Computerized physician order entry and quality of care

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In automated physician order entry systems, physicians enter orders directly on the computer. Compared with manual systems, advantages are that orders are legible, transcription is eliminated, the writer can be identified, and orders can rapidly be routed to their destinations. But most importantly, physician order entry allows order checking and provision of decision support to the orderer in real time. Disadvantages are that systems developed to date have been slower than pen and paper and they represent a major process change so that implementation is time-consuming and requires patience both on the part of the users and the developers.

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Order entry is a system in which orders are entered into a hospital computer system; this can be done by technicians, secretaries, nurses, or physicians. In physician computer order entry, physicians enter orders directly into a hospital information system. While this sounds straightforward, it has proved remarkably difficult to implement, but when successful it can have profound implications for care improvement. When order entry is in place, many aspects of the ordering process are substantially simpler; transcription is eliminated, and orders can be routed directly to the target areas (e.g., pharmacy). Also, putting all orders on-line makes providing care more efficient as orders can be written and viewed from many locations. The database of orders also represents an extraordinary resource for quality management. Perhaps the most important way in which order entry can improve care is that it allows the opportunity to give providers real-time decision support as they enter orders. The purpose of this article is to outline what is known about computer order entry in general and how it can improve quality and, in addition, to describe the Brigham and Women's Hospital (BWH) experience with it as well of some of our plans for the future.

Key words: *computers, physician order entry, quality of care, quality measurement, quality improvement*

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Tremendous effort has been devoted to developing computerized decision support systems.[1,2] Substantial evidence has been amassed that such systems can improve physician decision making in specific domains such as computer-assisted dosing, providing preventive care, and improving quality of active medical care.[3,4] Three of 10 studies that assessed patient outcomes reported significant improvement.[3] Despite these encouraging results, relatively few examples exist in which such decision support (i.e., provision of messages or information to providers) is being used in real time by providers.[5] One of the major challenges in medical computing in the coming years is development of methods to make decision support available to clinicians in ways that are both acceptable and effective.[2] Computer order entry can facilitate this in a number of ways:

- clinicians will interact regularly with the computer,
- decision support can be given to providers in close proximity to the time of their decisions, and
- the availability on-line of the information in orders allows processing that would not otherwise be possible.

Such real-time decision support has substantial potential for improving both costs and quality. For example, many ancillary tests are overused or redundant,[6–8] and the available noncomputerized interventions, while effective in the short term, are ineffective in the long term and are expensive.[9–11] Regarding quality improvement, these systems can be used to structure ordering, resulting in decreased process variation. In addition, entry of certain key items is required, resulting in more complete order specification. One example of a decision support system is a program called an event monitor, which scans the database, searches for events of interest, and notifies the appropriate person when something is found. Event monitors can be programmed to run every time a particular event occurs (e.g., to find the current blood potassium level when potassium is ordered for a patient and display it if elevated) or to run at prespecified intervals (e.g., to search for the presence of nosocomial infections). Some of the monitors that may be helpful include detection of "panic" laboratory values and drug-lab, drug-dose, drug-drug, and drug-allergy checks.

The major challenge in the design of decision support systems is providing this support rapidly and selectively in ways that do not adversely affect the flow of patient care. Both active and passive approaches are helpful. Some situations are sufficiently stereotyped that the computer can make an active suggestion; for example, when a clearly redundant test has been ordered the computer may suggest that a repeat is not necessary. In many other instances, the best approach may be to use a passive approach, such as rapid access to data and information (e.g., previous results, a clinical prediction rule, an algorithm, or text) that would help the provider make the most appropriate decision. There are many methodological problems in implementing decision support systems, most notably the tradeoff between the requirement for rapid response time by users and time required by the system to process the decision algorithms. This problem is of particular concern at peak loads. Physician computer order entry has generally been slower than pen and paper methods,[12,13] and physician acceptance of this change in process depends critically on the speed of the system. Interventions that slow the system appreciably may not be acceptable even if they improve care.

ORDER ENTRY AT OTHER SITES: WHAT HAS NOT WORKED

There is perhaps a longer track record of misadventures with order entry than of successes, although few have been documented in the literature. Weed, the developer of the problem-oriented medical record,[14] eventually encountered sufficient provider resistance at the University of Vermont that he moved on to work in other areas.

