Application of Information Technology

Supporting Patient Care in the Emergency Department with a Computerized Whiteboard System

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Abstract
Efficient information management and communication within the emergency department (ED) is essential to providing timely and high-quality patient care. The ED whiteboard (census board) usually serves as an ED’s central access point for operational and patient-related information. This article describes the design, functionality, and experiences with a computerized ED whiteboard, which has the ability to display relevant operational and patient-related information in real time. Embedded functionality, additional whiteboard views, and the integration with ED and institutional information system components, such as the computerized patient record or the provider order entry system, provide rapid access to more detailed information. As an information center, the computerized whiteboard supports our ED environment not only for providing patient care, but also for operational, educational, and research activities.


Introduction
Efficient information management and communication are essential for providing high-quality clinical care. Compared to other health care settings, the Emergency Department (ED) is one of the most information-intensive environments. Ever increasing patient volumes, an aging population, high occupancy levels, decreased availability of inpatient beds, nursing shortages, and increased patient complexity all require ED staff members to assimilate information from diverse sources to facilitate efficient information management and communication.

The ED is a challenging and dynamic environment from a clinical and operational perspective. The ED staff provides episodic care for acutely ill patients for whom historical information may be limited or completely missing. The fragmentation of patient information combined with a demanding work environment that includes frequent interruptions, handoffs, and multitasking can impact quality of care and lead to an increased error rate in the ED setting. Information technology may help clinicians to improve care by connecting the islands of information that frequently exist in an ED.

Patient tracking boards have become an essential instrument for clinical and operational management in the ED. The “whiteboard,” also referred to as the status board, bed board, census board, or locator board, is viewed as a central and indispensable instrument for communication and information management in most EDs. Whiteboards keep track of patient information and provide an up-to-date view of the overall ED operation. Frequently large dry-erase whiteboards are used to display information. Use of color markers, large grids, abbreviations, and special icons for confidential information can make the information on dry-erase whiteboards complex, busy, and sometimes artistic. The use of dry-erase boards to provide information to ED staff has numerous shortcomings. Providing information at a single viewing point is inefficient because ED staff members must return to one location to view, add, delete, or update information. Once information is deleted from the whiteboard, the data are permanently lost. Dry-erase whiteboards do not support the real-time tracking of patients, which helps to manage ED operations and to anticipate overcrowding. Lack of integration with other information resources, such as the computerized patient record or a provider order entry system, may contribute to delays or even errors.

Dry-erase boards are likely to be replaced by computerized whiteboards in many settings as information technology becomes more sophisticated. Computerization may result in more efficient information management, facilitate integration with other information sources, and lead to real-time patient tracking and ED capacity monitoring.

However, there is limited published information about the ways manual or computerized whiteboards can support a collaborative and integrative work environment for providing clinical care and improving operational efficiency. We describe design considerations, implementation, and experiences using an integrated, computerized ED whiteboard. Through its ability to display relevant patient and operational information in real time the integrated whiteboard is the primary point of entry for information access in the ED.

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Design Objectives
Creating an Information Center for the Emergency Department
The whiteboard should provide staff with an overview of the ED’s entire operation and assist clinicians with fast and easy access to more detailed information about individual patients. The computerized whiteboard is much like a real-time interactive spreadsheet that displays data elements along three discrete axes. The vertical axis lists patient location while the horizontal axis displays patient-specific information. A third axis represents the temporal aspect of a patient moving through the ED. Our goal was to create an ED whiteboard that provides a high-level summary view, which facilitates communication, supports collaborative work, and serves as the single point of entry for obtaining more detailed information for the clinical and operational information needs of all staff members within and outside the ED who are involved in the patients’ care.

Sharing Information: Integration with Hospital Information Systems
The ED is a crossroad for many different health care processes resulting in a complex stream of information that is necessary to manage various clinical and operational tasks. An increasing number of patients, some with complex comorbidities, present to the ED in severe medical conditions that require swift decision making; however, decision making is frequently hampered by the limited ability to access and share information. Access to information in the ED requires the availability of shared resources, such as the admit-discharge-transfer system, the hospital’s clinical information system, the radiology and laboratory information system, the hospital bed management system, or regional information systems. 29-31 To ensure continuity of care and efficient operational workflow between the ED and related health care services, information from the ED needs to be accessible outside the ED. Sharing of clinical and operational information such as triage information, ordered and completed exams and interventions, discharge instructions, operational activity, biosurveillance reports, etc., is equally critical from a patient and hospital management perspective. The bidirectional sharing of information between the ED and other health care entities supports continuity of care and was viewed as one of the most important and beneficial aspects of an integrated whiteboard application.

