Crit Care Nurs Q
Vol. 29, No. 4, pp. 354–361

Clinical Dashboards

Impact on Workflow, Care Quality, and Patient Safety

Marie Egan, MS, RN

There is a vast array of technical data that is continuously generated within the intensive care unit environment. In addition to physiological monitors, there is information being captured by the ventilator, intravenous infusion pumps, medication dispensing units, and even the patient's bed. The ability to retrieve and synchronize data is essential for both clinical documentation and real-time problem solving for individual patients and the intensive care unit population as a whole. Technical advances that permit the integration of all relevant data into a singular display or "dashboard" may improve staff efficiency, accelerate decisions, streamline workflow processes, and reduce oversights and errors in clinical practice. Critical care nurses must coordinate all aspects of care for one or more patients. Clinical data are constantly being retrieved, documented, analyzed, and communicated to others, all within the daily routine of nursing care. In addition, many bedside monitors and devices have alarms systems that must be evaluated throughout the workday, and actions taken on the basis of the patient's condition and other data. It is obvious that the complexity within such care processes presents many potential opportunities for overlooking important details. The capability to systematically and logically link physiological monitors and other selected data sets into a cohesive dashboard system holds tremendous promise for improving care quality, patient safety, and clinical outcomes in the intensive care unit. **Key words:** *alarms*, *dashboard*, *data*, *integration*, *technology*, *workflow*

YOU are an intensive care unit (ICU) nurse. Imagine: you get an admission, a postoperative heart. The patient arrives in a flurry of activity, bed pushed by a couple of staff members, one of whom is inflating the ambu bag. To the chirp of pumps running on battery and the sound of alarms, the team moves in well-orchestrated steps, hooking the patient up to every monitor and support device necessary to maintain homeostasis. Someone is drawing labs, someone reports off intravenous (IV) infusions, drug names and rates, chest tube drainage, urine output. You are the nurse—this is your patient. You are looking everywhere, listening to everything, synthesizing, evaluating, assessing, and getting a sense of how the case will play itself out over the next few hours. During this time—even over the course of many shifts—you and your colleagues will regularly run through a mental checklist, looking methodically at every display, every pump, every bag of fluid, every drain. You will draw labs, measure fluid outputs, assess waveforms—and record, record, record.

At change of shift, an incoming nurse will approach the bed and start over. You will give a complete, detailed report, covering the course of surgery, the procedure, and the time since arrival in your unit. You have handed off, but you will linger to write your notes and let your replacement get oriented. There is a great deal to review, to consider. You will need half an hour or more to complete a full evaluation, check all machine settings, and assure yourself that your replacement knows the patient and is fully prepared to assume responsibility.

What if there was a single large screen display that brought together all the various readouts you need to look at? If you could see

From the Massachusetts General Hospital, Boston.

Corresponding author: Marie Egan, MS, RN, Department of OR Administration, Massachusetts General Hospital, 55 Fruit St, Boston, MA 02114 (e-mail: mtegan@partners.org).

hemodynamic waveforms, vital signs, ventilator settings, drug infusions and drip rates, critical lab values—or more, depending on the extent and degree of information system integration? Staff often knows basic demographic information related to an upcoming admission to a unit, but otherwise may not know much more than the scheduled surgical procedure. The staff member preparing to receive the patient could choose to see the same hemodynamic waveforms, drug infusions and rates, ventilator settings, etc as the staff in the operating room (OR), before even seeing the patient. How much better might you prepare for an admission if you had already gotten a virtual report on your patient?

Nowhere does the opportune synchronization of time and events become as consistently critical as in the ICU, where having the right information at the right time has a direct impact on patient safety. ICU patients are surrounded by some of the finest, most sophisticated medical equipment available, devices producing a steady stream of data that require timely observation. Timing means everything when administrating drugs and adjusting the settings on such devices as ventilators and medication pumps. Observing and interpreting the interplay of physiological readings and drug infusions at the right moment can impact, for example, whether a patient is in the ICU for 2 or for 5 days.

The issue of patient safety hovers on the forefront of the healthcare industry, and hospitals are investing in new technology to help meet the challenge. Sophisticated real-time devices are designed to improve the accuracy of information on a patient's condition as well as bridge the gap between flow of events and clinician knowledge of what is occurring. Technological advancements are expected both to improve patient care and facilitate the way in which clinicians work.