The best description of the problems associated with implementing order entry is perhaps that of Massaro,[13,15] who described the University of Virginia experience. Residents and medical students were particularly frustrated by the system, and eventually a group of residents initiated a work action in June of 1990. The senior administrators and physicians supported implementation of the system but had not fully realized the enormous implications it would have in terms of changing work flow. Physicians' primary complaint was that they spent too much time at the computer. When work analyses were performed, however, it became clear that "excessive time" was as much a function of which rotation the resident was on as anything else. A few physicians did spend as much as four hours per day using the terminals. The developers, administrators, and users met in a confrontational meeting, and a number of changes in the system were made, in particular the development of personal order sets, which allow groups of frequently used orders to be grouped and ordered at once. The system was ultimately accepted by physicians, but only after it generated substantial discord.

Massaro identified a number of factors associated with the difficulties described above, which have been issues at many other sites as well. The primary determinant of physician acceptance turned out to be speed, which had not been given sufficient weight by the developers of the system, who were nonphysicians. The clinicians were not involved in developing the system and felt it was being foisted upon them by the administrators. When clinicians raised complaints, the initial approach taken by the system developers and the administration was confrontational, which proved ineffective. Only when the developers agreed to work with the users, and to make substantial revisions, was the crisis resolved. The leaders at the hospital had not anticipated the myriad ramifications that implementing order entry would have, and they had not fully bought in to the technology at the onset of implementation, which resulted in further discord.

ORDER ENTRY AT OTHER SITES: WHAT HAS WORKED

While a number of hospitals nationwide employ computerized order entry by unit secretaries and nurses, relatively few hospitals use physician order entry. Some of the other hospitals that are presently using physician-based computer order entry are New York University Hospital, the University of Virginia, Wishard Memorial Hospital in Indianapolis (where order entry has been instituted on the medical service), and LDS Hospital in Salt Lake City, Utah, which has a partial system in place. Many hospitals are either in the process of or have plans to implement computer order entry, either by physicians or by nurses or clerks. Similarly, many commercial vendors are currently developing order entry systems. TDS Healthcare Systems Corporation, Atlanta, Georgia, probably has the most mature system, with physician order entry in place in approximately 50 hospitals nationwide including New York University Hospital, although not all order entry in most of these hospitals is performed by physicians.

Much of the early work on order entry that demonstrated its potential was done in the outpatient setting in an elegant series of studies at Wishard Memorial by Tierney and McDonald et al. They found that providing information regarding charges for tests,[16] the time and result when they were most recently performed,[17] and the probability of obtaining an abnormal result[8] all decreased the number of tests that were performed, by 9–14 percent.

More recently, at Wishard Memorial, a randomized controlled trial of the impact on resource utilization on the inpatient medical service of computer physician inpatient order writing showed that charges decreased by 12.7 percent, or $887 per patient.[12] Significant charge decreases were found for diagnostic test charges, drug charges, and bed charges, and a trend toward decreased length of stay (.89 days shorter for intervention teams, $p = 0.11$) was also present. This system uses problem-based templates to guide test and drug ordering, so that only cost-effective tests and drugs are suggested to providers by diagnosis. Some counter-detailing is included for drugs and tests. Because the system was evaluated as a whole, it is unclear which parts of the system contributed most to decreased resource utilization. In addition, this system required modestly more physician time than the paper system, but physicians liked it and felt that it enabled them to provide better quality care.

Keys to success were felt by the Indiana group to be (1) development of the system by clinicians who have a high profile at the institutions; (2) a commitment by the developers to revise the system until it worked, which took several years; (3) regular weekly meetings with users, who were the housestaff; and (4) constant focus on the clinicians' highest priority: response time.

