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The multitasking clinician: Decision-making and cognitive demand during and after team handoffs in emergency care

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ABSTRACT

Several studies have shown that there is information loss during interruptions, and that multitasking creates higher memory load, both of which contribute to medical error. Nowhere is this more critical than in the emergency department (ED), where the emphasis of clinical decision is on the timely evaluation and stabilization of patients. This paper reports on the nature of multitasking and shift change and its implications for patient safety in an adult ED, using the methods of ethnographic observation and interviews. Data were analyzed using grounded theory to study cognition in the context of the work environment. Analysis revealed that interruptions within the ED were prevalent and diverse in nature. On average, there was an interruption every 9 and 14 min for the attending physicians and the residents, respectively. In addition, the workflow analysis showed gaps in information flow due to multitasking and shift changes. Transfer of information began at the point of hand-offs/shift changes and continued through various other activities, such as documentation, consultation, teaching activities and utilization of computer resources. The results show that the nature of the communication process in the ED is complex and cognitively taxing for the clinicians, which can compromise patient safety. The need to tailor existing generic electronic tools to support adaptive processes like multitasking and handoffs in a time-constrained environment is discussed.

1. Introduction

The working environment of an emergency department (ED) is a unique, complex and dynamic environment. This is reflected in the varying, often overwhelming volume of patients seen in busy emergency departments as well as the range of acuity of clinical encounters [1]. In addition, an ED is an example of a multifaceted organization composed of complex social environments, where interruptions are frequent and disruptive [2–4]. Such environments, where decisions are made under time pressure and with incomplete information, have been considered conducive to error [5]. Studies such as the Harvard Medical Practice Study reported that approximately 1.5–3% of observed adverse events occurred in emergency departments [6]. Most importantly, these studies found that emergency departments had the highest proportion of preventable errors, which were most commonly diagnostic errors. This data suggests that cognitive errors associated with clinical decision-

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making are critically important to the ED [7]. Some researchers have suggested that the nature of decision-making should not be studied in isolation from other processes such as situation awareness, problem solving, uncertainty management and the development of expertise [8]. In parallel, the patient safety movement has evolved from a "phenotypic" study of the surface descriptors of medical error (the who, what, where and when of adverse events) to a "genotypic" approach that seeks to identify how people, teams, and organizations coordinate activities, information, and problem solving in order to cope with the complexities of situations that can arise in daily life [9]. The link between cognitive error and decision-making, and the importance of characterizing the context in which they are interconnected, necessitates the naturalistic study of error in emergency departments [10].

Our study was conducted in the naturalistic environment of the emergency department in order to characterize the factors that constrain safe decisions in patient care. In this paper, we focus on the nature of interruptions, multitasking and shift change that have been recognized as important patient safety issues in dynamic clinical environments [2,11,12].

2. Background and theoretical foundation

"*First, do no harm*". While medical errors have existed since before Hippocrates, the true magnitude of adverse events in healthcare was brought to the forefront of public debate after the Institute of Medicine (IOM) reported in 1999 that approximately 98,000 deaths per year were attributable to errors in hospitals [13]. Critical care environments, such as emergency departments, ICU, and surgical suites, were characterized as complex, tightly coupled systems intrinsically prone to accidents. In a subsequent report [14], great importance was given to the concept of "seamless" healthcare as the means of improving patient safety. Seamless healthcare calls for interdependent people and technologies to function as a unified whole. This concept is highly significant at the points of information transfer such as clinician handoffs, where patient safety is at risk of being compromised [14].

To understand the functioning of the healthcare system and to successfully implement the recommendations of either report, it is necessary to study those components whose complex relationships constitute the system—humans, technologies and their interactions [13]. The study of human factors is an integral part of current safety research [15]. Human error in medicine can range from medication errors to diagnostic errors and has a spectrum of cognitive mechanisms associated with it [15]. Zhang et al. describe a hierarchy of the healthcare system that elucidates the role of the individual in the causation of error [15]. However, even though most error can be traced to action (or inaction) of an individual, the root causes of error go beyond a single individual [5,9]. Patient safety research has expanded to study team interaction and collaborative decision-making [16–18], the interaction of humans and technology [19], the importance of technology [20], organizational issues [13,20], institutional functions and national regulations [15]. Even though medical error is rarely due to only one of these factors, traditional patient safety research has not used an integrated approach to study error. As illustrated by Reason's "Swiss cheese" model, medical error is more likely due to a combination of various factors [21]. Perhaps even more alarming is the recognition that near-misses might be more prevalent than previously supposed, merely because they remain unreported when events do not end in harm [19]. These events are corrected only because of "filters" in the system, which usually are the actions of human operators that act to rectify the results of previous events [19]. The question of whether such filters benefit patient safety needs to be considered in terms of immediate and long-term consequences. In the short term, filters can be effective in avoiding error but do not address larger, system-wide problems that promote error. They do not rectify the root causes of unsafe practices and may even mask the true extent of the problem and allow situations to repeat with unintended consequences. These filters are ingrained in the workflow, and it is therefore important to take a comprehensive approach to the study of medical errors [9].