However, the reality is far more sobering. Many devices and systems designed to improve medical procedures are introduced in isolation. And this haphazard introduction of new devices in an already technologically complex environment can frequently lead to greater operational inefficiency, adverse events, and increased costs.

How does a hospital incorporate new technologies into its existing operational and physical structure without increasing operational costs and threatening patient safety? Can a hospital actually go a step further and use technology to improve the impact of technology in the hospital environment? Is it possible to bring the diverse data streams of existing equipment together and present them holistically and comprehensibly?

MASSACHUSETTS GENERAL HOSPITAL AND THE CIMIT OPERATING ROOM OF THE FUTURE

Massachusetts General Hospital (MGH) is one hospital that is actively responding to these challenges. In August 2002, it opened the Operating Room of the Future (ORF). The ORF was conceived as a collaborative research project funded by the MGH, Partners HealthCare System, and the Department of Defense Telemedicine and Advanced Technologies Research Center (TATRC) via the Center for Integration of Medicine and Innovative Technology (CIMIT), along with a small number of industry collaborators. This project was established as a result of limitations placed on innovation by present ORs with regard to room design, function, integration of equipment and people, and the ability to capture real-time data.[1]

The ORF is a high throughput OR designed specifically for performing minimally invasive surgical procedures.[2,3] It is an ongoing, living laboratory—a testing site—that develops and evaluates new technologies and systems without disrupting the delivery of patient care (Fig 1).[4–6]

Development and integration of surgical equipment and information/communication systems was a key goal of the CIMIT ORF project. Minimally invasive surgery is less intrusive to the patient's body than is traditional open surgery but it relies on a high degree of technological support within the OR. A plethora of devices in a minimally

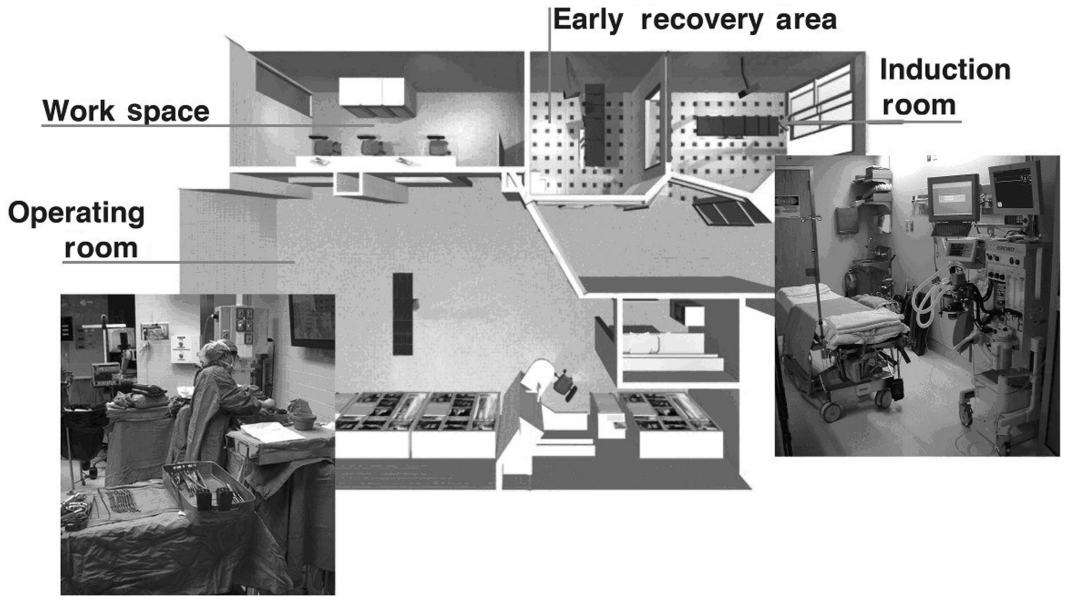

Figure 1. The Operating Room of the Future (ORF) at Massachusetts General Hospital. Patient flow is from induction into the OR and then to early recovery. Between cases surgeons use the work space for administrative tasks.

invasive OR provide a steady stream of real-time data, but the information can often be fragmented among various team members and equipment. For example, the anesthesiologist interacts with as many as 4 separate displays, each attached to its own computer: one each for the hospital's patient information and order entry system, physiologic monitors, automated anesthesia record keeping, and drug and supply management.