Another impressive series of results comes from the blood product ordering system at LDS Hospital.[4] This system was developed in 1987 to optimize blood ordering practices. Clinicians use the system to order blood products and, at the time of ordering, the relevant physiologic parameters (e.g., hematocrit, platelet count) are displayed. Computerized criteria for appropriate transfusion were developed and are also displayed at the time of ordering. Results include a one-percent drop in the hematocrit of persons being transfused ($p < 0.005$), and a decrease in the percent of orders requiring review by the quality assurance department from 100 percent to 14 percent; furthermore, only 0.4 percent of orders were found to be inappropriate on review. Perhaps most important, this system has facilitated further refinement and tightening of ordering criteria for blood. Although some have suggested that such systems might promote undertransfusion, its developers evaluated this possibility and found no evidence that it does.[18]

BRIGHAM AND WOMEN'S HOSPITAL INFORMATION SYSTEM AND ORDER ENTRY

BWH maintains an integrated computerized hospital information system that provides clinical, administrative, and financial functions, which is a descendant of the Beth Israel Hospital information system.[19] Independent development has proceeded at BWH since 1988. In the past, all applications ran on a network of 13 Data General minicomputers. Recently, a 3,000-node local-area-network (LAN) was implemented with 486-based personal computers (PCs) serving as workstations.[20] All new application development is occurring on the LAN and existing applications are being converted from the minicomputers to be able to run on the LAN. The PCs allow improved graphics capabilities (in particular, windowing, which facilitates the delivery of messages). The system is accessed over 25,000 times per day for all uses combined.

Key clinical data include inpatient and outpatient registration data, diagnostic test results (e.g., hematology, chemistry, microbiology, blood banking, cardiac testing, cytology, noninvasive vascular testing), text reports (e.g., radiology, surgical pathology, autopsy), medications, and outpatient clinic notes.[21] Other clinical applications include access to CD-ROMs and other free-text literature sources.

A physician order entry system was developed in 1992.[22] Before development, multidisciplinary teams representing some of the key customers (nursing, physicians, the pharmacy, and the laboratory) and information systems worked for months to prepare for this system change. Their goals were to define the specifications of each group and to brainstorm about how to interface current practice with the process changes demanded by order entry. The processes by which orders were carried out were substantially affected, and most often, simplified by order-entry (Figure 1). A key decision that was made early was that the goal would be, to the extent possible, to automate processes as they

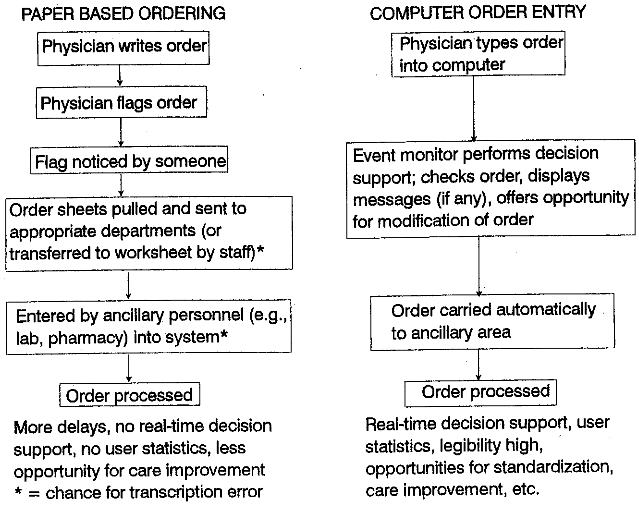

Figure 1. Flow chart comparing the path of an order in paper-based ordering versus computer order entry.

currently existed, and not, for example, to enforce policies that were in place but were not enforced before the advent of order entry. The perspective was that user acceptance was of paramount importance and that such policies could, if necessary, be enforced after users had endorsed the system.

After a pilot test,[23] a physician order entry system was implemented on the medical service (200 beds) in May of 1993 with the rest of the hospital scheduled for implementation by spring of 1994.[22,23] The order entry system allows physicians to enter all patient orders, with the large majority (94 percent based on early data) entered in coded form. At BWH, house officers write almost all orders. In the first six months of use, over 1,000,000 orders were entered. The system also allows patient-specific and order-specific information to be delivered to the provider in real time.

Implementation is going fairly smoothly.[23] Most user complaints have been about response time and the number of screens required to enter an order. These issues have been addressed by (1) implementing a series of hardware and network improvements to speed response time; (2) expanding the number of personal and departmental order sets and templates; (3) providing rapid access to the order entry system by changing the log-in procedure on order-entry units to decrease the number of keystrokes required to enter an order; and (4) developing a "quick mode" for textual (rather than menu-driven) data entry. Factors important to success have been (1) substantial physician involvement and leadership in development of the system; (2) the decision to automate systems as they currently exist rather than changing process at the time of implementation of order entry; (3) strong support from the administration and clinical leadership; and (4) the willingness to be flexible and modify the system according to user needs.

