Design of an Easy-to-Use Physician Order Entry System with Support for Nursing and Ancillary Departments

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The Brigham Integrated Computing System (BICS) provides a broad range of clinical and administrative data-management functions for Brigham and Women's Hospital (BWH), a 720-bed major urban teaching hospital. We describe here the development of an inpatient order-entry system (BICS-OE) which is fully integrated into the BICS clinical environment. BICS-OE uses direct entry of orders by physicians to improve order response time and minimize transcription problems.

BICS-OE includes a number of novel features to enhance its acceptance by physician users and its benefit to clinical practice in the hospital. Dual-mode input gives users a choice of full-screen assistance with ordering, or an intelligent text mode which provides rapid entry of orders by direct typing. An automated primary/on-call coverage list directs patient alerts and cosigning requests to the proper physician. Variable order sets allow a large group of orders to be stored and entered rapidly, even when some of the orders may change for different conditions. Multitasking allows the user to check prior orders and labs while concurrently entering new orders. The system permits a wide range of order checking and alerts.

ORDER ENTRY: BENEFITS AND PROBLEMS

Computer order entry provides a number of advantages to the hospital:

1. Orders are easier to read, and may be tracked as part of the patient's automated record.
2. Reimbursement is improved because of increased legibility.
3. A variety of ordering errors, inconsistencies, and conflicts can be checked.
4. Orders can feed directly into other information displays, such as medication administration, work lists, and Kardex.
5. If the order-processing departments are properly connected, faster order handling is possible because of reduced need to carry orders around the hospital by hand.

If order entry is performed by physicians, there are additional benefits:

6. Orders can be made from remote sites in the hospital, or even from outside the hospital. Thus, the need for telephone orders is lessened.
7. Errors due to faulty transcription and misreading can be lessened.
8. Order sets can be used to increase consistency and reduce errors in ordering.

Nonetheless, acceptance of computer order entry by physicians has been problematic [1]. The most common complaint is that using the computer is slower than pen and paper entry. Residents who only spend a few months of the year in the hospital may not have time to attain fluency with the computer. Other problems reported include unreliability; difficulty of ordering during computer downtime; difficulty in finding certain types of orders in the menu structure; incompatibility with usual practice patterns (particularly with work rounds); and inability to view prior orders and tests while ordering.

For nursing and order-processing ancillary areas such as pharmacy and laboratory, the concerns are that many systems generate too much paper [2], and do not reorganize the orders in a useful form for processing. In these cases, the orders may be just as hard or harder to process than they were on paper. At best, computerized OE may provide these services with the same input as they had before, with no added value to justify use of the computer.

In deciding to develop BICS-OE, we seek to make the computer both acceptable and beneficial by striving to reach the following goals:

1. Ordering should be faster than pen and paper. Although not every order may be faster, the use of order sets and most-common-orders screens should more than compensate for any loss of individual speed. At the same time, no individual order should be excessively slow to create.

2. The physician should have access to the same information as he/she would have using the paper chart. Physicians in our hospital often write orders in one book with lab results and notes in front of them in another book (or on the computer). If the computer is

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occupied with an order-entry program, the results must still be just as easy to access.

3. Nurses should be able to tell instantly and easily that an order is pending. This should be one of the key advantages of using the computer. Also, doctors should know whether an order has been taken off by a nurse.

4. Orders should be routed quickly to receiving areas. Even before the nurse has taken off an order, a medication order can be sent to pharmacy to start preparation, or a blood-test order can be added to the phlebotomist's work list.

5. All orders should be handled. Although this is not mandatory, many of the advantages of computerized entry will be lost if the doctor has to go to the computer for some orders and to a paper system for other orders.

6. Student and nurse orders should be handled. This illustrates some of the heuristics necessary to make a workable OE system. For example, orders by a medical student require cosigning by a physician, and are not accepted until cosigned; nurse orders (telephone or verbal orders) require cosigning but should be accepted for processing once entered by the nurse.