The ED of today has been described as a "natural laboratory for the study of error" [7]. However, few studies have focused on error in the practice of emergency medicine [7]. The factors that contribute to cognitive error in the ED are closely tied to the nature of emergency medicine [22]. The knowledge of the patients presenting to the ED is explicitly represented in their medical records and yet is incomplete at presentation, as the patients are typically unknown to the clinicians working there [7]. The acuity of their problems necessitates critical decisions to be made without complete information.

Due to governmental mandates (Emergency Medical Treatment and Active Labor Act, 1986), emergency departments are required to provide a medical screening examination and stabilizing care to all presenting patients, regardless of ability to pay [23]. With a significant segment of the US population lacking medical insurance, emergency departments have become an outlet for medical care for these patients. This can mean providing non-emergent care in addition to the acute care burden on the ED physician. ED overcrowding has been recognized as an emerging threat to patient safety and has been described by Trzeiack and Rivers as a prime example of a system problem that contributes to a high risk environment for medical errors [24]. The increased number of patients presenting themselves to the ED in recent years has compounded the cognitive load on clinicians who now have a greater number of patients under their care and more decisions to be made in the same period of time. In this setting, clinicians have to constantly prioritize these decisions, further increasing their cognitive load.

Feedback is critical to the well-calibrated performance of individuals, and is integral to effective team functioning [7]. It is also necessary for accessing the quality of care provided. There is also a relative lack of feedback for clinicians working in the ED. Unlike their counterparts on the in-patient hospital units, the long-term results of their interventions are not readily available to ED clinicians. With the advent of information technology, it will be easier for ED clinicians to seek results and outcomes beyond the emergency department [20,25].

Information technology plays both active and passive roles in patient safety. The active role is reflected in functions like error detection (alerts and reminders) [26] and data mining [27]. The passive role of IT is exemplified by how it facilitates communication, eases workflow and distributes information

effectively and efficiently. It also serves as an important cognitive tool that enhances and aids decision-making [28,29]. The passive role of technology in facilitating patient safety is more indirect and yet may be more important in that it strengthens and assists processes integral to patient safety [30]. Technology is expected to play an increasingly larger role in the ED and is projected to improve all aspects of patient care including patient safety.

With respect to medical error, the healthcare society has seen many paradigm shifts over the last century—from a culture of silence to a culture of blame and finally, to a culture of safety [9]. In order to integrate a culture of safety within healthcare, as recommended by the IOM report, it is necessary to identify and study current work practices that need improvement and tailor recommendations for their improvement.

Information transfers (handoffs) are a recognized vulnerability for medical errors [13], however they are also essential to current healthcare practices [16]. Although handoffs have been studied in other industries, they have not been adequately studied in naturalistic settings within the healthcare environment [16]. Multitasking has been previously touted as an important skill in today's workplace, yet it has been recognized as an inefficient process and a major contributor to cognitive overload [31,32]. The cognitive load of clinicians is further increased by the constant and considerable amount of interruptions. Coiera et al. [2] studied the communication loads on clinical staff of two emergency departments. They concluded that the combination of interruptions and multitasking could result in errors through disruption of memory processes. Handoffs, multitasking, and interruptions are inherent to the work practices of the ED. Our study is part of an ongoing effort to examine patient safety in naturalistic settings. The paper focuses on shift change (the handoff of responsibility to the next health care provider), interruptions and multitasking within an emergency department in view to make recommendations and present some possible solutions to simplify these processes.

3. Methods

3.1. Study setting

The study was carried out in the adult emergency department (ED) located within a large tertiary care, teaching hospital affiliated with two university medical schools in New York City. The hospital's Institutional Review Board approved the study and measures were taken to preserve the confidentiality of the data sources and patients.

3.2. Data collection

Data were collected using ethnographic techniques of observations and interviews.

3.2.1. Observation

The key aspect of qualitative research is the observation of phenomena in natural settings. Short-term observational studies focus on group behaviors and findings of a short-term qualitative study are presented based on the recorded observations [33]. During a period of three months, the researcher/physician observed the activities unfolding in the emergency department and recorded her observations at different representative times of the day. In order to be as objective as possible, the researchers were not responsible for patient care and did not take part in the decision-making process. Observational data were collected in order to provide insight into the cognitive workflow, information transfer and decision-making processes in the ED [34,35]. Each set of observations occurred for approximately 3 h, usually in two separate shifts (morning and afternoon).

3.2.2. Interviews

Detailed semi-structured interviews were also conducted. The interview data were collected in order to access information on the role, situational awareness and general work philosophy of the subjects in the ED [19]. These interviews were guided conversations where broad questions, which do not constrain the conversation, were asked, and new questions were allowed to arise as a result of the discussion. The prepared questions focused on two broad themes including (1) the perception and internal representation of the ED, patient care and role of physicians within the ED; (2) the nature of the workflow and environment of care within this specific emergency department. The researchers conducted interviews with six subjects who represented the core clinical team of ED physicians, residents, and nurses. These interviews were audio-taped and transcribed for analysis.