OVERVIEW OF PLANS FOR DECISION SUPPORT AT BWH

Development of decision support is expected to continue for years, but the first steps have been outlined.[24] Because we feel they are the most straightforward, the primary domains we have targeted to begin with include drug ordering, ancillary test ordering, and ancillary test reporting, independent of diagnosis. However, a number of critical pathways by diagnosis are currently being developed, and these will complement order entry by providing standardized orders by day for patients on a path; in addition, much of the critical path data will be collected using the order database. This database will also represent a rich resource for quality measurement and improvement.

The process for developing decision support tools at BWH is that ideas can come from many areas—hospital committees (e.g., Pharmacy and Therapeutics), quality improvement teams, individual providers, information systems—but that all must be approved by a core group responsible for quality improvement, the Clinical Initiatives Development Program (CIDP), and the Center for Applied Medical Information Systems Research (CAMIS). Most tools must either be endorsed by the relevent hospital committee or a content expert in the hospital. Ultimately, all are subject to review by the Care Improvement Council, which includes representatives from the administration and all clinical services. Already, there is a long queue of good ideas awaiting implementation; these are prioritized on the basis of clinical importance and ease of implementation by CAMIS, and this list is reviewed regularly by the CIDP.

DECISION SUPPORT TOOLS AT BWH

A prerequisite to implementing this decision support system has been the development of a number of tools to facilitate decision support. The key decision support tools (Figure 2) are (1) a rule editor that allows medical

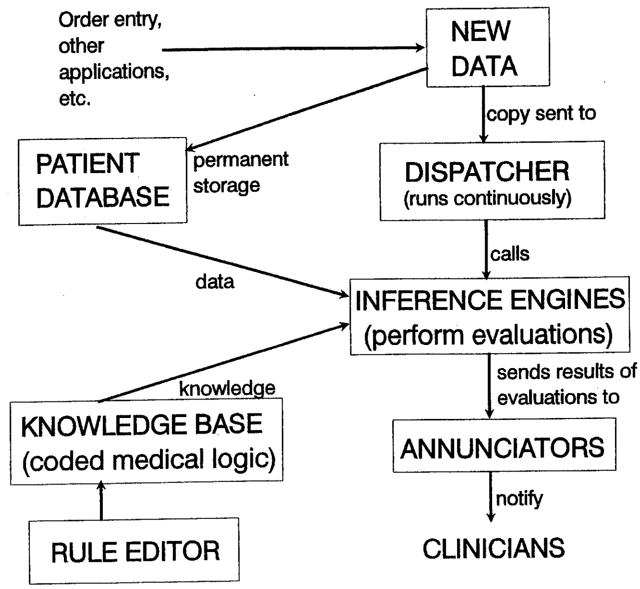

Figure 2. Decision support tools at Brigham and Women's Hospital.

experts to describe medical conditions of interest (e.g., rules about drug interactions, appropriate frequency of ancillary testing, and panic lab conditions); (2) a continuously running dispatcher to determine which new rules should be processed for new data (e.g., drug interaction rules for new medication orders); (3) inference engines that determine if the conditions are present (i.e., if the rules are true); and (4) annunciators that inform the appropriate clinician in the appropriate manner when the conditions are present.

In addition to the ability to provide real-time messages, providers can be alerted even when they are not immediately in front of a computer workstation. This is important because not all processing can be done in real time (as response time would be affected), and because many events can come to the database at any time (e.g., a new life-threatening laboratory result). A new computerized coverage list application allows a patient's covering physician—the single physician primarily responsible for first call regarding that patient, most often a house officer—to be determined at any time. The application (1) manages the rotation of physicians between services, (2) handles evening coverage and allows physicians to indicate when they are signing out, and (3) indicates who is the secondary person to be called should the primary person not be available (e.g., who is the resident if the intern is not available). The coverage list information can determine who should receive computer-generated messages. Since the BWH computer system has recently been interfaced to the hospital's paging system (Advanced Interactive Systems, Inc., Waltham, MA), messages created by the clinical information system can automatically be sent to providers.

