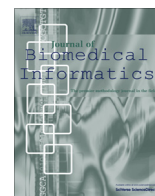


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Informing the design of clinical decision support services for evaluation of children with minor blunt head trauma in the emergency department: A sociotechnical analysis



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ABSTRACT

Integration of clinical decision support services (CDSS) into electronic health records (EHRs) may be integral to widespread dissemination and use of clinical prediction rules in the emergency department (ED). However, the best way to design such services to maximize their usefulness in such a complex setting is poorly understood. We conducted a multi-site cross-sectional qualitative study whose aim was to describe the sociotechnical environment in the ED to inform the design of a CDSS intervention to implement the Pediatric Emergency Care Applied Research Network (PECARN) clinical prediction rules for children with minor blunt head trauma. Informed by a sociotechnical model consisting of eight dimensions, we conducted focus groups, individual interviews and workflow observations in 11 EDs, of which 5 were located in academic medical centers and 6 were in community hospitals. A total of 126 ED clinicians, information technology specialists, and administrators participated. We clustered data into 19 categories of sociotechnical factors through a process of thematic analysis and subsequently organized the categories into a sociotechnical matrix consisting of three high-level sociotechnical dimensions (workflow and communication, organizational factors, human factors) and three themes (interdisciplinary assessment processes, clinical practices related to prediction rules, EHR as a decision support tool). Design challenges that emerged from the analysis included the need to use structured data fields to support data capture and re-use while maintaining efficient care processes, supporting interdisciplinary communication, and facilitating family-clinician interaction for decision-making.

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Abbreviations: CDSS, clinical decision support services; CT, computed tomography; ED, emergency department; TBI, traumatic brain injury.

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1. Introduction

Translating scientific knowledge into clinical practice is a challenge in any healthcare setting. The Agency for Healthcare Research and Quality (AHRQ) reports that it can take as long as two decades for new knowledge to become common practice [1]. As a result, Americans reportedly receive only about one-half of recommended care [2]. Clinical decision support services (CDSSs) are one strategy that may address this issue by enabling clinicians to use electronically-entered patient data to allow rapid access to scientific evidence at the time of clinical decision-making. Although CDSSs have been reported to reduce errors and improve quality of care, they have also been poorly accepted and sometimes associated with negative unintended consequences [3]. Informatics-based strategies for the design and development of CDSSs may enhance clinical integration and thus improve quality of care and mitigate unintended consequences [4–6].

The emergency department (ED) is a particularly challenging setting in which to implement CDSSs [7–9]. Although CDSSs may be an effective method to implement best available evidence, there is limited literature and considerable debate as to its potential effectiveness in improving outcomes in this setting [9–12]. With the goal of reducing unnecessary cranial computed tomography (CT) scans in children, the Pediatric Emergency Care Applied Research Network (PECARN) recently derived and validated two robust, clinical prediction rules that identify both younger and older children at very low risk for clinically-important traumatic brain injuries (TBI) following minor blunt head trauma for whom CT scans may safely be obviated [13].

The sociotechnical dimensions inherent in complex healthcare settings such as the ED influence the design features needed for a system that can successfully support evidence-based clinical decision-making [10]. These dimensions include institutional culture and goals, interdisciplinary workflow and communication, existing information systems and both local and external rules and regulations affecting clinical practice. Research examining the effectiveness of technology in various organizations has emphasized the importance of describing the details of these dimensions and their relationships prior to the introduction of new technologies. Failure to understand the interrelated nature of these dimensions can lead to solutions that support one while potentially harming another [3]. In healthcare settings, this is described as the unintended consequences of healthcare information technology (HIT) [14,15]. The complex sociotechnical facets of healthcare environments, while acknowledged to be inextricably connected, may be deconstructed in order to be examined and described prior to technology development. In any setting, these dimensions can be analyzed and their relationships described so that appropriate system features can be identified that address gaps while supporting existing positive structures. The objective of this study was to describe the sociotechnical environment in the ED setting to inform the design of a CDSS intervention to implement the PECARN TBI clinical prediction rules. In addition, we describe a modified sociotechnical model to reflect the unique requirements of the ED setting that could be used to inform the design of future CDSS interventions.

