the many electronic devices found within an operating suite. Ongoing advances in technology have led to the development of devices with embedded computers. This computer-based equipment offers a high-level of sophistication and clinical utility. Examples of this include:

- physiologic monitors
  - derived clinical values - SpO2, SvO2, cardiac output, . . .
signal analysis - ST-segment, arrhythmia, flow-volume loops, . . .
artifact identification and rejection
smart alarms
• mechanical support devices
  • intraaortic balloon pumps
  • cardiopulmonary bypass machines
  • implantable defibrillators
• infusion pumps
  • computer controlled infusion
  • closed-loop control

These devices have made a noticeable improvement in patient care. One device, the pulse oximeter, has made more of an impact on patients cared for in the operating room than any other device over the last quarter century. Our ability to detect and treat cardiac ischemia has been greatly improved by ST-segment analysis software, now standard on most physiologic monitors. There is no question that these computer-based devices have contributed to the improvement in perioperative outcomes that we are able to offer our patients.

The Medical Record

Physicians, nurses, medical technicians and others are caring for increasingly sick patients undergoing ever more complex and risky procedures in the operating suite. The primary tool used to manage these patients is the information found in the medical record. Starting with basic patient demographics (i.e. name, hospital number, height, weight) the medical record is the repository of information concerning the patient’s past medical history, current condition, and laboratory and diagnostic test results, and all other information associated with the current episode-of-care. Unfortunately, the vast amount of information about the patient is rarely available in a format that allow their care givers to find the pertinent information in a timely manner. As patients and the medical system that cares for them has grown in complexity this problem has dramatically worsened. The suggestion that physicians and nurses should continue to search through often random collections of mismatched illegible pieces of paper in order to piece together the current status of a surgical patient is unacceptable. Lost time and information is the rule. It is not uncommon for patients to submit to expensive and potentially dangerous diagnostic tests, and not have the results of those tests be used by their caregivers merely because the results are effectively lost. Today, the paper medical record is broken beyond repair.

In the operating room, rapid access to vital information can often mean the difference between a successful intervention and disaster. Information technology offers a solution to this problem. A number of centers, including Mayo Clinic, are in the process of developing comprehensive electronic medical records. From the perspective of the operating suite a subset of these tools and information are important:

• interfacing and display of physiologic monitoring
• interfacing and display of mechanical support devices
• stat-laboratory results
  • arterial blood-gases
  • electrolytes
  • hemoglobin
  • coagulation studies
• recent diagnostic studies
  • cardiac catheterization laboratory findings
  • radiographic images and readings
  • EKG and EEG tracing and results
• recent history and physical examination
  • patient problem list
  • current pathophysiologic state
  • summary of progress notes
• integrated nursing notes and forms with the rest of the medical record

The above, collectively, is defined as the Perioperative Information Management System, (PIMS). It is with this collection of integrated tools that a collated summary of information is produced that reflects the patient care and response to care during the perioperative period.

Automated anesthesia record keeping systems have been commercially available for a number of years, although few practices have embraced this technology. None-the-less, studies have demonstrated that the output of these systems are more accurate, complete, and legible than hand-written records. In addition, there are anecdotal reports that these records are much more useful during litigation.

It reasonable to extrapolate the success of computer-based anesthesia records to the additional information gathered and recorded in the operating suite, as seen above. The additional benefit of
eliminating multiple documentation, often conflicting, of the same information and the elimination of transcription errors can be expected to improve efficiency and distribution of appropriate patient information to all the medical professionals in the operating suite. Finally, the process of introducing this technology can spur medical organizations to rethink what information really needs to be recorded. It’s fair to say that a portion of the information we dutifully record each day is never read or used to care for our patients. If it’s not used, why enter the information? Manifesting a PIMS in the operating suite is vital to the continued success of this enterprise.

Selection of a PIMS product

An automated anesthesia record keeping system had been used in the cardiothoracic and vascular surgery operating rooms at Mayo since 1983. This system was based on the Hewlett Packard Patient Data Management System. It used a minicomputer for its processing and interfaced with the physiologic monitors, mass spectrometer, blood bank, cardiac catheterization laboratory, Radiology, and the blood gas laboratory. The user in the operating room entered information via a command-line interface. The anesthesia record was produced in real-time with a color X-Y plotter. Over the life of the system more than 75,000 anesthetics had been recorded and archived.