Integrating Information Technology with Workflow
The unpredictability and volatility of ED patient volumes have a substantial impact on workflow patterns as the ED and hospital staff have to adapt to a rapidly changing environment that requires dynamic shifting of resources to meet patients’ needs. ED workflow is characterized by multitasking, frequent interruptions, and a high volume of brief communication tasks. 32-36 It is not surprising that such a vulnerable environment experiences a high level of medical errors, some of which are related to breakdowns in efficient communication.

To decrease unnecessary communication fragments our design objectives included the requirement that the “most knowledgeable” staff member be responsible for any whiteboard changes that are related to a specific workflow process. For example, the bedside nurse is most knowledgeable about when the patient physically leaves the ED. He or she is responsible for documenting the discharge on the computerized whiteboard, a process that frequently was completed by the charge nurse, who had to be interrupted to update the whiteboard. Letting the most knowledgeable individual take responsibility also supports the timely completion of the whiteboard task, which should provide more accurate data. In addition, we attempted to avoid redundant documentation of whiteboard tasks on paper or in other information systems.

Providing Decision Support
One of the advantages of a computerized board’s tracking functionality is its ability to provide real-time and post-hoc decision support for clinical, operational, educational, and financial activities. 20,21 An example of real-time decision support is the calculation and display of operational statistics, which can support decisions about ED capacity and patient flow, including the management of ED overcrowding episodes. 21,37-39 The availability of an enterprise data warehouse provides the framework to analyze and trend historical data. 20,21 Combining data from the ED whiteboard and other electronic systems can create a rich information infrastructure that supports off-line decision support. An example is the generation of standardized reports and scorecards, which track clinical, operational, and educational metrics.

Facilitating Information Display and Ease of Navigation
Whiteboards provide a condensed and high-level summary view of ED information that is constantly changing. The limited amount of visual area available on a computer screen requires solutions that balance the need to display large amounts of data in a desirable level of detail with the need for a comprehensible overview that does not lead to information overload. Our design objectives included the ability to display condensed high-level summary information and to provide access to detailed information and other applications with little interface navigation and user manipulation.

Minimizing User Training
Many different staff members within and outside the ED are involved in providing care to ED patients and, therefore, need access to the whiteboard application to view, capture, or update information. The ED depends on an extensive staff network that includes rotating residents, medical students, consulting physicians, registration staff, environmental services staff, case managers, full- and part-time nurses, etc. With such a large number of staff supporting the care of ED patients, frequent staff changes are unavoidable. It was considered impractical to conduct ongoing education about whiteboard functionality. As a result, our design objectives included an intuitive interface that required minimal, on-the-job training, which can be provided by a peer.

System Description
Architecture
The system is deployed in the adult ED of Vanderbilt University Hospital and the pediatric ED of Vanderbilt’s Monroe Carell Jr. Children’s Hospital. Both settings have...
clinical workstations throughout the ED, including the patients’ rooms. Two 60-inch, touch-sensitive plasma monitors display the whiteboard in the adult ED (Figure 1). Wireless network connectivity is available in both EDs, which facilitates whiteboard access via PDAs and cart-mounted laptops.

The whiteboard system is a Java-based three tier client-server application currently running on Weblogic® 8.1. The whiteboard infrastructure is based on a relational database (Oracle®, 10g) and implemented with the Java programming language, Java Server Pages, Javascript, Servlets, Cascading Style Sheets, and stateless session and message beans. A Java Message Service provides connectivity to several interfaces. The application is browser-based (Microsoft Internet Explorer®). Components are housed on fault-tolerant, redundant servers. The hospital-wide Resource Access Control Facility® (IBM®) application manages user identification and authentication.

**Integration**

Using a component-based approach, the whiteboard integrates or exchanges information with other applications (Figure 2). The admit-transfer-discharge system provides patient registration data and receives patient disposition information. The ED triage component provides acuity levels, chief complaints, indicators for high acuity condi-

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**Figure 1.** ED treatment area: Clinicians rely on the ED information system components for communicating, documenting, and retrieving patient care information. The large, touch-sensitive monitor (arrow) provides clinicians with a central location for coordinating care, discussing high-level patient management information, and reviewing ED operational activity.

**Figure 2.** Functional integration of the ED whiteboard system with other ED information system components, and the institutional information system applications.
tions, such as symptoms suggestive of acute coronary syndrome, or results from screening questions, such as domestic violence. The institution’s electronic medical record and the provider order entry system can be launched directly from the whiteboard after user authentication. The order tracker application provides the number and status of clinicians’ orders. The radiology information system supplies radiology exam status information. For patients requiring hospital admission, clinicians submit an online bed request via the ED whiteboard to the hospital’s bed board application. In turn, the hospital bed board application informs the clinician’s order. The radiology information system supplies tracker application provides the number and status of clinical patients.