The electronic mail (e-mail) application at BWH is already being used to notify providers of a variety of clinical events (for example, when one of their patients is seen in the BWH emergency department and when a variety of text reports, including history and physical examinations, discharge summaries, letters, and clinic notes are ready for on-line review and signature). E-mail can similarly be used to notify providers of clinically important events that do not require the immediacy of the paging system.

As part of the provider order entry system, dedicated workstations have been installed on all nursing stations to display newly entered orders. Nurses check the displays of these workstations as part of their normal workflow. These monitors will be available to display computer-generated messages that should be delivered to nurses.

Thus, the BWH clinical information system has a vast amount of data with which computer-generated decisions can be made and a rich set of tools with which to convey those decisions to providers. The importance and difficulty of determining who is the responsible covering physician cannot be overemphasized, and few systems currently have this information.[25,26] A coverage list application is a critical piece for developing effective decision support.

DRUGS AND ORDER ENTRY

One specific example of how order entry can be expected to improve quality relates to medication errors and adverse drug events. Order entry can decrease the frequency of medication errors in several ways. One effect is to structure the input of drug orders, so that orders are required to include a drug name, dose, route, and frequency and are legible. Also, physicians choose from a menu of drug doses, which serves as a form of dose checking. Very high doses require a pharmacy contact.

This can be expected to reduce the rate of adverse drug events somewhat, but most important will be using an event monitor to do such things as drug-allergy and drug-drug interaction checking (Figures 3 and 4). Evaluations[27] suggest that drug-laboratory checks and guided dose algorithms hold the most potential for care improvement, but a number of these monitors will be helpful, and their effect will be cumulative.

In addition, order entry can be expected to have a major impact on drug utilization and will substantially facilitate drug utilization review. It will be possible to give providers information about drugs at the time of ordering, including counter-detailing, and to restrict the utilization of specific drugs, for example expensive antibiotics.

One early experience we had which illustrates the power of order entry in changing ordering behavior involved the medication ondansetron. Ondansetron, which is very expensive, is a powerful antiemetic used primarily in conjunction with chemotherapy. During fiscal year 1992, $756,000 was charged for ondansetron, and it was the most costly drug purchased during the year. At the request of the BWH Drug Utilization Evaluation committee, a multidisciplinary group evaluated the dose-response curve for ondansetron, reviewed the literature, and came to the conclusion that a lower dose and frequency would be equally effective. Providers were encouraged to use this lower dose and frequency, and were often doing so. However, when order entry was implemented, the default was set at the old dose and frequency, and providers generally chose the default. Representatives of the group that had evaluated the dose-response curve met with the oncology fellows,

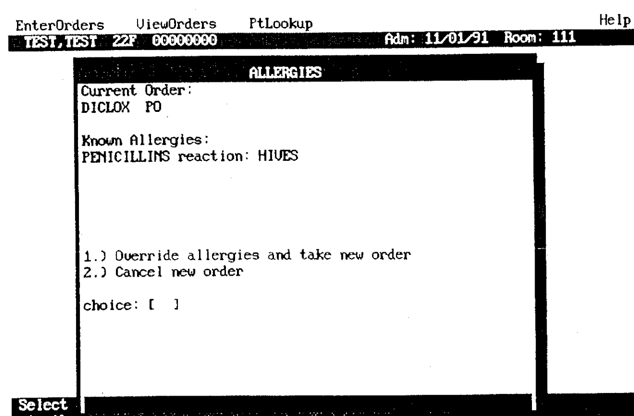

Figure 3. Computer screen alerting the provider when a drug is ordered to which patient has a known allergy.

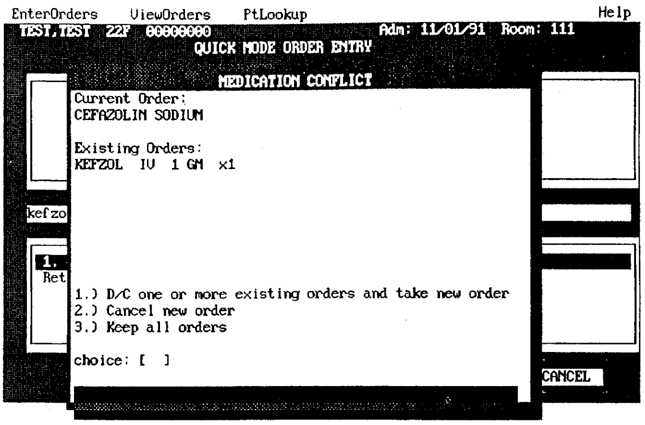

Figure 4. Computer alert to the provider when a medication conflict is detected. These include both redundant medications, as in this instance, and when serious drug-drug interactions are detected, for example meperidine and a monoamine-oxidase inhibitor. It is vital to screen the alerts that are displayed to providers carefully, as most such alerts have a low specificity.