2. Materials and methods

2.1. Study design

We conducted a multi-site cross-sectional qualitative study (workflow observations, clinician focus groups, key stakeholder interviews), over a four-month period (November 2010–February 2011) prior to developing the CDSS intervention for implementa-

tion of the PECARN TBI prediction rules. Institutional Review Board approval was obtained at each site and informed consent was obtained from all study participants.

2.2. Research sites

All 11 sites participating in the study were part of either the PECARN or the Clinical Research in Emergency Services and Treatments (CREST) network [16,17]. Sites included three free-standing academic children's hospitals, two academic tertiary care centers and six community hospitals located across the United States. All six community hospitals were part of the Kaiser Permanente Health System in Northern California. All sites were using the same vendor provided electronic health record (EHR) in the ED (EPIC[®], Madison, WI) although software versions varied across sites. Nursing documentation, physician documentation and computerized provider order entry (CPOE) were in use at each study site for at least one year prior to the study period.

2.3. Theoretical model

Exploring the complex interactions between the social and technical nature of healthcare work is recognized to be an important step in understanding the potential impact of a new technology [18]. This is often referred to as a sociotechnical analysis [5,18,19]. Sociotechnical approaches to understanding work processes are based on the notion that the social context of work is critically linked to the technical component and as a result, the two continuously influence and alter one another [19]. Although, there is no single, comprehensive sociotechnical theory or approach, there are a number of theoretical and conceptual models based on sociotechnical thinking that can be used to inform the design of suitable structures to support work practices in a given setting [18,20–22]. From the available models, we selected a model proposed by Sittig and Singh [5]. This model was developed based on an in-depth analysis of information technology implementation in healthcare settings and, therefore, we felt it would serve as an appropriate guide for the current study [5]. This model consists of eight-dimensions known to be important to the development of useful and safe IT in healthcare settings [5]. These dimensions include (1) hardware and software infrastructure; (2) clinical content; (3) human–computer interface; (4) people; (5) workflow and communication; (6) organizational policies, procedures and culture; (7) external rules and regulations; and (8) system measurement and monitoring [5]. These eight dimensions form a synthesized model that allows for their practical description while recognizing their complex, interrelated nature [5]. As was done for this project, each dimension can be described as it occurs within a particular healthcare setting. The existing connections among the dimensions can then be reviewed, allowing for an examination of the sociotechnical structures in place that influence the usefulness of a new technology.

We used the eight dimensions of the model to develop an open-ended guide for use in the focus groups and interviews. In addition, we used the model to guide observations of work processes with a focus on patterns of workflow and communication, as well as physical structures in each ED that would impact development and use of a CDSS intervention. The eight dimensions and their application to this project are described in the following paragraphs.

Hardware and software infrastructure includes a description of both the existing hardware and software in use as well as the structures in place that support the maintenance of hardware and updates to existing software [5]. This infrastructure includes IT personnel available to develop new software and support its use as well as the capabilities of available software to address

desired functions. We assessed these components from both the clinical and administrative perspectives, as these may differ and require reconciliation (e.g., clinician requests vs. financial burden). The clinical content and the interface design of any EHR system are recognized as critical components of its usefulness in a particular setting [23,24]. Outdated or inappropriate content has been blamed for overrides of suggestions from clinical alerting systems, while a difficult-to-use interface design can lead to errors [23–25]. We reviewed the proposed content (PECARN TBI prediction rules) of the new CDSS with targeted clinical users and organizational leadership to ensure appropriateness to the ED as well as consistency with organizational policies, procedures and culture. The focus was specifically on policies related to the use of IT systems for the implementation of prediction rules or clinical guidelines. We incorporated an examination of the roles and relationships of different clinician groups as well as clinical and administrative leaders who may be downstream users of CDSS data. An iterative approach toward user interface development was used in order to identify potential usability problems that could create errors so that these could be addressed prior to system deployment [26,27].

Existing patterns of workflow and communication both within the ED as well as across the organization were described so that the CDSS could be appropriately integrated. We assessed how the new CDSS intervention might alter workflow in both positive and negative ways [3,27,28]. External rules and regulations were explored to understand how the CDSS intervention may assist or hinder the organization from meeting its regulatory and quality improvement goals.