7. The system should support order feedback and alerts. To realize the quality-of-care advantages, a wide range of checking and alerting should be available.

8. The system should be easy to learn.

DESIGN PROCESS

Our hospital has some inherent advantages which favor the establishment of computerized OE. The great majority of ordering is done by residents, who have had more exposure to computers than senior staff have had (although experience with our ambulatory record system shows that many senior staff take to clinical data entry enthusiastically). They already are invested in the computer system, which is heavily used for results lookup, ambulatory record, and electronic mail. Our residents spend an average of 8-9 months per year on service in the hospital, as opposed to other sites, so that they have plenty of time to be comfortable with BICS.

The potential quality-of-care and cost advantages available with the automated system justify the effort to develop order entry. To head off some of the problems noted above, user groups representing the most common and complex uses of order entry were formed. The groups included physicians, nurses, representatives of pharmacy, laboratory, and medical records; each group also included members of the information systems department. Each group wrote a document that expressed their key needs and caveats about OE. The design team reviewed all of these documents and used them to guide the specification of the system.

As the system was being built, regular meetings were held in which progress could be reviewed by members of these groups. This process led to several major and minor revisions of key program sections.

SYSTEM ARCHITECTURE

Input modes

BICS-OE supports pointing device input, but is designed so that a keyboard is sufficient for all functions. When the physician user first enters the Order Entry section of a patient's file, a pop-up window indicates any pending unsigned orders for the patient. This would occur if a user had terminated a session without completing orders, or if orders were entered by a nurse or a student. The physician can choose to complete and sign those orders. The other available options are to view existing orders, or to enter new orders.

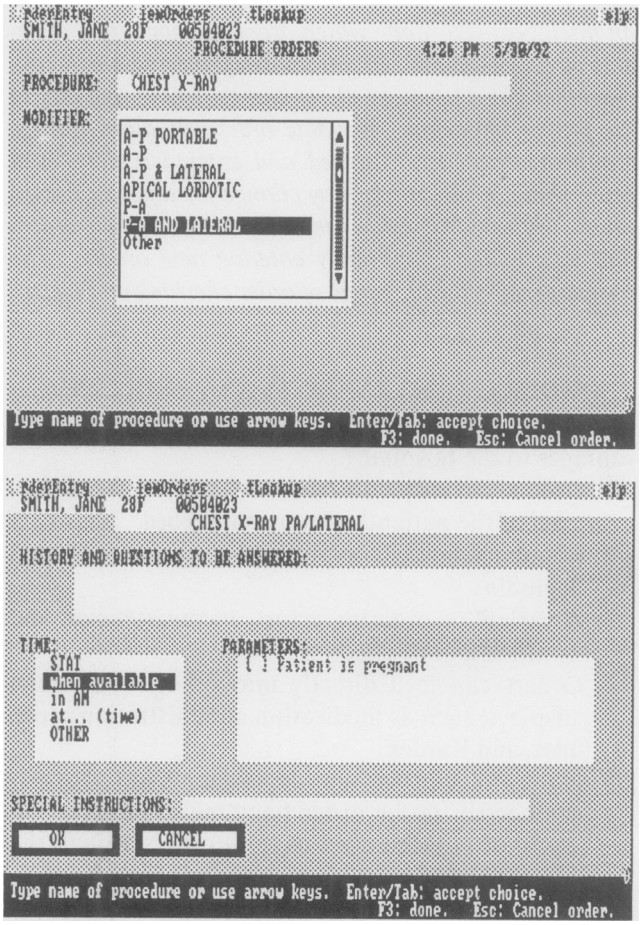

Fig. 1,2. Two steps in the ordering of a chest x-ray.