3.3. Data analysis

Key concepts from the observations and the semi-structured interviews were extracted with assistance from clinical collaborators to check for accuracy at the intuitive level. Data analysis was based on the principles of "grounded theory," which refers to theory developed inductively from a corpus of data [35]. The basic idea of this model of analysis is to discover variables and their interrelationships. Grounded theory is a method used in sociology that is very similar to content analysis, except that the categories are not predetermined, but are identified from generated data through the process of induction. Preliminary analysis of the cognitive workflow, information transfer and decision-making processes in the ED resulted in identification and understanding of a number of variables (e.g., interruptions by introduction of a new patient into the ED, or unavailability of materials or chaperons). These variables were used in the development of a more fluid and comprehensive model of the workflow in the ED.

4. Results

4.1. Analysis of observational data

4.1.1. The ED workflow

The workflow diagram (Fig. 1) was constructed to reflect the process of movement and flow of patients and the process of care from the moment the patient entered the emergency department until they are either discharged or transferred to a different district of the ED or hospital. The workflow model

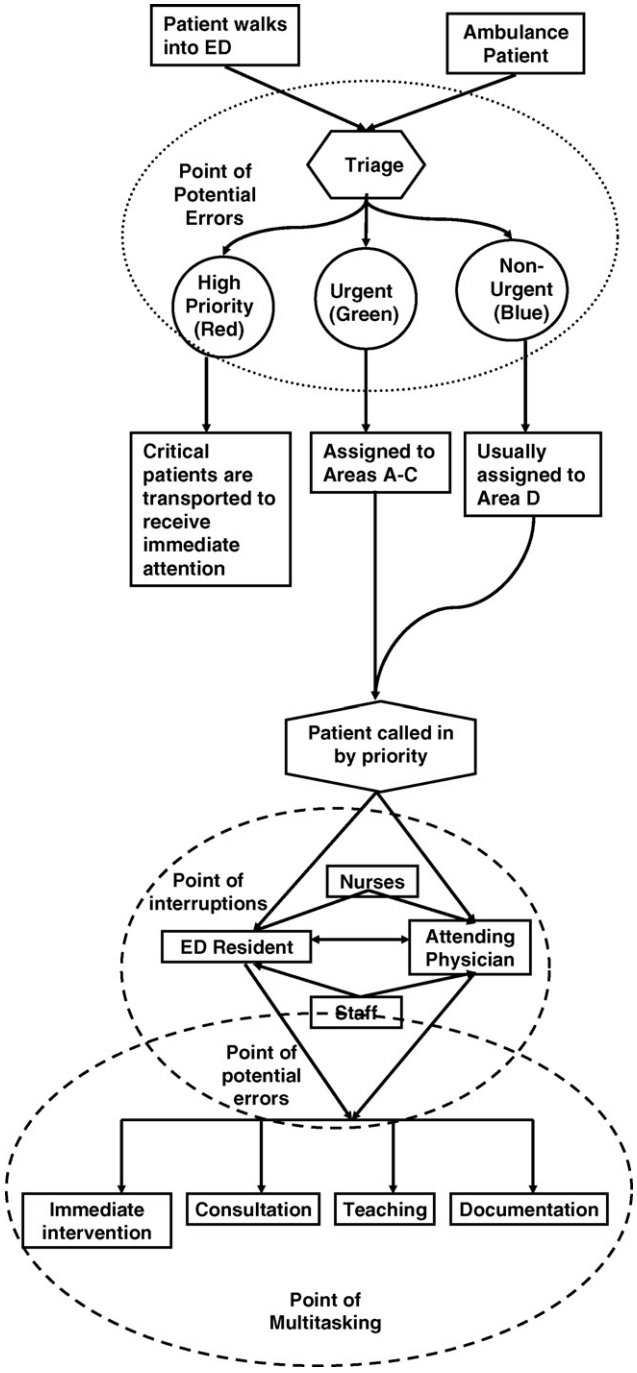

Fig. 1 – Workflow of the emergency department: transfer, treatment and processing of patients.

was drawn, based on the observation of the patients and clinicians over the period of study. A summary of this process is given below.

Patients either walk into the ED or are brought in by ambulance services. The triage nurse then evaluates each patient individually. The nurse assigns the patient to one of three color-coded categories of urgency: (1) red—requiring immediate attention, (2) green—requiring urgent care, or (3) blue—indicating a non-urgent condition. Registration of the patient's demographic information into the ED database occurs after the initial triage assessment. The order in which patients are evaluated by a physician and the time interval from triage nurse to physician evaluation is dependent on the triage category as well as the overall ED patient volume.

No patient is turned away from the door, similar to the process reported elsewhere [24]. This means that patients who might be ideally served in a less urgent or clinic setting must be processed through the ED. These patients contribute to the workload and thus add to the constraints that must be considered in making decisions.

After triage, patients are assigned to a specific location within the emergency department. Within that location, they are designated to a nurse working in that district, who will be responsible for providing nursing care. There are four districts in the emergency department studied, named A, B, C and D (Fig. 2). Except for district D, all other areas receive patients from all three triage categories and are open 24 h a day. District D receives only the non-urgent category of patients and is open only from 12 noon to 10 p.m. on weekdays. It serves as an avenue to reduce the patient load in the other districts. District B, in addition, houses patients with suspected or confirmed psychiatric conditions and has additional security personnel for that purpose. Each district has its own "brain" center. This is the central workspace that houses the cognitive artifacts required for decision-making: (1) the clinical information systems (computers) that provide access to laboratory information as well as a synopsis of patients' previous medical history including results of previous investigations, (2) the paper charts, (3) the telephones, (4) the lab delivery system, and (5) auxiliary forms.