Functionality
Limited and fully functional whiteboard versions provide users with various information access modalities. One limited whiteboard version allows operational tasks, such as signing up for patients or changing patient locations. This version operates as a screen saver and is the default view on the large screens and on computers that are closely monitored by the ED staff (Figure 3, Table 1). On computers that cannot be monitored closely, such as those in hallways, the standard hospital screen saver is displayed preventing unauthorized individuals from viewing any patient information. A second limited whiteboard version that excludes patient information was developed for display in patient rooms and on PDAs. The two limited versions were implemented to uphold the required level of patient confidentiality even though this conflicts with the demand for ease of information access.

Access to the fully functional whiteboard version from liberally distributed clinical workstations in the ED requires a two-level user identification and authentication process. The full version is integrated with the institution’s computerized patient record allowing ED clinicians to select patients directly from the whiteboard and providing easy and rapid access to a patient’s entire electronic medical record. Time-outs on the ED computers have been set aggressively to a few minutes reflecting the computer usage pattern of a busy ED environment, which is characterized by frequent, but relatively short interactions from different users. As a browser-based application the whiteboard is accessible to eligible hospital staff outside the ED, such as the admission office, the offsite ED administrative offices, hospital administration, or research staff.

Patient-Related Demographic Information
The hospital’s admit-discharge-transfer system provides the patient’s name, medical record number, encounter number, age, sex, gender, time of arrival, and security indicator. A rapid, abbreviated registration process assures that a new patient encounter appears on the whiteboard shortly after a patient enters the ED facilities. For patients in life-threatening conditions pre-registered STAT names can be activated directly from the whiteboard. Mounted, wireless laptops facilitate registration updates and bed side registration for ambulance patients who are brought directly to a treatment room. In our environment the time of quick registration is defined as the patient’s time of ED arrival and used for tracking length of stay times.

For ease of use and patient safety concerns we prefer displaying patient names’ using the full last name and the first letter of the first name. However, the HIPAA privacy and confidentiality requirements do not routinely allow displaying patients’ names publicly. At registration, patients are given the opportunity to sign a waiver for displaying their names on the whiteboard. The vast majority of patients consent to name display. For the rare patient who declines allowing the name to be displayed or who is considered a security risk (e.g., gun-shot wound, assault), a “No Info” label replaces the patient’s name on the whiteboard. When a qualified caregiver signs in to view medical information, the patient’s full name is displayed on the clinician’s workstation.

It is not uncommon to have two or more patients with the same or similar names in the ED. To avoid confusion over patient identities the whiteboard system applies the soundex algorithm to recognize two or more patients with identical or similar sounding last names. The respective patients’ names appear automatically on a different colored background (“name alert”) alerting staff that potential for error exists for these patients. In our setting, the name alert function also provides an unanticipated benefit by notifying the registration staff when a duplicate registration has occurred.

Staff Information
All staff members are required to sign in and state their assigned role for the shift, e.g., charge nurse, attending physician, medical student. This allows assigning staff to functional groups, e.g., only attending physicians are displayed in the attending column. Medical students can sign up for resident roles if desired. A placeholder in the resident’s drop-down list allows attendings to advise residents not to sign up for a patient. This allows attendings to treat patients without involving a resident, such as during periods of peak census, for special types of patients, or when treating patients in the “fast track” area. The names of the charge, triage, and flow nurse are displayed at the top of the whiteboard. Residents and attendings have a flag next to their respective columns for annotation purposes, e.g., indicating that they have seen the patient or that a patient’s chart has been dictated.

Management of Bed and Patient Location
An ED bed board view supports staff in moving patients within the ED environment. The whiteboard’s bed column gives access to the ED bed board, which displays patient information for occupied beds and the status level for unoccupied beds. If a bed is unoccupied, the whiteboard’s empty patient name field provides access to a drop-down list that allows staff to indicate various bed status levels (Table 2). When a nurse completes the discharge documentation on the whiteboard indicating that a patient has physically left the ED, the “needs cleaning” status is displayed automatically. Once the room has been cleaned, environmental services staff indicate on the whiteboard that the room is available again. Some bed status levels, such as “needs cleaning” prevent the ED staff from placing a patient in a room. Displaying the elapsed time since the last status change provides information about ED room utilization and turn-around times. At times of increased ED volume the charge nurse can dynamically activate temporary hallway locations to predetermined locations on the whiteboard. On the waiting room display, the triage staff can also prioritize
patients requiring a treatment bed, or indicate patients who may not require a bed to complete their treatment.