The user entering orders has a choice of two modes of entry. A typical *assisted mode* screen se-

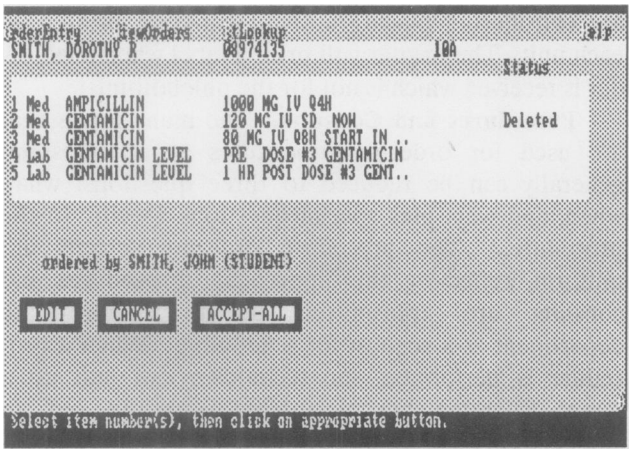

Fig. 3. The edit/confirm screen.

quence is shown in Fig. 1 and Fig. 2. Here, the user has ordered a chest X-ray for the patient, by typing in CHEST X-RAY, CXR, or any subset of these in the Procedure box. The program prompts for any modifiers -- in this case, the view desired. Once the program identifies the procedure, it guides the orderer through the required parameter and special instruction fields.

The choices for order-specific parameters, such as medication dosage, were acquired from a survey of six months of orders at BWH. When the OTHER choice is selected, the program allows free-text input. OTHER input is surveyed periodically to find additions to the regular parameter list.

Some choices may lead to special dialogues. For example, one dosage option for insulin is "Sliding Scale". When this option is chosen, a pop-up window contains a form for entering serum glucose values and a corresponding insulin dosage for each.

The alternative to assisted mode is *text mode*. The user in text mode types orders much as he or she would write on a blank order sheet. A lexical analyzer recognizes the possible token types of each word in the order, making use of large dictionaries of medications, lab tests, procedures, and other keywords. The tokens are passed to a parser, which recognizes sequences of tokens as valid orders and extracts the order parameters. The parser recognizes many valid sequences for a given order type -- thus, "Ampicillin 500 mg iv q6h" and "Please give 500 mg of IV ampicillin q 6h" will both be recognized. Compound orders such as "CBC,Electrolytes,Urine Na in AM" are permitted.

The parser has some tolerance for incorrectly entered orders, whether incomplete or containing misspellings. When an order contains enough information to identify it as a particular order type (e.g., an order for "Grxbfjh at 100 cc/hr" is presumably a request for an infusion), the parser will set the parameters it can identify, then bring up an assisted-mode screen for completion.

When an order is completed, a user may enter other orders or quit to confirm the orders that have been entered already. The edit/confirm screen (Fig. 3) displays the orders in text mode (this also helps the user learn how to use text mode easily). The orderer may delete or edit individual orders before accepting and electronically signing the group of orders.

Action bar functions

At any time in the session, the orderer can make a selection from the action bar at the top of the screen. The *View Orders* menu can display prior orders by order type or in chronological order, or show active treatment orders. The user also can see which orders have been reviewed by a nurse.

When a user selects *Patient Lookup*, the computer provides access to the patient's lab, procedure, and other data. This choice also allows access to the BWH ambulatory record [3], showing problems, outpatient treatments, and notes. A multitasking process allows both order entry and patient lookup sessions to continue, without having to restart either one.

VARIATIONS ON ORDER SETS

Order sets are created by specifying the name of a set, then entering orders in the normal fashion. The user may omit parameters from any order; the program will indicate the missing parameters but will accept the order. When an order set is played back, each order is checked in turn; the incomplete orders will be flagged and the program will prompt the user to complete the order. In this way, order sets can be variable. For example, an order set could include standard admitting orders, but leave out the diagnosis and condition; the user would enter these specifically for the patient being admitted. Or, an order set for heparin would include the bolus dose, the mixture and the order for a partial thromboplastin time, but leave the flow rate to be entered at the time of the order.