who order much of the ondansetron. When the default dose and frequency were changed on the order entry system, overnight more than 90 percent of the use changed to the new dose and frequency. This single change is expected to save the hospital $250,000 in the coming year.

ANCILLARY TESTS AND ORDER ENTRY

The literature suggests that many ancillary tests are unnecessary either because they are not clinically indicated or are redundant (i.e., they are repeated too early to provide additional useful information). To evaluate the situation at our hospital, we performed a number of studies to evaluate the frequency with which tests are performed, the frequency with which they are repeated earlier than test-specific predefined intervals, and the frequency with which tests fall into "normal strings" (i.e., a series of tests in which all the results were normal). While normal tests may be clinically helpful, such tests are less likely to be helpful than abnormal tests.[8,28]

With regard to unnecessary repeated tests, we performed a detailed analysis of 15 laboratory tests ordered during the hospitalizations of all patients on all services, over a recent three-month period. First, the hospital information system identified all instances in which these tests were repeated within a test-specific time frame. Then, for each such instance, a trained reviewer evaluated the medical record to determine whether the repeat test was indicated, using explicit criteria. The reviewers also looked for evidence that the repeated test contributed to the care of the patient. Results for the tests with the highest numbers of eliminable repeats are shown in Table 1. This work has been very helpful in a variety of ways; for example, it demonstrated that we needed to

TABLE 1

NUMBER OF AND CHARGES FOR REPEATED TESTS IN ONE QUARTER

Test name	Number of repeats	Charge ($)	Percent eliminable*	Total potential savings ($)
Blood gases	5492	62.96	42	145,226
Routine cultures	4328	26.11	89	101,038
Digoxin	1770	42.77	64	48,450
Chemistry 20	528	31.70	32	5,350
Routine urinalysis	998	10.89	30	3,260
Dilantin	75	30.00	84	1,890
Gentamicin	67	40.17	94	2,266
Theophylline	31	41.94	82	1,066
Total			**$308,546/quarter, X4 = $1,234,184/yr**	

*Percent eliminable was determined by reviewing a random sample of charts for each test and, using predetermined criteria, looking to see whether a clinical indication for repeating the test early was present.

change the planned time intervals for giving reminders for a number of tests and that, for some tests, chest radiographs in particular, early repeat examinations were almost always appropriate.

In addition, an ICU committee has focused on the use of ancillary tests within the ICUs. This group found that within the ICUs a high percentage of charges were being generated for a relatively small number of tests (e.g., 40 percent of all chemistry charges are for arterial blood gases). Moreover, many of these tests occurred within "normal strings" (59 percent of PT/PTTs) or were normal (45 percent of blood gases). Many practices that may be suboptimal were identified—for example, performing of blood gases every four hours, always performing a blood gas after reducing the inspired oxygen content despite having oximetry available, or having daily blood testing ordered on admission and never discontinued.

Based on these data, we plan to implement a series of interventions using order entry to improve both efficiency and quality of ancillary test use. Specific interventions we are planning include (1) restricting future test ordering so routine blood testing will not continue ad infinitum; (2) developing protocols for nurses to use to define appropriate instances for ordering specific tests; and (3) providing information about the test such as the charge, the date and result when it was last performed, and, for some tests, the likelihood that a positive result represents a true positive. We will also test the utility of giving providers information rapidly—for example, contacting them directly when life-threatening laboratory abnormalities are discovered (Figure 5). We will also develop a method of providing concise, actionable feedback to management about how tests are being used and misused.