Chief Complaint
During the registration process an administration clerk captures the patient’s free text chief complaint, which the whiteboard displays in an upper case font. In our ED, captured free text chief complaints are occasionally inaccurate, clinically obscure, may not represent a chief complaint, and include misspellings or abbreviations. In an effort to standardize chief complaints we added an ICD-9-CM coding schema to our ED triage component. As part of the computerized triage documentation the triage nurse or the patient’s primary nurse converts the patient’s chief complaint from free text into an ICD-9-CM coded format. Coded chief complaints are displayed in lower case, allowing staff to identify uncoded chief complaints. Patients with high risk conditions, such as acute coronary syndrome, are identified during the triage process. To alert staff about patients presenting with a high risk condition selected chief complaints are displayed on a red background. Similar flags

Figure 3. Display of the ED Whiteboard in a top-level view (limited functionality): Operational information is displayed at the top of the whiteboard, such as the charge and triage nurse, diversion status, or ED occupancy levels in the waiting room (right upper corner: “WR”) or the treatment area (right upper corner: “ED”). Below the operational information is the menu bar, which provides access to different whiteboard views such as waiting room, recent discharges, staff roster, “My Patients,” or the registration log. Below the menu bar patient related information is displayed. Table 1 explains the patient related data elements of the ED whiteboard in more detail. For confidentiality relevant data elements were altered.

<table>
<thead>
<tr>
<th>RN</th>
<th>BED</th>
<th>ARR</th>
<th>LOS</th>
<th>AHR</th>
<th>NAME</th>
<th>DT</th>
<th>S/A</th>
<th>M/NR</th>
<th>COMPLAINT</th>
<th>MD</th>
<th>AT</th>
<th>CONSULT</th>
<th>LR/RR</th>
<th>ADMIT</th>
<th>D/C</th>
<th>R</th>
<th>P</th>
<th>Plan</th>
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</tbody>
</table>

| Figure 3. Display of the ED Whiteboard in a top-level view (limited functionality): Operational information is displayed at the top of the whiteboard, such as the charge and triage nurse, diversion status, or ED occupancy levels in the waiting room (right upper corner: “WR”) or the treatment area (right upper corner: “ED”). Below the operational information is the menu bar, which provides access to different whiteboard views such as waiting room, recent discharges, staff roster, “My Patients,” or the registration log. Below the menu bar patient related information is displayed. Table 1 explains the patient related data elements of the ED whiteboard in more detail. For confidentiality relevant data elements were altered.

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exist for other situations including patients who screen positively for domestic violence or patients who represent a security risk to the patient or the hospital staff, such as public figures, victims of violent crimes, or patients with a history of aggressive behavior towards healthcare providers.

Coding chief complaints has several advantages. Sensitive chief complaints can be recognized and replaced by abbreviations that may not be easily identified by patients and visitors inside the ED. For example, any alcohol-related chief complaint is displayed as “a&d.” Standardized chief complaints help support data abstraction and reporting mechanisms. They also have the potential to facilitate research, support the implementation of clinical guidelines, assist in quality improvement activities, and allow epidemiological studies and ad-hoc syndromic surveillance based on specific chief complaints. The availability of ICD-9-CM codes has the additional advantage of supporting order entry because EDs are required to provide a reason for ordering specific laboratory tests and radiologic exams.

**Order Status Notification**

From the whiteboard the nursing staff can launch an order tracker application which supports the management and documentation of orders entered through the computerized provider order entry system. Color-coded notifications in the order tracker column inform staff about the presence and the number of new, incomplete, and completed orders. For majority of patients for which a single consult is ordered and allows basic tracking.