The ORF team has sought to facilitate data integration in a manner that will reduce "technology crowding" around the patient as well as improve situational awareness. But integration of devices has proven elusive, and even industry collaborators find the regulatory and economic barriers to interconnectivity formidable. To address the challenge of integrating devices if not directly with one another than indirectly through an intermediary party, CIMIT facilitated an introduction between the ORF team and Livedata, Inc. Based in Cambridge, the company has experience in data integration and visual display systems for the manufacturing and energy industries.

INCORPORATING NEW TECHNOLOGY

In January 2006, MGH actively began displaying real-time information on the dashboard in the ORF. The new system monitors, captures, synthesizes, and automatically displays essential patient information on a large flat-panel screen.[7] It is capable of integrating all device data in the ORF, including detailed physiological waveform data and critical data elements, without data loss and in real time, as well as real-time data from administrative, patient care, and hospital information systems (Fig 2).[8]

The ORF dashboard follows the patient's transition through the stages of surgery, triggered by the manual entry of data into other systems and by automatic triggers such as radio frequency identification tags worn by ORF staff. Dashboard screens entitled "Case setup," "Time out" (safety pause), and "Intraoperative" present data relevant to the advancing phases of the operation. For example, when clinicians arrive to set up the OR, the dashboard displays a panel specific to preparation. Case setup includes such

Figure 2. Wall-mounted displays in the Operating Room of the Future. On the left is the livedata dashboard and on the right is a plasma screen showing images from the surgical cameras.

information as supplies, surgeon preferences, and special equipment. Key facts about the patient and operation—patient allergies and team members in the room, for example—are on display throughout all phases of the perioperative process. This includes real-time updates on the room itself, comparing actual room performance with the schedule originally prepared for the OR. This allows staff to see if the room has fallen behind schedule (or moved ahead) and by how much—providing this information to the control desk can help with staff planning (Fig 3).

When surgery begins, the panel displays information relevant to the intraoperative phase of surgery. At one glance, everyone in the OR can see the physiological status and surgical equipment readings along with patient and operation data (Fig 4).

With input from MGH staff, the dashboard has been designed to both increase the situational awareness of all staff in the OR at any given moment and remain unobtrusive. This problem of combining full visibility with discretion had already been met with the ORF's earlier installation of a video screen, which projects the surgery in progress. The display panel's location adjacent to the surgical video display has proved to be ideal; information displayed on the dashboard is given additional contextual meaning when viewed in relation to surgical activity at any given time.

In June 2006, a similar real-time data integration system was also deployed in 21 ORs of a second US hospital.[9] Some of the ideas developed to meet the needs of those clinicians have influenced and improved the technology being used at the MGH ORF. In fact, development of both the systems was simultaneous and synergistic. As the development teams traveled back and forth between the