Any physician can create his or her own order sets, which are available only to that physician. In addition, "official" order sets can be created or edited by selected persons in each clinical department; these sets are available to all users.

ORDER PROCESSING

Nursing. When an order has been entered and confirmed, the nursing display (Fig. 4) indicates to the patient's nurse that orders are pending. This display shows the time of the oldest pending order, the types

of orders pending, and an indicator for stat orders. A permanent nursing display is located above the nursing station work area; the same display is accessible on any workstation. To acknowledge an order, a nurse selects the patient; the program displays the full list of pending orders. The nurse can accept all orders, or choose some for limited re-editing if necessary. The most common re-editing operation is to modify the times of administration of a treatment; nurses often adjust treatment times from the "standard" times ordered to ones which better suit the patient.

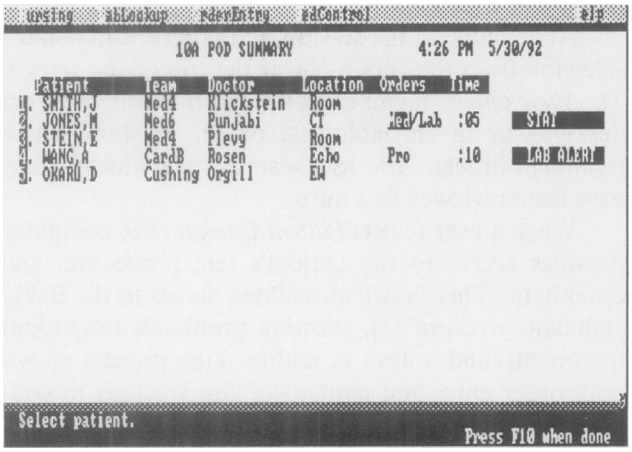

Fig. 4. The nursing pod summary.

All orders are routed to the nurse. In addition, most orders are also sent to individual departments. Some examples are mentioned here.

Medication orders. Medication orders are routed directly to the appropriate satellite pharmacy. A display there shows pending orders for the units covered. The pharmacist translates each order into the proper formulation needed, and prepares it for the patient. The formulation is entered into the pharmacy subsystem for clinical review and billing purposes. The pharmacists also can see non-medication orders for the patient. They use these to help determine any new conditions or potential for adverse reactions.

Medication orders are also routed to the nurse's medication administration record, and to the nurse's worklist.

Laboratory orders. Requests for lab orders are placed on a worklist which is printed for the phlebotomist's rounds. The amount of blood needed and the type of tubes required can be calculated by the computer. A label is printed for each specimen container which contains the patient's name and tests, and a bar code. When the specimen is received in the lab, the computer matches the bar code to the tests ordered.

Tests that are drawn by the doctor or nurse can be sent to the lab in a regular laboratory envelope. We are considering placing a small bar-code printer on each unit. The printer will print a label when a lab order is received which is not for the phlebotomist.

Procedures and Consults. The many forms that are used for ordering procedures at our hospital generally can be reduced to three questions: what, when, and why, plus special questions specific to the procedure. The procedure ordering screens are uniform, reflecting this approach. Procedures and consults are transmitted to the appropriate department as a request for scheduling. When a procedure is performed, the technician can pull up a screen which matches the ordered procedure, and can add necessary clinical and billing data (Fig. 5).