**Table 1 • ED Whiteboard Information Content**

<table>
<thead>
<tr>
<th>Element</th>
<th>Abbreviation</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedside nurse</td>
<td>RN</td>
<td>RN responsible for patient</td>
<td>(from staff roster)</td>
</tr>
<tr>
<td>Bed</td>
<td>BED</td>
<td>patient’s location in ED</td>
<td>(from ED bed board)</td>
</tr>
<tr>
<td>Arrival time</td>
<td>ARR</td>
<td>time of registration</td>
<td>ADT system</td>
</tr>
<tr>
<td>Length of stay</td>
<td>LOS</td>
<td>length of stay in the ED</td>
<td>derived from arrival time</td>
</tr>
<tr>
<td>Acuity level</td>
<td>A</td>
<td>triage acuity level</td>
<td>(during triage process or at bedside)</td>
</tr>
<tr>
<td>Health risk indicators</td>
<td>HRI</td>
<td>indicator for known provider risks</td>
<td>(triage or bedside RN)</td>
</tr>
<tr>
<td>Application launcher</td>
<td>AL</td>
<td>initiates institutional applications</td>
<td>ADT system</td>
</tr>
<tr>
<td>Patient name</td>
<td>NAME</td>
<td>patient’s first and last name</td>
<td>ADT system</td>
</tr>
<tr>
<td>Order tracker</td>
<td>OT</td>
<td>initiates order tracker system</td>
<td>order tracker application</td>
</tr>
<tr>
<td>Gender</td>
<td>S</td>
<td>patient’s gender</td>
<td>ADT system</td>
</tr>
<tr>
<td>Age</td>
<td>AGE</td>
<td>patient’s age</td>
<td>ADT system (derived from DOB)</td>
</tr>
<tr>
<td>Medical Record Number</td>
<td>MRN</td>
<td>unique patient identifier</td>
<td>ADT system</td>
</tr>
<tr>
<td>Chief complaint</td>
<td>COMPLAINT</td>
<td>patient’s primary complaint</td>
<td>(from registration, triage or bedside RN)</td>
</tr>
<tr>
<td>Resident name</td>
<td>MD</td>
<td>resident physician responsible for patient</td>
<td>(from staff roster)</td>
</tr>
<tr>
<td>Attending name</td>
<td>AT</td>
<td>attending physician responsible for patient</td>
<td>(from staff roster)</td>
</tr>
<tr>
<td>Consultation</td>
<td>CONSULT</td>
<td>consultation requests</td>
<td>user (physician)</td>
</tr>
<tr>
<td>Laboratory notification</td>
<td>LR</td>
<td>indicates presence of new lab results</td>
<td>CPR/laboratory information system</td>
</tr>
<tr>
<td>Radiology notification</td>
<td>RD</td>
<td>indicates completion of radiology exams</td>
<td>radiology information system</td>
</tr>
<tr>
<td>Discharge status</td>
<td>ADMIT</td>
<td>indicates initiation of hospital admission</td>
<td>hospital bedboard application</td>
</tr>
<tr>
<td>Departure status</td>
<td>D/C</td>
<td>indicates initiation of departure process</td>
<td>user (physician)</td>
</tr>
<tr>
<td>Registration status</td>
<td>R</td>
<td>indicates completion of registration process</td>
<td>ADT system</td>
</tr>
<tr>
<td>Primary Care Physician</td>
<td>P</td>
<td>indicates availability and notification status of the patient’s primary care physician</td>
<td>user</td>
</tr>
<tr>
<td>Discharge/Departure</td>
<td>DCRN</td>
<td>actual ED discharge/departure process</td>
<td>user (RN); only on authenticated version</td>
</tr>
<tr>
<td>Comments/Annotations</td>
<td>PLAN</td>
<td>information about current treatment plan</td>
<td>user (ED staff)</td>
</tr>
</tbody>
</table>

**Table 2 • ED Bed Board Status Levels**

<table>
<thead>
<tr>
<th>Bed Status</th>
<th>Description/Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available</td>
<td>the bed location is open for a patient</td>
</tr>
<tr>
<td>Occupied</td>
<td>the bed location holds a patient</td>
</tr>
<tr>
<td>Hold EMS</td>
<td>bed is reserved for an arriving EMS patient</td>
</tr>
<tr>
<td></td>
<td>(not yet arrived)</td>
</tr>
<tr>
<td>Hold Heli</td>
<td>bed is reserved for an arriving aeromedical</td>
</tr>
<tr>
<td></td>
<td>transport (not yet arrived)</td>
</tr>
<tr>
<td>Hold Team Triage</td>
<td>bed is reserved for a patient being seen by a physician in team triage</td>
</tr>
<tr>
<td>New Patient</td>
<td>a patient has arrived in the ED, but not yet</td>
</tr>
<tr>
<td></td>
<td>registered (e.g., trauma patient)</td>
</tr>
<tr>
<td>Seen by Resident</td>
<td>a resident has seen a newly arrived non-registered patient (e.g., trauma patient)</td>
</tr>
<tr>
<td>Needs Cleaning</td>
<td>notifies environmental service that location</td>
</tr>
<tr>
<td></td>
<td>needs to be prepared for next patient</td>
</tr>
<tr>
<td>Isolation Hold</td>
<td>notifies environmental service to wait for 60 min before cleaning the room</td>
</tr>
<tr>
<td>Closed</td>
<td>the bed location cannot be used (e.g., not</td>
</tr>
<tr>
<td></td>
<td>staffed, requiring repair)</td>
</tr>
<tr>
<td>No Bed</td>
<td>indicates the absence of a bed after the room</td>
</tr>
<tr>
<td></td>
<td>has been cleaned</td>
</tr>
</tbody>
</table>
example a red flag indicates new orders that the nurse has not yet acknowledged.