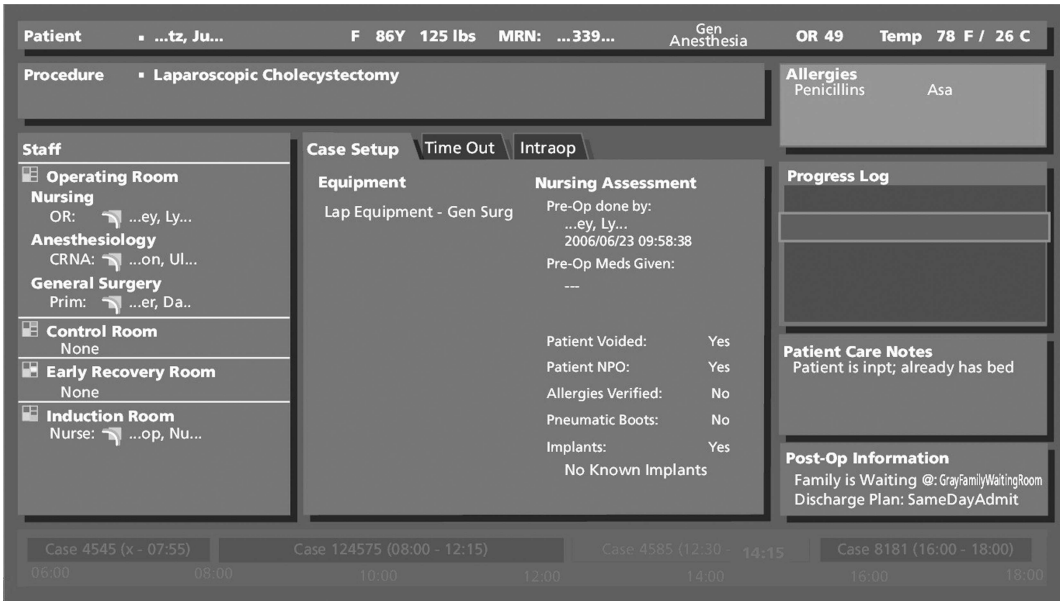

Figure 3. The case setup screen displays pertinent preoperation information for nursing staff. Events entered in other databases cause the display to advance to the next screen.

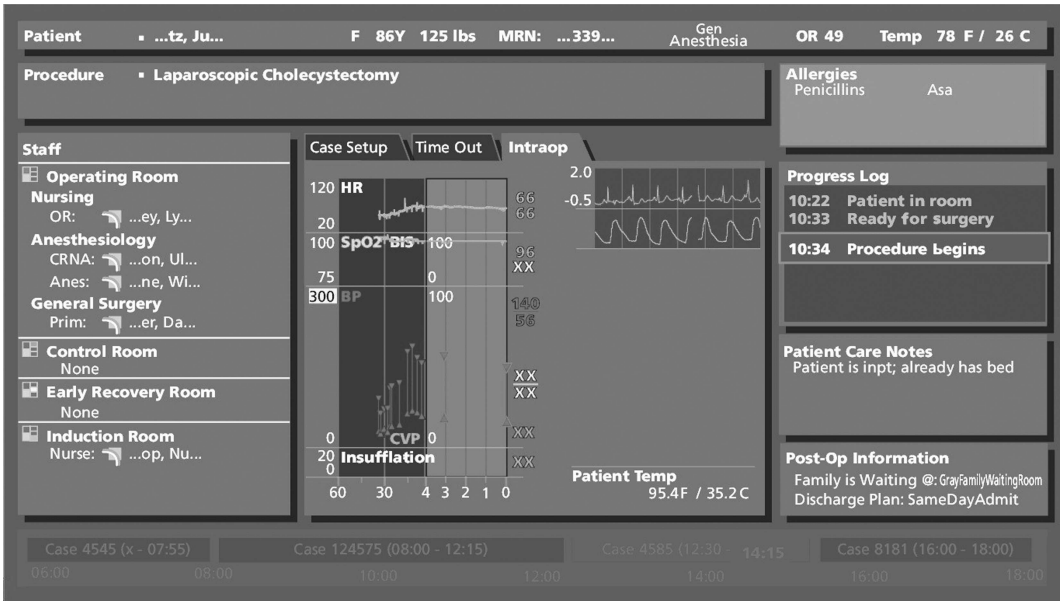

Figure 4. The intraoperation screen displays hemodynamic waveforms, the case progress log, and family location information.

two hospitals, they carried ideas from each hospital with them.

IMPLICATIONS FOR CRITICAL CARE UNITS

If data integration and display tools can be developed flexibly across hospitals, why not develop them across departments? Is there an opportunity for visually integrated technology dashboards in ICUs, postanesthesia care units, and other critical care hospital units? Would combining data from ICU physiological monitors, ventilators, and medical infusion pumps, for example, into one display improve patient care and clinical efficiency?

Like the OR, the ICU has become technologically very sophisticated. More data become available as the number and diversity of monitoring modalities increase; and this ever-increasing flow of information requires thoughtful human analysis. Like a pilot in the cockpit, an ICU nurse is systematically reviewing a number of displays, lab results, intravenous pump settings while assessing and synthesizing data and making decisions.

Alarms provide an obvious example of the need for human intelligence in face of an array of data from diverse technological devices. Many alarms are essentially nuisance alarms, conveying no significant change in patient condition. However, ICU nurses must set them and allow them to go off simply because 1 in 10, or 1 in 20, times the alarm will be meaningful. Sometimes, the cause of an alarm is clearly artifact, such as patient movement, but at other times, the nurse must interpret an alarm to ascertain whether it indicates a significant event. This often involves looking at the patient, looking at all the displays, considering the interplay between the patient and the therapeutic interventions in place, and taking some course of action.