4.1.2. *Interruptions and multitasking*

As in other workplaces, multitasking was found to be an integral skill developed by personnel working in the emergency department. Observed sources of interruption in the ED included other patients, other staff, telephones, and pagers. Fig. 3 represents the relationship between the agent of interruption and the duration of interruption. Interestingly, whereas interruptions by the ED nurses took the most time, the average duration of each interruption was not very high. There was also a difference in the average interval for interruptions between attending physicians (9 min) and residents (14 min). This difference was not confined to interruptions alone. As Fig. 4 shows, attending physicians performed a higher number of tasks than residents in all of the six observed categories.

Graphical representation of the timeline of events for 1 h of observation (Fig. 5) showed considerable overlap of different activities within the ED. Most clinicians continued to finish the subtask they were performing before they attended to the interruption. Clinicians constantly prioritized their subtasks and the interruptions. Only if they deemed the interruption as a higher priority did they take a break from the current task. The nature of prioritization was dynamic, and changing across time, making the process of prioritization itself cognitively taxing.

4.1.3. *Information flow and shift change*

The majority of information transfer occurred during shift changes. This process was conducted differently based on the

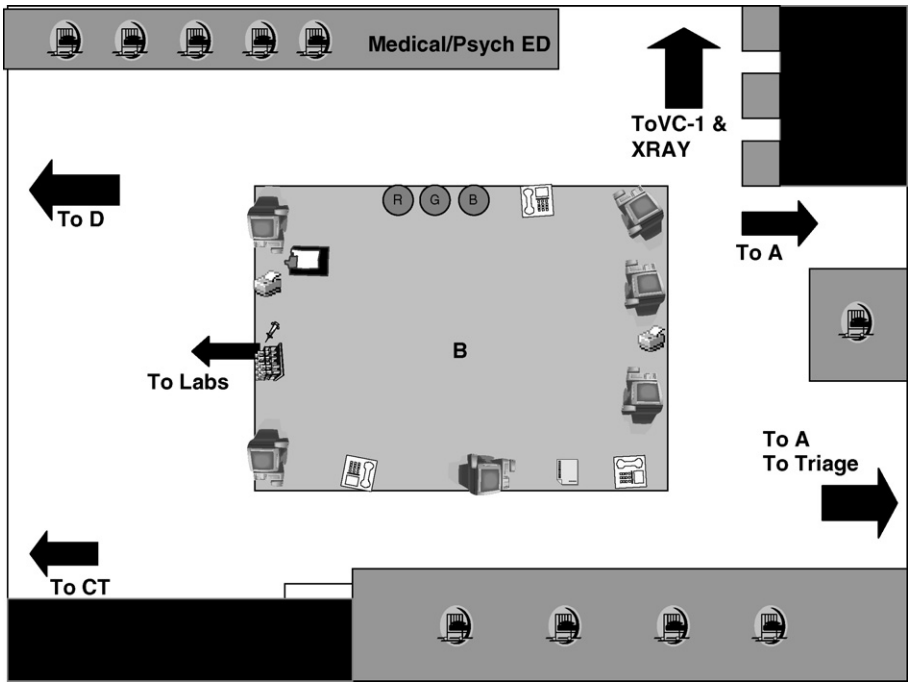

Fig. 2 – A diagrammatic representation of Area B displaying the "brain center", the distribution of artifacts, and the triage categories accepted in the area. A, B, D: areas of the ED; R: red (high priority), G: green (urgent), B: blue (non-urgent).

preference of the incoming and outgoing physicians. In one scenario ("sit down rounds"), the outgoing physician printed out a list of his or her patients from the electronic patient tracking system (EPTS) and explained each patient's case to the incoming physician, occasionally consulting the individual patient's chart. The incoming physician then made necessary notes with regard to each patient on the list. In the second scenario ("walk rounds"), the two physicians walked to the bedside of each patient and exchanged information at the bedside. As in the first scenario, the incoming physician recorded written notes on the printout list. Ideally, both modes of information transfer would be carried out. In this third scenario, the two physicians first sat down and discussed the information together, exactly as in the first scenario. Subsequently, the two physicians performed the bedside rounds and visited each individual patient (similar to the second scenario).

Fig. 6 shows the total time spent on consultation, multitasking, documentation and teaching activities. All of these processes involved transfer of information about patients in some form. As the graph indicates, more time was spent on multitasking than any other activity. The transfer of information during multitasking consisted of documentation with one or more additional activites, since the physicians often documented or taught, while also listening to information about a particular patient. The consultations involved retrieving information through conversation between APs, residents and nurses and were conducted in various ways, including over the phone or through teaching the interns and residents.