By early 1996 it became evident that the system was reaching the end of its useful life. Hardware failures were increasing and the vendors had made it known that spare parts would no longer be available. In addition, the software had reached the limit of functionality and the ongoing process of modifying the software as the practice evolved was no longer possible. A search was begun to find a replacement for the cardiac system with the intention of expanding the use of automated anesthesia record keeping to the entire anesthesia practice and to incorporate information from preoperative care, intraoperative nursing, procedural data, and post-operative care.

At the 1996 American Society of Anesthesiologists annual meeting, a team of anesthesiologists and information services staff examined all the PIMS related products presented at the meeting. Four manufacturers were invited to present their systems in greater depth at Mayo. They were asked to demonstrate the ability of their products to chart both a complex (aortic valve replacement and coronary artery bypass graft) and simple (myringotomy with tubes) procedures. The systems were evaluated for their clinical utility, ease of use, and completeness, as well as technical compatibility with the institutions installed base of clinical instrumentation and networked information systems. After a six-month evaluation a decision was reached. It was decided to purchase a replacement system for the cardiothoracic and vascular practice, which consisted of 14 operating rooms, and if successful to expand the implementation to the entire anesthesiology practice of approximately 150 anesthetizing locations, 75 post-anesthesia recovery beds, and 60 pre-procedural waiting beds.

The initial replacement project was carefully defined to only manifest the functionality of the existing system. It was concluded that trying to expand functionality would add too much complexity to the project and could prevent successful implementation prior to the failure of the existing system. A detailed scope document was produced to fully define the expected functionality, the steps necessary to manifest the project, and the project time-line. The stated operational philosophy of the project was to design and implement a system that was consistent with the clinical practice. It is considered paramount not to expect the practice to change in order to use the new system, but to modify the system to fit the practice. Finally, the project was strictly managed in order to prevent scope creep, the addition of new functionality as the project progressed. In fact, some expected functionality was deferred when it became apparent that continued development would lead to unacceptable delays in the project.

Design and Configuration of a PIMS

The first part of the project was to configure the software. This consisted of building a variety of database tables that listed every fluid, medication, procedure, personnel, and text based patient care documentation. These lists had already been created on the existing system, but since the new product was built around a relational database the tables had to be constructed in more detail than the previous system. The design of the different screens had to be configured as well. The home screen was modified repeatedly. At first, it was thought that maximizing
the information content of the home screen would be ideal, but when the project team and clinical users interacted with mock ups of the system it was realized that the content was too complex and information could not be easily extracted from the screen. The final version of the home screen only presents a graphical representation of the vital signs (i.e. blood pressure and heart rate) and the most recent output of the pulse oximeter and mass spectrograph (i.e. inhaled oxygen and exhaled carbon dioxide and inhalation anesthetic concentrations). Details such as physician signature and other time and security sensitive documentation were also solved. Macros were programmed in order to speed documentation of complex portions of the anesthetic such as induction and emergence. The final portion of configuration consisted of designing the printed anesthesia record.

While the configuration team was doing its work, the project’s computer scientists and engineers went about the process of interfacing the system with the clinical instrumentation and networked systems in the institution. The architecture of the system is that of a thick client-server. The workstations that would be used in the operating room consisted of Intel P3 processors at 300MHz and 128Mb of RAM. The operating system is Windows NT, v.4.5. The majority of information is transmitted via an Ethernet connection to the institutional network. Information from the operating room is archived to a server every five minutes in order to assure data redundancy.

**Validation and Implementation of a PIMS**

After design and configuration were completed the system had to be validated prior to implementation. This consisted of the production of a number of clinical scenarios where every step of documentation was scripted. This information was entered into the PIMS, in the computer lab, when the system was interface and gathering data from networked monitors in an operating room. These clinical scripts were run repeatedly until all the automated and manual information entered was correct and the printed anesthesia record was complete and error free. Once the computer lab portion of validation was completed the system was then brought into the operating room for further testing. This testing consisted of the computer programmers entering the information into the system, during operative procedures, and then comparing the output to the hand-written record.

Once all the bugs were identified and corrected in the computer laboratory, the system was turned over to the clinical staff. After training, the staff first used the system in the “background”. One clinician would care for the patient and produce the hand-written record, while another clinician would chart on the computer system. When the project team was satisfied with the computer charting process the last validation step consisted of charting in the “foreground”. The clinician caring for the patient would chart on the computer record while a second clinician would produce the hand-written record for inclusion in the medical record. This last step was considered most important since it was vital to determine prior to formal use that it was possible to use the system and conduct an anesthetic in a manner consistent with the clinical practice.