In order to ensure that a new CDSS intervention meets its intended goals, a plan for measurement and monitoring should be determined from the beginning of its development [5]. We examined this dimension to ensure that goals for the new CDSS were identified early, a plan for data collection was determined and incorporated into the service and appropriate data analysis occurred after system implementation. The ability to monitor and respond to problems helps to facilitate safe and appropriate CDSS use [3,4].

2.4. Work-flow observations

We applied the method of contextual inquiry to observe clinicians' (residents, attending physicians, nurse practitioners (NPs), triage nurses, staff nurses and physician assistants) workflow in the ED at each site prior to the focus group discussion for the purpose of describing the processes of patient assessment, documentation and decision-making. Contextual inquiry incorporates observations of actual work practices in the work environment with interviewing of those observed [28]. As the clinician was observed, the interviewer asked questions and clarified specific processes in which the clinician was engaged with a focus on areas of interest [28]. Observations were conducted by three members of the research team: one pediatric ED attending physician and two nurse informaticians with expertise in observational techniques. At least two observers were present at all 11 sites. We developed workflow diagrams from notes taken during observations and presented the diagrams at the focus group meetings to generate a discussion of workflow processes.

2.5. Focus groups

Participants in the focus groups consisted of clinicians practicing in the ED and IT professionals at each site. We used purposive sampling to ensure inclusion of a representative sample of practicing ED clinicians at each site as well as site-specific IT

specialists. At least one nurse with expertise in informatics and one ED physician facilitated each focus group. The groups were held in a conference room separate from the ED. We audiotaped all focus groups and conducted a debriefing session after each session in which the research team reviewed the discussion and identified key points and process modifications for the next group.

2.6. Key stakeholder interviews

We conducted interviews with nurse managers, ED medical directors, nursing IT specialists and organizational IT leadership such as chief medical information officers and chief information officers. There was no overlap between focus group and interview participants. We chose IT professionals based on their role in the organization and their knowledge of current informatics systems. Site principal investigators (PIs) and research coordinators identified appropriate ED management and IT leadership for participation in stakeholder interviews. Interviews were conducted by one pediatric ED attending physician and one nurse informatician with expertise in qualitative interview techniques. All but one stakeholder interview were audiotaped (one participant declined audiotaping but consented to written notes to ensure accurate documentation of the content discussed).

2.7. Data analysis

Through triangulation of data sources from the workflow observations, focus groups, and interviews, we conducted a thematic analysis to summarize and describe the sociotechnical issues important to CDSS design. In the first phase of data analysis, an inductive process was used in which specific clinician quotes were divided into categories (Appendix 1). These categories were summarized into 3 themes. This was followed by a deductive process in which we mapped the categories to the eight sociotechnical dimensions. Next, we condensed the original eight dimensions from the sociotechnical model into three dimensions based on the category mappings. Following this, we created a sociotechnical matrix in which the identified categories were cross-mapped with the three themes we identified and the three sociotechnical dimensions (Fig. 1). We managed the data analysis using NVivo 9 (QSR, Cambridge Mass). Results are presented according to the three new sociotechnical dimensions and their related categories identified from our data.

3. Results

We conducted 90 h of workflow observations in total across the 11 sites. Overall, 126 clinicians and IT professionals participated in the focus groups and interviews (Table 1). ED attending physicians, nurses, ED technicians and IT liaisons were included in the focus groups at their respective sites depending on their role – ED resident physicians, fellows and NPs participated at the academic sites where they were employed. At the non-academic sites, participants included attending physicians, ED physician and nursing leadership and clinical IT leadership.

3.1. Thematic analysis

Using an inductive process, we identified a total of 1385 quotes. These were summarized into 19 categories (Appendix 1). We further summarized these categories into three major themes, (1) interdisciplinary assessment processes – 833 quotes (60%); (2) clinical practices related to prediction rules – 315 quotes (23%); and (3) the EHR as a decision support tool – 237 quotes (17%). In