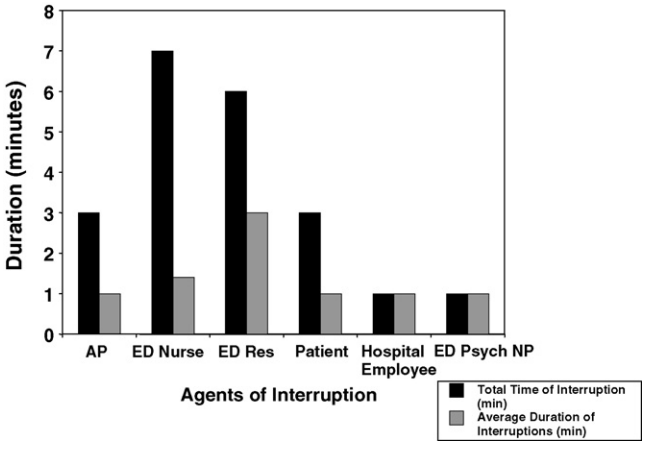

Fig. 3 – Time and duration of interruptions as a function of the agents responsible the interruptions, over a period of 3 h.

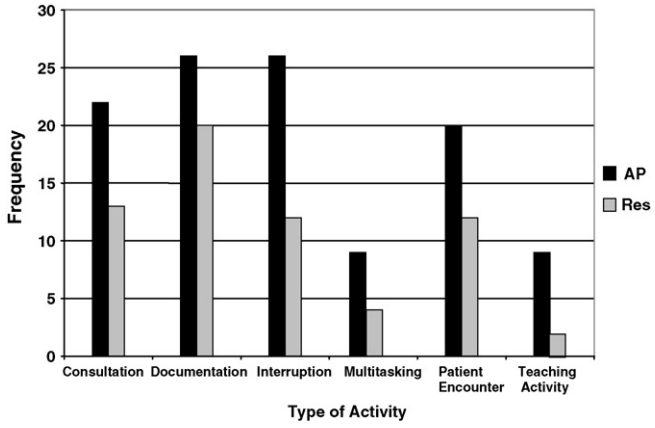

Fig. 4 – Overall frequency of activities performed by physicians and residents over 12 h of observation.

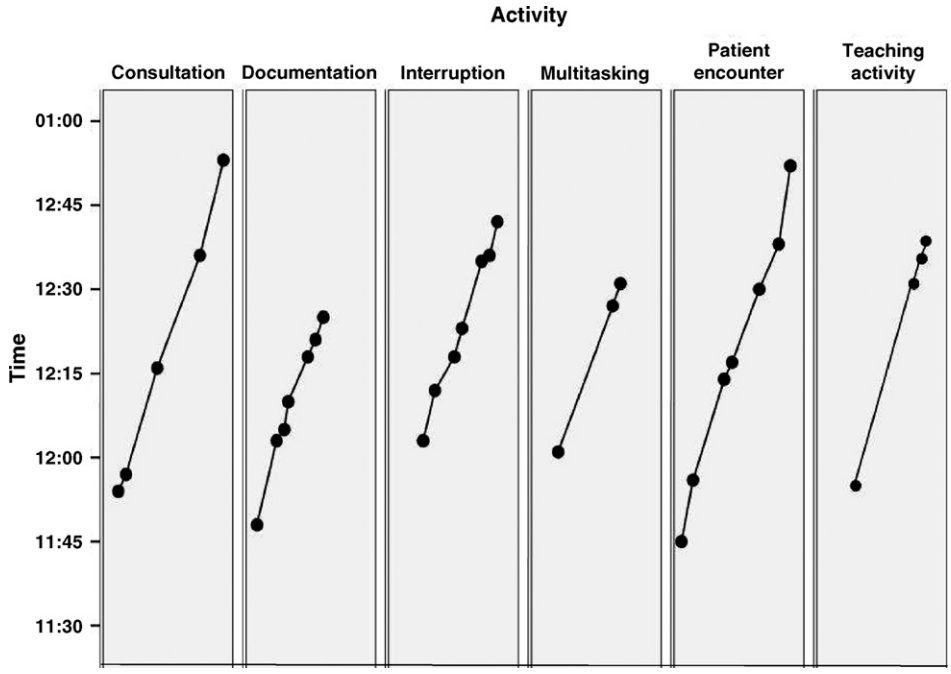

Fig. 5 – Timeline of activity over a period of 1 h. Each activity is placed in a vertical column, against the horizontal timeline.

Other consultations were conducted over the phone, such as communication with the patient's personal doctor or a specialist consultant.

With regard to the use of existing computer systems, nearly 25% of multitasking and 20% of documentation involved the use of the two computer systems, the electronic patient information system, *WebCIS* and the electronic patient tracking system (EPTS). In general, *WebCIS* was used for clinical purposes, particularly for retrieval of test results and patient history, whereas *the EPTS* was primarily used for administrative purposes. The process often involved retrieval of information about a particular patient, a check for laboratory test results, or admission and discharge information. Similar patterns were also observed for documentation and consultation, where information was entered into or retrieved from the computer.