The final step in the replacement project was implementation. As with the rest of the project, this was done in an orderly step-wise manner. The entire clinical staff, physicians and nurses, was trained on the use of the system. These classes consisted of four hours of hands on training. The go-live process started with only four operating rooms. Each room had a clinical user paired with a “super user” who was part of the project. The system was used for charting the anesthetic by the primary clinician while problems and questions were solved by the project team member. After the first three days the four rooms were successful implemented, and then an additional four rooms were brought on-line in the same manner. This process continued until all 14 rooms were implemented. Once all 14 rooms were up and running, 1-2 project team members remained in the OR suite, during the day, for two weeks. They remained available to answer questions and promptly solve problems.

Post-implementation review concluded that the system worked well in the context of the cardiothoracic and vascular anesthesiology practice. Time spent on documentation was less than either the hand-written record or the previous computer system. The new system was stable and produced an acceptable anesthesia record. Further modifications were made once the system was fully operational and the clinical users had the opportunity to evaluate the system and feedback to the project team what problems or enhancement
were needed. Based on this experience it was decided to expand the use of the system to the entire anesthesia practice at Mayo Clinic.

Further configuration was needed to incorporate the specific documentation needs of the rest of the practice. This was particularly true for procedure listing and patient care events. As with the cardiothoracic and vascular rollout, further implementation was done in a planned stepwise process. As of this writing approximately 35 operating rooms are using this system and the current time-line is for a total of 100 operating rooms to be up and running by the end of 2000. The rest of the anesthesia practice, consisting of non-operative anesthetizing locations, recovery rooms, presurgical waiting areas and the like should be completed in 2001. In addition, it is expected that preoperative assessment, OR nursing documentation, and further interfacing with additional electronic devices, (i.e. infusion pumps, ventilators, anesthesia machines, . . . ) and network resources will be incorporated into this initial manifestation of the PIMS. Since initial implementation more than 10,000 anesthetics have been recorded.

Ongoing issues include PIMS support for the clinical staff. This consists of on-site support during the first first few hours of the work day, help desk support, and 24 hour - 7 day/week on-call support from programming and engineering staff. As the system expands to a greater number of clinical sites, a greater demand is placed on the network and the different servers that support the system. Network connections have been upgraded from twisted-pair wire to fiber optic cable. Servers have been upgraded to very fast, multiprocessor devices with RAID drives. Finally, the complex issue of user expectations and demands must be engaged. The ongoing demands for added functionality and customization is an expected outgrowth of computer-based documentation. The project team has put in place a formal process to review these requests and determine which changes are appropriate, cost-effective, and when and to what degree to develop the requested added functionality. With this process in place the PIMS is positioned to evolve over time with the clinical practice.

Care Management

Once information about the patient, the course-of-care, and resource utilization is entered into a database it can be processed and displayed as a tool to improve both the quality and efficiency of the practice in the operating suite. This kind of analysis is a major value-added with the implementation of a PIMS. For example, examining the relationship of a variety physiologic variables to adverse outcomes can identify easily solvable problems. Close attention to the economic as well as medical impact of new pharmacologic agents can assist in the appropriate utilization of new drugs. Analysis of laboratory testing with practice decisions help to identify which tests are really needed for clinical management. Comparing the practices of physicians to that of their peers allows for the identification of “best practices” as well as problematic issues. The ability to carefully examine ones practice offers the possibility of accelerating practice improvements and improved patient outcomes.

Conclusion

Recent advances in computer technology are now making their way into the operating suite. The application of this technology is manifested in a number of ways. Computers are inside the majority of monitoring and other equipment used in the operating room. These devices have improved the quality and accuracy of information used to make clinical decisions. Management tools are used to track personnel and resources throughout the operating suite allowing for the delivery of cost-efficient care and that we get paid for what we do. The development of the electronic medical record will solve the current chaotic status of the hand-written record. The clear and timely access to the patients medical information will be used to better care for our patients. The power of database analysis to assist in practice analysis and improvement is just now being learned. Finally, computer-technology is advancing at an ever-increasing pace and it’s reasonable to expect that these advances will continue to have a positive impact on our practices.

References

2. Abenstein JP, DeVos CB, Abel MA, Tarhan S. Eight Year’s Experience with Automated Anesthesia Record Keeping: Lessons Learned - New Directions

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