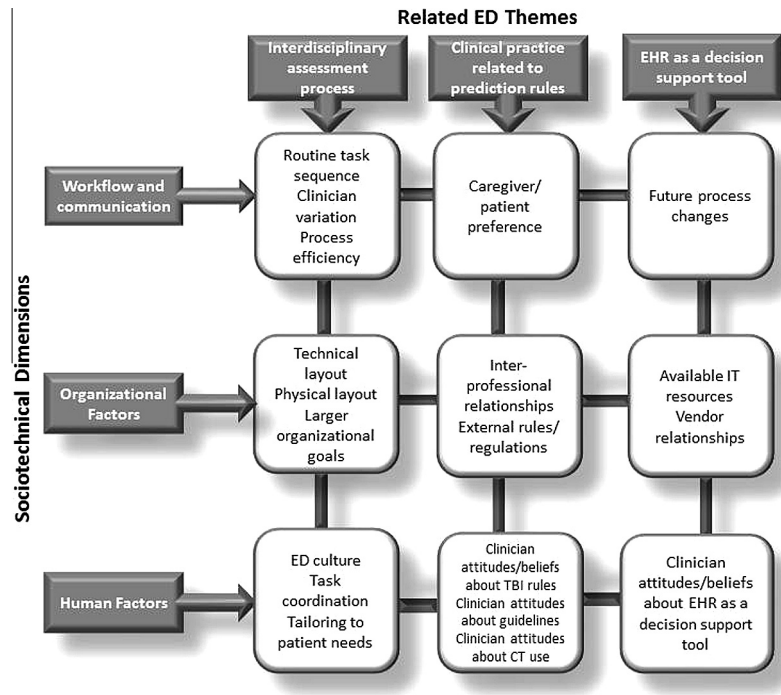


Fig. 1. Sociotechnical matrix.

Table 1
Number and type of clinicians and stakeholders participating in focus groups and interviews.

	Physician attendings N	MD residents N	Nurses (RN/NP) N	Nurse managers N	Other clinicians N	IT liaisons/staff/leaders N	Total N
Focus group participants	27	8	48	0	6	2	90
Key stakeholder interviews	15	0	0	13	0	7	36
Total	42	8	48	13	6	9	126

the second phase of analysis, a deductive process was used to map the nineteen categories to the eight sociotechnical dimensions. When a particular sociotechnical dimension had no mapped categories, it was incorporated into another that better described the data. For example, none of the categories mapped to the sociotechnical dimension 'clinical content'. In our data, the clinician's attitudes and beliefs about the proposed content were more

important than the content itself. For this reason, the category we identified called "clinician attitudes and beliefs about the prediction rules" was mapped to the dimension 'people'. 'Clinical content' was considered to be inseparably related to the perceptions of the people involved. We re-named this dimension 'human factors' to better describe the issue of attitudes, beliefs and cultural relationships that it is meant to capture [5]. Based on the sociotechnical matrix, we identified specific CDSS design implications (Table 2).

Table 2
Sociotechnical dimensions with associated CDSS design implications.

Sociotechnical dimensions	Related design implications
Workflow and communication	Obtain minimal documentation up front Support inter-disciplinary data sharing Support shared decision-making Utilize current summary screens, support new views Tailor documentation and CDSS to patient/caregiver needs
Organizational factors	Use flowsheets to facilitate data entry and capture Use mobile tools Develop replicable design approaches
Human factors	Provide for and facilitate data validation Provide TBI risk information Avoid over use of pop-up alerts

Below, we describe the three identified themes according to each of the related sociotechnical dimensions and the categories associated with them.

3.2. Theme: Interdisciplinary assessment process

In order to implement the TBI prediction rules in a CDSS, specific risk factors for TBI must first be assessed and documented. We identified nine categories (Fig. 1) related to the patient assessment process in the ED that would affect the design and use of a CDSS intervention to implement the prediction rules.

3.2.1. Sociotechnical dimension: Workflow and communication

Routine task sequence, clinician variation, and process efficiency were common issues raised by the participants related to workflow and communication. We found that ED clinicians often followed a

typical sequence of activities when assessing patients that could inform the most appropriate point in the process to collect needed data elements and to insert CDSS recommendations. Most clinicians used summary screens within the EHR to view patient information before examining patients, a process which may facilitate the use of a CDSS intervention. However, we noted varying clinician practice styles related to patient assessment and timing of documentation in the EHR both across and within sites (*clinician variation*). For example, some nurses documented triage findings exclusively on flowsheets using checkboxes and some used a combination of notes and flowsheets. Access to documentation tools was also accomplished through varied approaches within the EHR both across and within organizations.