**Exam Status Notification**
Color-coded alerts notify staff about the status of radiology studies or the availability of laboratory results. The ED information system is interfaced with the hospital’s computerized patient record, enabling direct access to more detailed information about laboratory results, imaging exams, and documentation of ED procedures. For example, if the whiteboard displays a laboratory notification, the physician may select the patient’s laboratory notification field and be directed to the patient’s current and previous laboratory results in the computerized patient record. Similarly, the three-level, color-coded notification of radiology exam status provides direct access to a summary of imaging exam information including the status of individual tests, initial interpretation and whether an attending radiologist has reviewed the study. ED physicians are required to acknowledge that they have reviewed information from radiology exams. This allows the system to identify new information that is available as part of updating the preliminary exam interpretations, which occur frequently, such as when attending radiologists review resident radiologists’ interpretations and enter additional information. The goal of providing detailed radiology exam status information was to improve the timeliness of notification and the communication between radiologists and ED physicians. Due to the recent focus on monitoring quality indicators for pneumonia, the system queries the radiologists’ preliminary interpretation for keywords suggestive of pneumonia. If keywords are found, the radiology column notifies clinicians about the possibility of pneumonia, prompting the clinician to review the radiology information.

**Patient Disposition Process**
Because different processes are involved for hospital admitted and treat-and-release patients, separate columns are implemented to notify clinicians about a patient’s planned disposition. Through the admission column physicians submit an electronic bed request to the hospital’s bed board application. The bed request includes mandatory information such as requested unit, accepting physician and service, observation or inpatient status, and the need for a monitored or isolation bed. When the bed management team assigns a bed the whiteboard displays time and type of the bed request. A three-level bed status notification informs the ED staff about the progress of the hospital bed allocation process, including proposed patient status, bed request time, and final hospital bed assignment. For treat-and-release patients, physicians activate the departure field informing the nursing staff that the clinical evaluation process is complete, and the discharge instructions and prescriptions have been finalized.

**ED Disposition**
After completing patient education, the nurse activates the discharge page, which collects disposition information and removes a patient from the whiteboard, indicating that the patient has physically left the ED. The discharge page includes required disposition information, such as how the patient left the ED, or alerts, such as a reminder to cancel any pending bed requests for patients who were eventually not admitted to the hospital. A registration alert informs the nurse whether the patient needs to pass by the registration desk to provide any additional information or to compensate the ED for any financial obligations.

**ED Registration Information**
The ED registration process has the potential to become lengthy and time-consuming. When the registration staff has completed rapid registration, the admission-discharge-transfer system updates the whiteboard indicating whether a patient’s registration is complete or not. After the medical screening exam, the staff captures any additional patient registration information in the waiting room or at the bed side. Once the staff has completed the registration process, they set the registration flag on the whiteboard. The discharging nurse is required to accompany the patient to the discharge station when a red flag is displayed indicating that the patient owes a co-payment or a yellow flag indicating that additional administrative information is needed. A green flag indicates that the registration process is complete and the patient can be discharged from the ED without delay.

**Patient Referral Information**
The efficient identification of and communication with the patient’s primary care physician remains a challenge for every ED. Although primary care physician information is available in the institution’s computerized patient record, the information may not be accurate at the time of the ED encounter. Our ED captures the patient’s current primary care physician information in free text on a separate data entry form including name, phone number, and a checkbox for denoting notification. A flag is displayed on the whiteboard to indicate that primary care physician information is available and whether the primary care physician has been notified.

**Treatment Plan**
Most ED physicians like to keep track of a patient’s workup plan, pending studies, and comments, which helps providers at shift change when patient care is turned over to new ED staff members. The patient’s free text plan field is displayed on the whiteboard. A separate provider note field captures information that clinicians prefer not to display on the whiteboard, and an additional sign-out field facilitates reporting among residents.

**General Information and Operational Statistics**
The whiteboard computes and displays operational statistics in real-time and keeps the ED staff informed about the occupancy rate and overall turn-around times. For the waiting room, the whiteboard displays the number of patients and their average wait times. For the clinical exam area the occupancy rate and the average ED length of stay are displayed. In addition the whiteboard displays the number and average length of stay for boarding patients, the number of expected patients, such as announced transports, and the average Emergency Severity Index acuity level. The whiteboard also displays in real-time the diversion status of specific service units, which is maintained by the institution’s aeromedical service.