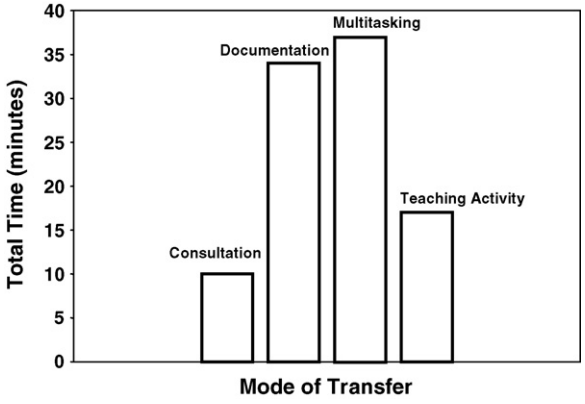

Fig. 6 – Total time and mode of information transfer during one observation session (3 h) shift in the emergency department.

5. Analysis of interview data

5.1. *Understanding of workflow by clinical agents*

A summary of the analysis of the interview data is given in Table 1, with data categorized into a number of response themes. Subjects' responses (across type of medical personnel) demonstrated a consistency of views with regard to perceptions of their individual roles within the system, suggesting a pattern of uniformity within and across each type of medical personnel.

5.1.1. *The ED resident*

Interview data revealed that, upon evaluation of a patient, the resident decides a plan for patient care. The resident then presents a formal report of the patient case and proposes a course of action to the attending physician. Together, the resident and attending physician devise a final management plan for the patient. A resident encounters on average about 10–15 patients per shift. The workflow of the resident closely reflects that of a physician. However, the attending physician supervises the care provided by the resident.

5.1.2. *The ED physician*

A physician working in any one of the districts chooses a medical record from the queue of charts of patients awaiting physician evaluation. Factors influencing the physician's choice include triage category and time of arrival. As an attending physician described his typical day in the ER, "I attend to the emergent needs of patients signed out to me, then the patients waiting to be seen. Patients are typically waiting 2–12 h. Most of my day is spent triaging patients based on my perception of urgency." After the patient encounter, the physician decides

Table 1 – Thematic summary of interview responses from clinicians in the emergency department

Theme	Responses
Typical day	• Begins and ends in shift change/handover • Attend to patients • Consultations when necessary • Attending physicians: have teaching/supervision role in addition to primary patient care
Collaboration	• For residents, it is primarily with attending physicians and nurses have a specific question or plan in mind and verbalize it to AP/consultant/nurse • For Attending physicians: primarily patients and consultants - Request involvement of consultant via phone call - Listen and give advice to residents • For both: translators, clerical staff, radiologist, consultants, nurses, patients family • For nurses: nursing staff, doctors, residents
Communication	• Verbal, face to face • Call or page for assistance/guidance (consultation) • Communication gaps in shift changes • Written communication in chart/computer - Problems: charts get lost, handwriting illegible
Readiness of patient information	• Great satisfaction with WebCIS, all information is right there as long as patient seen at Columbia • Problem: when patient seen in another institution/clinic/office → data not there
Perceived quality of care in the ED	• All responses were 4: good quality • Patient gets great medical care but very inefficient: patients have to wait too long
Critical events that adversely effect patient care	• Volume is most problematic • Terrible tracking system (interviews conducted before e-track) • Racks of charts and name on whiteboard of patients waiting to be seen, if chart missing patient will not be see and lost in the chaos • Urgent (green) patients wait too long, may be in pain for 4 h • Cannot get beds quickly → clog ER
Improvements in patient care	• Make things faster and more efficient by computerization → want nearly paperless ER but with adequate backup • Shorter patient wait time • Larger clinical space • More nursing and support staff • Increase hospital inpatient bed capacity especially critical care bed availability • Expanded ancillary testing capability at all time of the day such as Radiology attending availability
Differences between this ED and other ED	• Excellent clinical care, high expertise of entire staff/faculty • Lack of computerization/automation • Language barriers • Large uninsured population
Differences between ED and other clinical environments	• "The door is always open"—no means to control inflow of patients (inpatient units limit workload by limiting entry to the unit based on staff and bed availability) • "24 × 7 × 365"—function every day, every hour of the year. May need to have information and consultation support urgently during hours in which they are often not readily available • Multitasking • When busy, priority is identification of instability and subsequent stabilization; all else is secondary

the course of action and communicates the decision to the appropriate team members. The decision includes the need for immediate intervention and stabilization as well as the need for hospital admission, the requirement for follow-up, or the referral to specialized services either immediately, or in a less urgent fashion. This process of decision-making in the emergency department is made more complex by the large number of patients under the care of a single clinician at any one point in time as well as the number of distributed tasks across personnel, information systems and laboratories. Being

a teaching hospital, the attending physicians are also responsible for the medical students and physicians-in-training (residents) under their supervision. The physicians have to strike a balance between the care of patients they see directly and those seen by the residents, depending upon the physicians' level of confidence in the trainees, the number of trainees assigned to their districts and other factors such as the number of ancillary staff and the number of patients present in the emergency department.