We found that process efficiency was important to the ED clinicians. Clinicians were interested in ED CDSS solutions that allow for rapid patient assessment while minimizing additional documentation, or duplication in assessments. Clinicians often preferred to use free-text documentation tools which were perceived to be easier and faster to use, and facilitated better inter-disciplinary communication. Assessments completed early in the ED process were often focused on determining the most appropriate location for patient evaluation within the ED (i.e., acute care vs. fast track area) and minimal documentation was preferred.

3.2.2. Sociotechnical dimension: Organizational factors

Participants consistently noted that factors related to the organization of the ED can impact CDSS design choices. The *technical layout* of the ED could potentially facilitate or inhibit the integration of the CDSS into patient care workflow. In the workflow evaluations, we noted that well-placed hardware enables its use. For example, nurses in triage with computers easily accessible were able to use the EHR for documentation concurrent to patient assessments. This would enable triggering a CDSS intervention in real time. Clinicians in the ED were less likely, however, to document concurrently with patient assessments. In many cases, they did not have computers in the patient rooms or the computers in the rooms were not placed in a way that was conducive to use during the patient encounter. Physicians and nurses often preferred not to use computers on wheels as these tended to create a physical barrier between the clinician and the patient and family. Uncommonly, clinicians used laptop or tablet computers.

Other issues related to the *physical layout* of the ED were noted to potentially create barriers to the use of an EHR integrated CDSS. For example, computers on wheels were often difficult to use because of limitations in the physical layout such as small rooms and narrow hallways.

Larger organizational goals related to the use of the EHR, particularly to guide ED patient assessments, were also important to respondents, particularly administrators. Process-oriented tools that incorporated evidence and guided clinicians to provide evidence-based care were viewed favorably. On the other hand, challenges arose when trying to use elements of the EHR (e.g., the Glasgow Coma Scale score assessment) that were shared across the organization and might have unintended consequences for EHR users in other parts of the health system.

3.2.3. Sociotechnical dimension: Human factors

Participants consistently felt that both clinician-related factors and patient-related factors had critical impact on the success of CDSS implementation. *ED culture*, particularly, inter-professional relationships and the perception of each professional's contribution to the ED evaluation process, was an important consideration of the patient assessment aspect of the CDSS intervention. Positive professional relationships and respect for each other's contributions were felt to provide the foundation for a more efficient process.

Another cultural issue, the point in the ED process in which patient assessments take place, also impacted participant responses. For instance, some sites were redesigning the care process from one in which more detailed information was collected before rooming the patient to one in which a detailed assessment would not take place until after the patient was placed in a room. In general, triage nurses were more likely to document concurrent to patient assessments while bedside nurses typically documented after the patient interaction. Physicians and NPs also typically (but not uniformly) documented after the patient encounter, representing a potential barrier to CDSS success related to *task coordination*.

The process of care also changed based on patient injury or illness severity, with documentation considered secondary for the more severely ill patients. Severity of illness particularly affects the initial assessment, which is generally more focused in cases of increased illness severity and more comprehensive when illness appears to be less severe. With the most severely injured children, clinicians often made decisions regarding radiologic imaging before EHR use.

3.3. Theme: Clinical practice related to prediction rules

Clinicians' use of and attitudes toward clinical prediction rules in practice would impact the design of the CDSS intervention.

3.3.1. Sociotechnical dimension: Workflow and communication

Clinicians felt that evidence-based prediction rules may facilitate a conversation with parents (facilitating *caregiver/patient preference*) by providing data that supports a particular decision regarding the need for a CT scan. CDSS design that supports the clinician's ability to discuss specific risk factors for serious injury with the caregiver would promote its usefulness.

3.3.2. Sociotechnical dimension: Organizational factors

We found that designated "trauma" patients were usually managed by trauma services. This means that in addition to the ED provider, the trauma surgeon makes decisions about diagnostic tests. Typically this included the decision about obtaining a CT scan. The nature of existing *inter-professional relationships* between ED clinicians and clinicians such as trauma surgeons or primary care providers could potentially create a barrier to the use of the prediction rules if the relationship is one in which decisions are made in a hierarchical way and the prediction rules are not accessible using a shared medium. Clinicians expressed a need to share their decisions with primary care providers, suggesting that facilitating communication of information to the other non-ED clinicians may be an important goal for CDSS developers. Additionally, healthcare organizations must respond to regulatory agencies that often require documentation of certain practices (*external rules and regulations*). Participants noted that implementation of a CDSS intervention that includes the prediction rules would be more readily supported and prioritized by the organization if it helped to meet regulatory requirements.