**Additional Whiteboard Views**
The whiteboard allows the display of the entire ED, or each of the two subunits (A- and B-Pod) separately. A personalized “My Patients” view lists only patients for which the
user has resumed responsibility. The whiteboard’s detailed electronic registration log has eliminated the need for maintaining a manual log book. Additional log files include information about all clinicians who cared for a patient and a room trace capturing all beds that patients occupied during the ED encounter.

**Downtime Periods**
The whiteboard depends on the reliable functioning of a complex information system infrastructure. To successfully manage scheduled and unscheduled ED information system failures, downtime procedures need to be available. The unavailability of whiteboard information, even for a short time period, slows ED operations, delays patient care, and may jeopardize timely decision making with the increased potential to introduce errors. When the computerized whiteboard is unavailable, its information is transferred to a traditional, dry-erase whiteboard. Depending on the type of information system failure, the downtime may result in two different whiteboard behaviors.

If the primary ED information system service becomes unavailable, all whiteboard information disappears immediately. To prevent complete loss of information, a local computer in the ED driving the main display continually saves an image of the whiteboard content every five minutes. If an error prevents the whiteboard from being displayed, the computer defaults to the most recent saved whiteboard image, which can be printed out and supports the transition to the dry-erase whiteboard. In addition to storing whiteboard screenshots locally, the images are transferred to a database, which allows the review of the whiteboard view in 10 minute increments. The availability of historical whiteboard images supports the bi-monthly review of appropriateness of diversion episodes and is helpful in managing patient complaints.

**Status Report**
The ED whiteboard application has been in operation since September 2002 and been used during the care of >400,000 patients in the adult and pediatric ED. Staff compliance with non-mandatory whiteboard elements is high; for example, >97% of patients have a coded chief complaint or an acuity level assigned, >98% have an attending of record, and 86% have a bedside nurse assigned. The whiteboard has become the primary instrument for the ED and the hospital to manage various aspects of health care operations, both clinical and administrative. Besides its clinical and operational functionality, the whiteboard infrastructure has been used for various clinical, administrative, educational, and research purposes.

**Clinical Benefits**
The primary clinical benefits are associated with enhanced communication among care providers, optimized workflow, better continuity of care, and improved access to clinical and operational information through the whiteboard’s integrative role as a point of entry for ED clinicians’ information needs. Some examples may illustrate how the application can support diverse clinical tasks. The hospital implemented a daily influenza watch report based on the ED whiteboard’s coded chief complaints. During a recent influenza season, which resulted in up to 70% volume surges in the pediatric ED, hospital administration cancelled elective surgery during peak days in order to have capacity available for patients requiring hospital admission. In addition, the coded chief complaints are transmitted daily to the Nashville Metro Health department to contribute to city-wide biosurveillance. The whiteboard’s chief complaints are used to recruit patients into research studies or to evaluate a patient’s eligibility for guideline initiation. The whiteboard infrastructure also supports the implementation of quality indicators, such as for pneumonia or patients presenting with chest pain. Due to the lack of baseline data prior to implementing the computerized whiteboard, we were unable to measure any direct effects of the whiteboard on throughput times or documentation error rates.

**Financial Benefits**
Direct financial benefits from the whiteboard application are related to improved administrative processes. The previously paper-based ED facility level charge capture was incorporated into the whiteboard’s discharge process, resulting in >99% posted charges, an increase of 2% that translated into additional annual revenue of >$1 million. In addition the time to post charges decreased from an average of three to less than one day, and one charge entry position was freed up for other responsibilities. Recently, the hospital implemented additional improvements in determining and capturing ED charges and discontinued the use of nurses to capture facility level charges at the time of discharge. An annual revenue increase of about $40,000 resulted from having an attending of record for each patient, which helped the billing office to identify responsible attending physicians when patient charts remained unsigned or dictations were missing. The whiteboard supports the completion of registration information and the collection of ED co-payments by alerting the discharging nurse that the patient is required to visit the discharge station. The indirect financial benefits likely outweigh the direct benefits, but they are challenging to estimate because the application indirectly supports numerous intertwined clinical and operational functions, such as improved clinical data quality for billing purposes. The primary benefits are likely be linked to the whiteboard’s ability to streamline processes, improve efficiency, enhance data quality, or facilitate tasks that were previously not possible.