DIAGNOSIS-SPECIFIC INITIATIVES AND ORDER ENTRY

Nationally, many institutions are investing substantial energy in developing critical pathways. Two major issues with pathways are how to implement them and how best to collect variance data. Many are using a "computer blackboard" approach. Critical paths will clearly interface well with order entry, as one of the results of pathways will be to generate "order sets," which can readily be implemented on a daily basis. The information available because orders are on-line should

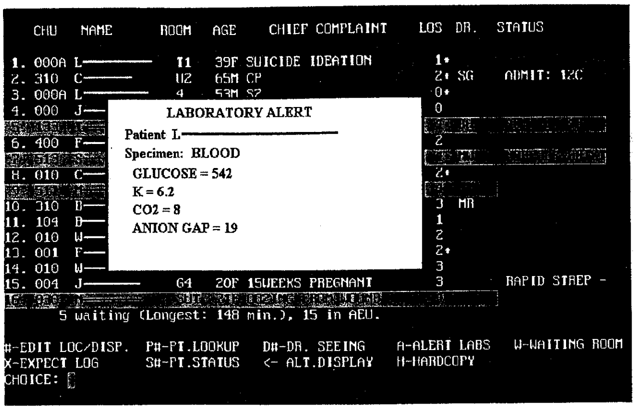

Figure 5. Computer alert to the provider when a markedly abnormal laboratory test is recovered. Depending upon the urgency of the abnormality, providers will be notified by having the computer system page the provider directly or deliver an electronic mail message.

be very useful as a source of variance data as well; it greatly facilitates the task, for instance, of determining when a medication was given on time.

QUALITY-RELATED INFORMATION SYSTEMS AT BWH

Until recently, the quality support system at BWH was of a standard type. Long, detailed reports were compiled by individual departments, which periodically submitted these reports to senior leadership. While most departments reported performance improvements due to specific programs, few were able to sustain their gains. Little feedback was given to individual departments by senior leadership.

This system was dismantled, and the BWH quality management department is currently developing a new system, in collaboration with information systems. It will be organized according to the following principles: (1) it will include ongoing measurement of meaningful outcomes including patient care outcomes (e.g., adverse event rates, functional status), efficiency outcomes (e.g., charge, length of stay), process measures (e.g., delays), and satisfaction outcomes (e.g., patient and provider satisfaction); (2) it will use reporting by exception so that information is transmitted effectively; and (3) it will facilitate vertical and horizontal data transmission. A number of initiatives are now underway within the hospital to incorporate measurement of both processes and outcomes. For example, SF-36 scores[29] are being routinely collected by nursing for all admissions, and critical pathways are being developed for a number of diagnoses.

The hope is that this system will facilitate the transition described by Berwick[30] from the monitoring of a few indicators in retrospective, static fashion to a dynamic, proactive system in which meaningful data are readily available to the relevant individuals. Increased use of the information system to gather and aggregate quality-related data should both improve reliability and decrease cost. Order entry, together with the development of event monitors, will also greatly facilitate this transition because of the huge additional volume of clinical data that will be available for analysis.

Although we are only beginning to mine the potential of the order entry database, several uses that are already underway may prove illustrative. For example, the availability of these data will greatly facilitate meeting regulatory requirements, in particular those of the Joint Commission on Accreditation of Healthcare Organizations (Joint Commission). One of the Joint Commission mandates has been that hospitals conduct regular drug utilization evaluations by provider, and that this information be made part of providers' records, to be used for accreditation. Before the advent of order entry, this was a monumental task; it was not even clear who had written most drug orders.

Another example comes from the utilization review group at BWH, which has found that order entry has made doing its work dramatically easier. Much of the information about what treatment the patient is undergoing is now available on-line, making review of the paper chart frequently unnecessary for utilization review to respond to the numerous queries from managed care organizations.

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Physician order entry has tremendous potential for improving the quality of care, as illustrated by the experience of BWH and others to date. Since many of the important actions that take place within the hospital occur as the result of an order, simply having this information on-line is enormously helpful in evaluating processes within an organization. However, the most exciting ramification of physician order entry is the opportunity it gives to provide real-time decision support such as reminders or information. Future directions include substantial amplification of this capability and development of tools for extracting information contained in these databases in ways that help the organization. Finally, implementation of physician order entry in any health care organization will be difficult, and for it to succeed, it is critical that the opportunity be used judiciously.

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