3.3.3. Sociotechnical dimension: Human factors

Clinician attitudes/beliefs about guidelines describe the clinician's viewpoint on the use of guidelines for decision-making in the ED setting. Although clinicians supported the use of guidelines in practice, they drew a distinction between guidelines and strict protocols. Clinicians preferred guidelines that suggest a particular decision but also allow for flexibility with an individual patient based on clinical judgment.

Clinician attitudes and beliefs about the PECARN TBI prediction rules were generally positive but three concerns were expressed: difficulty in the assessment of specific predictors according to study definitions (particularly mechanism of injury), potential

change in clinical course (and, therefore, the predictors) over an ED observation period, and unintended increase in cranial CT scans in children with one or more PECARN predictor. Overall, the prediction rules were felt to largely reflect current practice but specific definitions of risk factors would need to be provided in the CDSS intervention to avoid misinterpretation.

Clinician attitudes about CT use in children were also felt to potentially influence how the CDSS intervention would be used in practice. Overall, clinicians recognized the risks of ionizing radiation exposure associated with CT scans and supported alternate management strategies such as observation. However other factors such as the likelihood that a caregiver would bring a child back to the ED if symptoms worsened were acknowledged to be important and could potentially influence decision making.

3.4. Theme: EHR as a decision support tool

The last central theme that emerged was the use of the EHR as a decision support tool. Four categories were identified related to this theme: *Future process changes, vendor relationships, available IT resources and clinician attitudes about the EHR as a decision support tool.*

3.4.1. Sociotechnical dimension: Workflow and communication

Future process changes describe the desire for CDSS to facilitate changes in clinical processes. Organizational leaders verbalized a desire to use the EHR in more creative ways to enable streamlined workflow processes. One goal noted for the design of a CDSS intervention was to enable the use of novel shared workspaces, making it easy for all clinicians to use and build on previously-collected patient information.

3.4.2. Sociotechnical dimension: Organizational factors

Participants noted that their organizations often had many different EHR-related initiatives they were trying to move forward. The nature of the relationship between organizational leadership and the vendor (*vendor relationship*) determined how likely EDs were to implement novel CDSS processes. If the perception was that the vendor may not support a particular design approach, then organizational leadership felt they would prefer to follow the vendor's standard approach to the design of the CDSS intervention.

Another important factor affecting the use of the EHR as a platform for delivering decision support was the availability of *IT resources* including software, hardware and personnel with the appropriate training to build and maintain a sustainable CDSS intervention. For example, the software in use provided a component within its note-building feature that enabled discrete patient data elements to be imported into a note in a manner that allowed for their subsequent retrieval and re-use. However, use of this functionality was noted to be time and labor intensive and required special training, making it a less desirable choice for this CDSS intervention. Flowsheets provided an alternative method for data capture and were easier to build and maintain over time.

3.4.3. Sociotechnical dimension: Human factors

Clinician attitudes/beliefs about the EHR as a decision support tool for implementing the PECARN TBI rules were influenced by their experiences using their EHR. This was illustrated by the perception that order sets and CPOE had become so ingrained in workflow that they were not even perceived as decision support. Clinicians remarked that for the EHR to be helpful for CT decision-making, the CDSS intervention would need to be seamless, easy to use and helpful.

4. Discussion

4.1. Implications for ED CDSS design

We identified three overarching themes that are critical to CDSS design for use in the ED: the *interdisciplinary assessment process, clinical practice related to prediction rules* and the use of the *EHR as a decision support tool*. Within these three themes, we identified three important sociotechnical dimensions for CDSS design: workflow and communication, human factors and organizational factors [5]. Based on the analysis, we detail in Table 2 important design features that will potentially lead to more successful CDSS for implementation of the PECARN TBI prediction rules. The impact on clinical outcomes of CDSS in the ED setting has been reported, but most of these reports do not discuss system design [29,30]. One study that reported on the use of a guideline-based order set for management of acute coronary syndrome in the ED found no improvement in compliance with recommendations after implementation of a CPOE-based order set [9]. The authors suggested that a lack of patient specific information at the point of care contributed to this finding [9]. Prior single-site studies reporting on the design and acceptance of CDSS have often been conducted using prototypes that are separate from currently used EHRs. Our study represents a unique approach, reporting a workflow integrated design strategy that utilizes a currently implemented EHR across multiple EDs.