5.1.3. *The ED nurse*

In addition to assessing patients' clinical status and assigning a triage category, the triage nurse also assigns patients to a nurse in the ED who will provide care to the patient during their ED stay. This involves a distribution of patients across different districts depending upon the patient's triage category (level of urgency), the nurse to whom the last assignment was given and the number of patients waiting to be seen in that particular district. Prior to the implementation of EPTS, this was performed manually in the ED, with the triage nurse needing to visit each district within the ED in order to assess its state. In addition, because there are at least three triage nurses it becomes difficult to track the dynamic state of the ED. The nurses working within the area monitor the vital signs of their patients and assess the status of their patients at regular intervals. They carry out orders written by the physicians and residents including phlebotomy, intravenous line placement and the administration of fluid and medications. They also provide assistance for procedures performed within the ED, provide patient education and look after the general comfort of their patients.

5.1.4. *The ED clinician*

Each task on a clinician's mental "to-do" list is weighed and prioritized before it is undertaken. Furthermore, the personnel working in a district varies, not only in the composition according to the time of day (the number of nurses, physicians or residents, for example), but also in that the personnel are not static. At shift changes, different tasks in varying degrees of completion must be handed over for completion by the incoming healthcare staff. In order to handoff these tasks, temporal information about these tasks needs to be transferred. This takes place during shift change when the outgoing clinicians hand over the patients currently under their care to the corresponding incoming clinicians in form of a brief verbal discussion. All clinicians, including physicians, residents and nurses identified shift changes as a source of the communication gap in the ED workflow. The remainder of the information is distributed across the clinicians who are not changing shift, the medical record, the paper chart and other artifacts.

Collaboration is critical in the ED. In addition to teamwork involving colleagues within the department (nurses, nurse practitioners and physicians), ED physicians must often collaborate with consultants representing the various disciplines of medicine, due to the wide spectrum of illnesses seen in the ED. An ED physician not only has to have skills to care for the undifferentiated sick and injured patient, but also has to collaborate with colleagues in the other disciplines of medicine on a regular basis, initially requiring a transfer of information and, at times, a transfer of care.

6. Summary of results

The observation and interview data revealed the overall structure of workflow and the interaction of various artifacts within the functional and organizational infrastructure of the emergency department. Interruptions within the ED were prevalent and diverse in nature. Clinicians, requiring continual reprioritization of the tasks at hand, were constantly multitasking. Considerable differences exist between the level of activities and the number of interruptions encountered by attending physicians and residents. Transfer of information began at the point of hand-offs/shift changes and continued through various other activities, such as documentation, consultation, teaching activities and utilization of computer resources. A significant portion of multitasking was performed in concert with the use of the computers, namely *WebCIS* and *the EPTS*. Furthermore, interview data revealed consistent perceptions of medical personnel about their roles within the overall ED infrastructure. The results show that the nature of the communication process in the ED is complex and cognitively taxing for the clinicians, which can compromise patient safety.

7. Discussion

Our results show that the effective functioning of the emergency department seems highly dependent upon the outstanding operation of the human aspect of its work system. Although technology plays an increasingly important role in decision-making, its full potential is yet to be utilized. This realization is important in developing a safer healthcare environment in the ED. A system that is highly dependent upon the exceptional functioning of its human components to make up for its deficiencies is fertile ground for the occurrence of error [36].

7.1. *Process of multitasking*

Multitasking is a necessary skill for the execution of daily activities in the ED, but may fail to be an effective mechanism when a large number of tasks and the subtasks associated with them demand the attention of the concerned clinician. Our results showed a difference between the interruptions caused by nurses and residents. This difference suggests a higher frequency of interruptions by nurses that were resolved quickly by the attending physician (AP). In most of these cases, the AP returned to his prior work after being interrupted. On the other hand, the interruptions caused by the ED residents, such as discussing a new patient with the attending, being less in number, had a much longer average duration. In these cases, the AP spent some time discussing the case with the resident and might have followed up with a patient consultation.

Clinicians go through a dynamic and continuous process of prioritization of tasks. The clinicians have to mentally keep track of the different tasks they have performed and also have to fall back on the tacit knowledge they acquire from working in this environment [32]. Our results also show that, on average, there is an interruption every 9 min for attending physicians and every 14 min for residents. This suggests that

there is an increased burden of memory load as a result of the combination of multiple, simultaneous tasks and numerous interruptions, which may result in a higher number of medical errors [2]. This issue is particularly significant with regard to the cognitive burden carried by the attending physicians. The considerably higher number of tasks performed coupled with more frequent interruptions, requires the APs to have greater multitasking skills. Furthermore, this added burden can also prove a point of potential vulnerability for making errors. Our interview data revealed that while residents come up with diagnoses and an appropriate course of treatment the final approval is given by the AP. Thus, minimization of cognitive load for APs is of the utmost importance in order to reduce potential errors.

Facilitation of the process of multitasking may limit the number of errors that occur. One method is to provide cognitive support for a clinicians 'internal schema through the provision of an effective external representation of clinicians' task and their subtasks. For example, the use of instant messengers or electronic checklists tailored to the clinician may decrease loss of information and enhance communication amongst ED staff. Electronic tools must also be designed for ease of use in a time-constrained environment to improve efficiency of work practices. More systematically, the multitasking activities, including interruptions, can be classified into three categories: (1) those activities that can be completely eliminated by restructuring the workflow; (2) those activities that cannot be eliminated but can be delegated to machines for automated processing; (3) those activities that cannot be eliminated nor delegated but have to be handled by people [37]. For this third category, cognitive artifacts, defined as physical objects made by humans for the purpose of aiding, enhancing, or improving cognition [29], can play an important role in helping the clinicians.