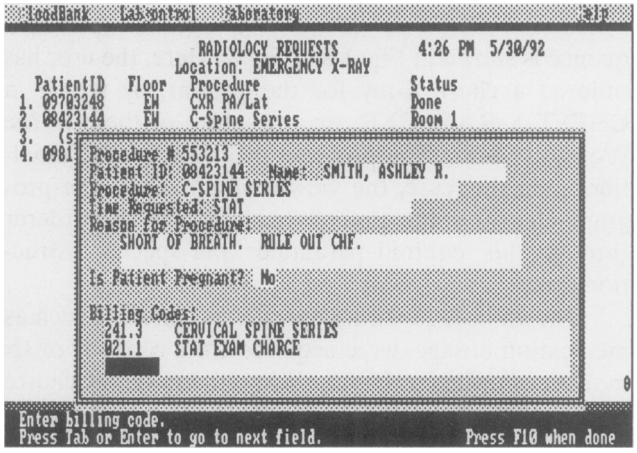

Fig. 5. The radiology technologist has selected an ordered study. The screen allows the tech to add specific procedure and billing information.

SIGNATURES AND COVERAGE LIST

As mentioned above, the occupation of the person signing an order determines how the order is processed. We have established five security categories for order entry: Doctor, Staff Nurse, Medical Student, Agency Nurse, Nursing Student. Orders written by the first two groups are processed fully once they are signed (although the nurse's order requires a follow-up co-signature). The other groups require co-signatures before their entries are valid. Any physician can co-sign an order, and a physician who accesses the patient's order entry area will see a notice that there are orders to co-sign for this patient.

We expect medical students to inform the physician personally when they write orders. The Coverage List subsystem provides a backup to this by allowing BICS to keep track of which physicians are responsible for an inpatient at any given time. By keeping cross-references from physician to patient, a user can always determine a patient's care provider, or a provider's patient group. Mail can be sent

automatically to the correct physician based on information about the patient. For order entry purposes, mail is sent to the doctor whenever there are orders to co-sign on one of his or her patients. This mail falls in a higher-priority category than regular mail. When the doctor signs on to BICS, a message will announce that there is clinical priority mail to be read. Upon reading the notice that there are orders to co-sign, the doctor can jump directly to the patient's file to handle the task, then return to see other mail.

DOWNTIME

BICS-OE runs on The New Platform (TNP), a large microcomputer network which is being implemented at BWH to replace the existing minicomputer-based system. Real-time system monitors, and shadow servers for all major databases, are designed to ensure reliable 24-hour operation. Nonetheless, the possibility of unexpected downtime still must be considered. Two provisions must be made: it must still be possible to give and process orders when the system is down, and users must be able to view past orders and pending orders.

A paper backup ordering kit has been designed for each patient care unit; this allows orders to be handwritten and processed in the way that paper orders have always been processed. A separate function allows retroactive entry of orders in the computer. For the near term, this does not require additional work for the processing areas, because BICS-OE is not yet present on all units, and because it is not being implemented for outpatients at present. As the hospital becomes more dependent on computerized order entry, provisions will need to be made in each area to handle paper orders during downtimes.

All orders are transmitted to a stand-alone logging computer as they are entered. In the event of a system shutdown, the logging computer can display the prior orders over the network. If the network is unavailable, it can print out a summary of all patients' active and prior orders.

Interrupted sessions with unconfirmed orders are stored on disk. The session can be resumed when the system returns on-line.

RESEARCH

There is very little hard data concerning the effect of order entry on the ordering process and patient care. There are many questions to consider: ordering time, convenience, and errors, amount of tests and treatments ordered, patient outcomes, and billing implications, to name a few. The initiation of BICS-OE affords us an opportunity to look at these questions, measuring data before and after the full implementation of computerized OE, and before and after the institution of clinical feedback and reminders. There has already been work done at BWH on the subject of test ordering [4,5] and preventable adverse outcomes [6].

SUMMARY

We have presented the design of an order entry system which is easy for the ordering physician to use, and which allows rapid communication of orders to nursing and processing departments. All involved clinical departments participated in the initial design process and in reviewing the program during development; this participation was instrumental in making the system acceptable to users. Dual-mode input, partial order sets and concurrent patient lookup give the physician flexibility in using the system. The development of the system provides a chance to study the effect of order entry systems on inpatient hospital care.

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