Our results point to key challenges in using the EHR and designing CDSSs to meet the needs of the ED setting. First, efficiency of clinical care is crucial, so additional documentation requirements to meet specific data needs for a CDSS intervention may create unacceptable interruptions in workflow. In order to support efficiency, clinical data that are collected in the routine process of care could be re-used for the CDSS. Re-use of routinely collected data is consistent with recommendations for successful CDSS interventions [4,31,32]. Data re-use, however, can present particular design challenges because clinical data must be captured, stored and easily retrieved. Currently, this requires the use of structured data fields, which were perceived by physicians and nurses in our study to be inefficient and cumbersome, potentially interfering with communication of important patient information. Data that is entered using a checkbox method should be easily incorporated into a note that is formatted in a way that mimics free-text to enable clear communication of the patient's story from one clinician to another.

The inability to easily re-use data entered by clinicians via free-text notes limited user interface design decisions to those features that enable data capture. In our case, this included either a structured note or a flowsheet. Nurses often initiated patient data capture early during ED assessment using flowsheets, allowing TBI assessments to potentially fit into this existing process. Although nurses were often comfortable using flowsheets with checkboxes, other clinicians were not. Therefore, one key future design challenge is to create a process that facilitates clinicians' ability to enter data without disrupting current EHR work processes. A solution that preserves flowsheet functionality (e.g., data re-use) with a user interface that is consistent with clinician preferences is likely to be more acceptable. Future solutions may use natural language processing methods to support multiple uses for free-text data [33], or creating physician-specific documentation templates which can pull in data from flowsheets.

Creating efficient, acceptable clinician notes is an important design challenge. The software presently in use allowed for data to be imported from a flowsheet into the clinician's note, likely enhancing the acceptance of this strategy. However, modifications needed

in order to create a comprehensive note cannot be burdensome or they will be poorly accepted. These findings are consistent with other research in which efficiency and familiarity of format was important in successful transition from paper to electronic note writing [34].

A second key challenge is to champion the EHR as a platform for delivery of CDSS. We found that faculty or attending clinicians interface with the EHR very little in the course of clinical care prior to decision-making, as note-writing was often deferred until after treatment decisions. However, clinicians did view data entered by nurses or residents prior to examining patients, thus offering an opportunity to provide an initial set of data that may support decision making. Nevertheless, the expectation that clinicians will view, use and update this information to receive the best possible decision support before clinical decision-making still requires some changes in current workflow processes. CDSS solutions must, therefore, support different EHR usage patterns and provide multiple options for data viewing and entry. Other studies of CDSSs that integrate evidence-based guidelines suggest that clinicians will welcome them provided they are easy to use, integrated into workflow, are modifiable according to individual patient needs and do not interfere with professional judgment and decision-making [27,35]. Our participants were clear that professional judgment must be supported by the CDSS. To do this, an important consideration in system design is to ensure that recommendations for decision-making are not perceived as mandatory. Rather the system should provide the evidence-based information needed to make an informed decision. In this way, there is no strict requirement to follow a particular recommendation nor is there any need to “override” it. In the case of the PECARN prediction rules, a useful CDSS will provide information about the patients’ risk for serious head injury as opposed to strict recommendations for obtaining a CT scan.

An interdisciplinary shared process for patient assessment and documentation may also be desirable, facilitating early assessment (e.g., in triage) that could be completed or updated later. Another strategy to support efficiency is process-oriented documentation that uses automated decision logic to identify patients with minor blunt head trauma based on their chief complaint and then pushes the appropriate assessment tools to the clinicians for completion. This tailors the assessment to the needs of the patient and avoids relying on the clinician to remember which tools are needed for which patients.