Furthermore, overcrowding, which is an epidemic in emergency medicine, contributes greatly to error risk. Efforts to reduce this overcrowding will reduce the workload of ED clinicians, and in turn reduce the number of information transfers, thus reducing the risk of error. The sooner a patient is transferred to their primary inpatient team, the better it is for the patient. Work environment changes that limit the number of negative or useless interruptions and maximize positive or useful interruptions would have a strong positive impact on efficiency and error reduction. For example, ancillary staff can participate in answering simple patient/family questions, providing basic necessities such as food and beverages, as well as assisting with feeding or use of bathrooms.

7.2. *Process of information flow*

The observed information handoffs during shift change reveal communication gaps where there is a potential use for structured electronic tools to facilitate an efficient and accurate information flow. In a physically and cognitively demanding workspace like the emergency department, a delicate balance exists between the need to ensure continuity of care and the need to restrict the demands on the personnel [38]. Handoffs are inevitable but not necessarily unsafe practices, especially if measures are taken to ensure the continuity of information flow [16]. We have also shown that some of these gaps in information are mitigated by the integration and use of various artifacts and additional processes within the ED. The ideal transfer of information during a handoff is described as a combination of the two modes of transfer, namely discussion of patients while using *the EPTS* and performing the rounds. This process is advantageous for two main reasons. The interaction with the patient helps put a face to each name and helps the incoming physician remember the information in a better way. In addition, the two levels of information transfer help reduce the possibility of error by repeating the information, such that if any information is omitted or forgotten by the outgoing physician, the subsequent interaction with the patient provides a second opportunity for information transfer. This should result in a more comprehensive flow of patient information, which is less prone to error. Furthermore, we have also shown that filters [20] are in place in the form of processes and artifacts that make the flow of information a continuous process. These involve the two attending physicians, but also, residents, interns, nurses and the computer systems. The combination of consultations, documentations, multitasking and teaching activities may further reduce the rate and/or possibility of error.

8. Implications

The ED, a unique clinical environment, requires distinctive solutions to address the workflow issues that contribute to the occurrence of medical error. Although long-term solutions must be sought to reduce the root causes of error, the adaptive behavior of the human components of this system must also be bolstered in the meantime. Even though the adoption of technology may benefit the ED, our results suggest that the existing generic electronic tools might alone be ill-suited for this environment. These tools must be tailored to support adaptive processes like multitasking and handoffs that occur in a time-constrained environment. Through the course of our interviews and observations, we found that there is a considerable level of reliance on electronic systems such as the *tracking system* and *WebCIS*, currently in use in the emergency department. Furthermore, most clinicians expressed the need for adequate computer-based systems to facilitate the workflow within the ED.

The electronic patient tracking system (*EPTS*) was implemented during the course of this study as a response to the clinicians' growing need for increased utilization of electronic resources. This tool replaced a cognitive artifact previously heavily used in the emergency department—the dry-erase board. The dry-erase board was a visual aid used to track the location and number of patients in the ED and their assigned nurses. A major limitation of this method was its dependence on human resources to enter the patients' details. Nurses, residents, and physicians have all expressed concern about the ease at which paper charts can be misplaced, which results in patients not being seen for long periods of time. The new tool contains information entered from the point of registration, reducing the gap in information transfer from the registration desk to the clinical district and decreasing the possibility of patients being "missed" in the clinical area due to lags in the work system. In addition, the *EPTS* allows the clinician to add

notes that help with task management and helps other clinicians, including the incoming clinician after shift change, to have visible access to task and patient information needed to bridge into the ongoing ED workflow process.

It is also important to note that the emergency department is highly dependent on the efficiencies of other departments. If the lab or radiology data processing becomes inefficient or bogged down, or malfunctions, the internal schemas of the physicians for the process are useless and their efficiency is negatively impacted. For instance, an attending knows to check for the results of lab tests about 1.5 h after they are sent. If the lab has a broken machine, or loses the specimen, the physician can no longer predict when the results will come and must continually check for their arrival. Similar problems apply to radiology in that if they have a problem with PACS, the digital radiology system, and cannot read the X-rays, the clinicians cannot predict when they might get the results and thus must continually check for them. An automated system that can automatically alert clinicians when the results are ready might alleviate this type of uncertainty and increase efficiency.

9. Conclusions

Interruptions within the dynamic environment of the emergency department are multifaceted, diverse in nature and varied with regard to the benefits they provide to clinicians. Multitasking is a necessary aspect of such an environment, requiring physicians and other clinicians to constantly assess the priority of their tasks. As such, clinicians often rely on internal schemas, implicit knowledge, and interruptions in order to perform their tasks and are thus burdened with a considerable cognitive load. Information transfers and shift changes are another necessary aspect of the working environment of the emergency department and cannot be avoided. However, these processes are not necessarily a vulnerable point if steps are taken to ensure the continuity of information flow. Technological solutions may prove helpful in reducing the burden on clinicians and consequently, the rate of medical errors.

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