Could a data integration and display system assist in interpreting the alarm systems? Would alarm readings be more meaningful if related information groups were organized together on one display? When diverse information is organized systematically and cohesively, clinicians are better able to assess data efficiently and effectively. A change in blood pressure may or may not be significant, but if it occurs in conjunction with an increased infusion of beta-blocker drugs, for example, the blood pressure alarm becomes meaningful. Could a display that displays hemodynamic waveforms and data beside drug infusions and rates be of value?

In many respects, ICU nurses may actually find a dashboard-like display more directly useful than would OR nurses. This technology provides information to 3 distinct caregiver groups with different but overlapping needs: the nurse, the surgeon, and the anesthesiologist. The information, therefore, tends to be relatively general as far as the specialized interests of each group are concerned. During surgery, nurses typically look at such dashboard information as patient identity, allergies, staff in the room, and the attending surgeon—information that is peripheral to the workflow process panel, the intraoperative panel. This center panel contains physiologic readings, the type of information that is most relevant to the work of the anesthesiologist. In the ICU setting, however, the role of the anesthesiologist is most closely mirrored by the nurse. It is the nurse in the ICU, not the doctor, who most carefully monitors blood pressure, heart rate, and other physiological waveform data.

Determining who looks at what information and at what stage during the perioperative process was integral to the development of the ORF dashboard. Development of an ICU display would require similar investigation. There are fundamental differences between the two departments with regard to not only who is looking at real-time continuous data but also the concept of workflow and process.

ICU workflow and data integration

The dashboard technology in use in the MGH ORF reflects the perioperative process itself; it is workflow driven. An ICU, on the other hand, is dedicated to continuous care and a good data integration and display system would respond to this. At MGH, a team of 4 to

6 people who work together for a day at a time staffs the OR. Throughout the perioperative process, the patient moves through a series of physical spaces from caregiver to caregiver, in which the OR is but one stop. The challenges to patient safety are many and include the transfer of the patient along with that patient's data, such as allergies, fasting status, medical history, drug regimens, and preexisting implants. A number of patients pass through any one OR throughout the course of a day. The challenge for the team is to remain aware of the case at hand—specific patient history and plan of care—and to prepare efficiently for the next patient. Real-time dashboard technology is specifically designed to help the OR team respond effectively to these challenges as a number of patients move through the perioperative environment.

In contrast to the OR patient, the ICU patient is relatively stationary, assigned to a room or bed slot. The ICU patient care process occurs over days or even weeks, versus hours in the OR. Typical postoperative patients, if all goes well, follow a relatively predictable path to recovery. They arrive with a given amount of equipment, drugs infusing, monitors in place, perhaps intubated and during their stay require less monitoring and intervention until ready for discharge to the next level of care.

Caregivers come and go over the course of hours and days. A challenge for those in this environment is to present diverse streams of data to one another in a clear meaningful way. An incoming nurse must orient herself to a certain point in a complex story, and be prepared at any time to respond rapidly to a negative change. Patients' status is likely evolving, hopefully for the better, during their ICU stay, but at some point they will have been intensively monitored, often invasively. How would the ICU integrate technology to support both the intensive, constant monitoring and the transfer of complex patient information from shift to shift?

All clinicians involved in ICU care typically want to see the same essential information, which could provide further incentive for having a real-time data integration display. Patients who develop complications create interruptions in the ICU path of continuous care toward recovery; in such cases, outside specialists become involved. For example, renal specialists attend to patients with kidney-related problems; infection control specialists are frequently called to the ICU. Visiting specialists, typically, spend hours reviewing diverse data sources such as the paper chart, lab results, and radiology reports, before even examining the patient. This is the work of getting to know the patient.

Could a data integration and display system facilitate the acquisition of a comprehensive set of ICU patient reports? It is possible to envision a consulting physician approaching a patient bedside and using the large screen display to present multiple images, reports, and results simultaneously. For example, a pulmonologist might want to co-display ventilator settings and vital signs over time, the latest chest x-ray and computed tomography scan, lab results, sputum culture results, and current medications. New displays make it possible to subdivide the screen for different purposes and then revert to a single interated hemondynamic display function. These displays are interactive tools that make the evaluation of multiple data sources simultaneously possible. This type of ICU real-time data integration system could also offer attending physicians and other caregivers the opportunity to view a patient's status remotely, from a workstation or even from home.