A third challenge in applying CDSSs in the ED is the need to address parent or caregiver preferences when making treatment decisions, despite the lack of a previous relationship with them and the intensity of the situation. As ED clinicians felt that parents are integral to the decision-making process, a CDSS intervention potentially could support an interactive discussion by providing information that can be shared with patients and their caregivers. A study of a kiosk-based CDSS for the care of children with asthma in the ED suggested that parents may benefit from CDSS interventions. However, lack of integration with the EHR used by clinicians in the study interfered with its overall success [7]. More research is needed to determine whether an EHR-integrated CDSS intervention could facilitate educational conversations with family caregivers and better support parent-clinician shared decision-making when there is clinical equipoise.

4.2. Theoretical implications

Our results illustrate the interrelated nature of the eight dimensions described in the original sociotechnical model [5]. We found that the original eight sociotechnical dimensions could be

integrated into three dimensions that describe the sociotechnical environment in the ED. In our analysis, it was clear that the sociotechnical dimensions were too interdependent to allow them to be easily separated. For example, one could not examine workflow without describing communication patterns which, in turn, could not be described without understanding how various technologies mediate information transfer and how these technologies are used in the environment. The specific categories identified from our data could be organized into three themes and cross-tabulated with the three sociotechnical dimensions, producing an integrated and comprehensive matrix. The three sociotechnical dimensions may exemplify a more parsimonious view of the issues that are important to developing health IT solutions in the ED and other complex healthcare environments.

Healthcare organizations are sociotechnical systems. Our findings are consistent with early descriptions of sociotechnical systems in a variety of organizations [18,22]. According to Cherns, designing work-related tools that are mindful of the inherent sociotechnical nature of the organization requires joint optimization of both the social and technical facets of that organization [22]. Making the most of human abilities such as critical thinking and adaptability enhances organizational goal achievement as opposed to strict technical processes which suppress the best of human capabilities [22].

The work of healthcare like other fields is social in nature, requiring the interaction of people in various disciplines who each have unique but often overlapping and interdependent roles. The existing relationships among those who carry out the work are inevitably impacted by the tools used and the way in which tools are used is shaped by the social climate. In our study, we found that the social relationships between the different disciplines would affect the usefulness of a CDSS intervention. For example, in order for the CDSS to present real-time head injury risk information prior to the time of decision-making, nurses would be collecting an initial set of assessment data which would be viewable by physicians and nurse practitioners. A collegial relationship between the disciplines would foster trust in the data collected and therefore, trust in the CDSS recommendations. Optimal design would foster the relationship by promoting the use of interdisciplinary tools that clearly communicate the data and allow for updates when different providers determine that the patient’s status has changed. In another example, the relationship between different providers such as ED providers and trauma surgeons may also affect how the CDSS system might be used. Our participants were concerned that differences of opinion may make it difficult to apply CDSS recommendations. On the other hand, the presentation of risk information in real time using actual patient data may stimulate conversation and promote the development of enriched relationships. When the CDSS are in use, it will be important to examine differences in its use at different sites where relationships among staff members may be different and evaluate how these relationships evolve over time.

When developers are approaching the design of a new EHR or specific add-ons to an EHR to assist with patient care in a particular healthcare setting. Our data suggest it may be important to identify setting specific issues related to each of the sociotechnical dimensions when approaching system design. In this way themes that are important to a particular setting can be identified and grouped according to the matrix. As the themes we identified may be specific to the ED environment, a new matrix may be identified for other healthcare settings by beginning with the high-level sociotechnical dimensions, then letting the more specific themes emerge. In this way, specific CDSS design implications can be discovered that may be unique to that setting.

5. Limitations

Our study has some limitations. First, we focused on the implementation of two specific clinical prediction rules for the treatment of children with minor head trauma. The creation of CDSS interventions for the implementation of other prediction rules and guidelines requires additional research. In addition, our study was focused specifically in the ED and, therefore, the results may not be generalizable to other healthcare settings. However, our model may be easily adapted to meet the needs of other settings. Finally, all of the EDs in this study used the same EHR vendor; our results may not be generalizable to health systems and settings using other vendor products.

6. Conclusions

An in-depth understanding of existing workflow patterns, clinical tasks, culture and environment, available EHR tools and personnel enabled us to identify key features needed to create a CDSS intervention for implementation of specific prediction rules in the ED setting. CDSS interventions developed for use with an EHR must minimize clinical workflow disruption in the ED and balance the interests of clinicians, caregiver/patients, and organizations.

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Appendix 1. Supplementary material

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.jbi.2013.07.005>.

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