**Administrative Benefits**
The whiteboard database and enterprise data warehouse support daily reporting and updating of the monthly scorecard, which tracks ED specific metrics such as volume, throughput, discharge levels, boarding patients, patients who left without being seen or against medical advice, hours of diversion, etc. Daily reports track ED census, length of stay measures, patients who left prior to ED discharge, and influenza watch report. For other reporting needs the ED leadership can access the enterprise data warehouse through a commercial business intelligence application (ProClarity™) allowing them to create and change queries dynamically. Examples include queries for various performance measures, such as tracking attendings’ relative value units or providing residents’ with educational feedback about their patients. The whiteboard information allows assessment of the impact of improvement initiatives, such as team triage, which added an attending physician to the triage team. ED administration adjusted the staffing models to better match daily
volumes and eliminated triage during morning hours. In addition, the whiteboard information has supported administration in participating in national surveys, managing patient complaints, responding to inquiries from state agencies, or in legal matters associated with ED patient care.

Research Benefits

The whiteboard infrastructure supported various research activities related to clinical or operational studies that include an ED patient flow component, such as examining ED crowding,38,39,58 studying the impact of ED expansion on diversion episodes,59 developing a simulation environment to predict ED operational variables, understanding the effect of ED team triage on time to order a CT in patients presenting with abdominal complaints, tracking workload of providers,62,60 or measuring stress levels of resident physicians.

Discussion

The whiteboard has long been a centralized place for communication and coordination within the ED.61 With its cross-sectional and patient-oriented view the whiteboard has the potential to serve as the primary portal for information needs in the ED. The computerized whiteboard’s ability to integrate, track, and compile information from various sources provides the ED with an indispensable tool to access patient-specific information, coordinate patient management, track individual patient care, and monitor overall ED operations in real time. In our ED the whiteboard has demonstrated its potential to support the redesign of workflow processes, enhance communication within and outside the ED, support the transition of care, provide the infrastructure for decision support, and share and aggregate information. After the institution’s electronic medical record, the whiteboard was the second major information system component and is believed to have paved the way for the successful implementation and acceptance of other information system components, such as computerized provider order entry.

Our experience has shown that in order for the whiteboard data to be accurate and reliable, electronic documentation and data capture must be an integral part of the ED’s regular workflow patterns and cannot require additional or redundant steps. Because the whiteboard was designed around workflow processes, data entry is performed by the most knowledgeable ED staff member with the primary responsibility for capturing a particular piece of information. Tracking operational data became a side-product of regular ED processes rather than being a primary task. For example, information about the times patients were brought back to rooms is accurate because electronically moving the patient out of the waiting room and into a specific room was a necessary step in patient management. Whiteboard functions that are disconnected from regular workflow processes or require additional steps will usually be performed inconsistently.

Automatic real-time updates have improved communication among the ED, inpatient staff, and hospital administration. The clinical and operational hospital staff that support the ED for various tasks have real-time access to the whiteboard and are able to respond faster to an ever changing ED environment. Operational statistics, length of stay alerts, bed status information, diversion status information, the number of patients awaiting inpatient beds, and consultation requests all contribute to the whiteboard’s ability to provide increased visibility of the ED’s current stage of operation. The whiteboard may also serve as a platform for an early warning system that anticipates an ED reaching full capacity. This has the potential to assist EDs with earlier mobilization of support services and inpatient resources. We believe that computerized whiteboards are a critical tool for studying and implementing proposed measures for monitoring ED capacity and overcrowding situations.15,19,38,58

The ease of integrating whiteboard elements that are collected via other components of the ED’s or the hospital’s information system differs among various EDs because they often depend on different information technology infrastructures. An ED may elect to implement a computerized whiteboard with basic functionality and display only ED generated information. Increased functionality and data exchange with other information systems can be implemented in a stepwise approach.57

Our experiences with the integrated computerized whiteboard are limited to a single, academic ED environment. Our objectives and general approaches may be applicable in other ED settings, but other EDs may benefit from alternative solutions due to differing operational processes, patient and provider populations, information management infrastructure, physical layout, or integration capabilities.

One of the most important steps during the implementation and incremental development phases was the creation of a large variety of reports. They stimulated discussions, identified areas of priority, helped to manage expectations, illustrated the potential, and reinforced the importance of capturing data by the most knowledgeable person. The whiteboard data now allow the ED to generate reports and compare them to national benchmarks. Reports on average wait times based on time of day, charge nurse or specific physicians on duty can easily be produced. Drill-downs help the ED to identify processes that have the potential for improvement. In addition to standardized daily or weekly reports, the database can be exploited for ad-hoc queries to answer other operational, clinical, research, or educational questions.

Conclusion

The computerized whiteboard has become an essential instrument for communication and coordination of care in our ED. The real-time availability of cross-sectional and patient-centric data helps to improve the efficiency of patient flow, create transparency and accountability, optimize information management, and maximize effective communication within and outside of the ED. As many EDs move to apply information technology to address operational and patient management challenges, we are convinced that the computerized ED whiteboard will become the center of most ED information systems.

References

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