ICU display for a data integration system

The technology currently available offers static as opposed to interactive capabilities. Should an ICU dashboard—the static display, only, of real-time data—be part of a larger, interactive software program that functions in a manner more like Windows applications or sophisticated Web sites like Amazon.com? Is it possible to imagine an ICU user interface as straightforward as that of Amazon.com's homepage, a user interface that is easy to navigate through in order to pull down, for example, various reports?

An interactive display available to anyone with a computer and Web access could

serve any number of clinicians involved in ICU care. Although larger medical centers may have dedicated ICU specialists—intensivists—many hospitals are staffed by resident physicians during the off shifts. When presented with a puzzling patient presentation, would it not be convenient if a physician at home could access all relevant information on a Web-style user interface from his or her own computer—rather than engage in lengthy phone conversations detailing vital signs, lab results, ventilator settings, IV drugs and rates, and so forth? How much more effectual a conversation would be if both participants could simultaneously view the same data streams.

Finally, while the ORF dashboard is intended to be unobtrusive in order not to distract the OR team from the patient, a real-time integration and display system could play a very different role in the ICU. If a nurse could view all relevant status on any PC screen, perhaps she could more effectively meet one of the greatest challenges facing ICU nurses, particularly novices—allowing patients sufficient rest. It is all too tempting to stay by the patient's bed, spreading tasks such as restocking, tidying, and checking labs over the course of a shift. To group such tasks together in order to arrange a patient's day with sufficient periods of undisturbed rest requires discipline and organization. An interactive display accessible on any PC could provide ICU nurses with much needed reassurance as to the condition of their patients.

SUMMARY

Until now, much of the innovation in medical technology has been geared toward developing stand-alone advanced systems. The emerging trend is toward horizontal integration, integration across traditionally disparate hospital systems. Clinicians would like as much patient data as possible available electronically; they do not want to log in and out of multiple systems such as labs, radiology, pharmacy. Would it not it be equally convenient to have all real-time data flowing from disparate devices on a single, easy-to-read display, an interactive display where clinicians can dig deeper into any aspect of interest? Just as a team manages patient care best when all voices contribute to the discussion, it seems natural to assume that bringing diverse streams of data together into one conversation will enhance overall patient awareness on the part of critical care nurses.

REFERENCES

1. Sandberg WS, Ganous TJ, Steiner C. Setting a research agenda for perioperative systems design. *Semin Laparosc Surg*. 2003;10:57–70.
2. Sandberg WS, Daily B, Egan M, et al. Deliberate perioperative systems design improves operating room throughput. *Anesthesiology*. 2005;103:406–418.
3. Stahl JE, Sandberg WS, Daily B, et al. Reorganizing patient care and workflow in the operating room: a cost-effectiveness study. *Surgery*. 2006;139:717–728.
4. Sandberg WS, Hakkinen M, Egan M, et al. Automatic detection and notification of "wrong patient-wrong location" errors in the operating room. *Surg Innov*. 2005;12:253–260.
5. Stahl JE, Egan MT, Goldman JM, et al. Introducing new technology into the operating room: measuring the impact on job performance and satisfaction. *Surgery*. 2005;137:518–526.
6. Stahl JE, Rattner D, Wiklund R, Lester J, Beinfeld M, Gazelle GS. Reorganizing the system of care surrounding laparoscopic surgery: a cost-effectiveness analysis using discrete-event simulation. *Med Decis Mak*. 2004;24:461–471.
7. Levine WC, Meyer M, Brzezinski P, et al. Usability factors in the organization and display of disparate information sources in the operative environment. *AMIA Annu Symp Proc*. 2005:1025.
8. Meyer M, Levine WC, Brzezinski P, et al. Integration of hospital information systems, operative and perioperative information systems, and operative equipment into a single information display. *AMIA Annu Symp Proc*. 2005:1054.
9. Anonymous. Surviving the demands of an OR design and construction project. *OR Manager*. 2006; 22:1, 5.

Provided courtesy of LiveData, Inc. 1030 Massachusetts Av, 3rd Floor , Cambridge, MA 02138
Direct: 617-576-6907 Email: jnovakoff@livedata.com URL: www.livedata.com