International Journal of Medical Informatics (2005) **74**, 827—837

International Journal of Medical Informatics

www.intl.elsevierhealth.com/journals/ijmi

Emergency physicians' behaviors and workload in the presence of an electronic whiteboard

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Received 10 January 2005; accepted 22 March 2005

KEYWORDS
Emergency department;
Whiteboard;
Interruptions;
Workload

Summary
Background: As the demands on the emergency medicine (EM) system continue to increase, improvements in the organization of work and the access to timely clinical and system information will be required for providers to manage their workload in a safe and efficient manner. Information technology (IT) solutions are beginning to find their place in the emergency department (ED) and it is time to begin understanding how these systems are effecting physician behavior, communication and workload.
Methods: The study used a time-in-motion, primary task analyses to study faculty and resident physician behavior in the presence of an electronic whiteboard. The NASA-Task Load Index (TLX) was used to measure subjective workload and the underlying dimensions of workload at the end of each physician observation. Work, communication and workload were characterized using descriptive statistics and compared using Mann—Whitney *U*-tests.
Results: Physicians in our study performed more tasks and were interrupted less than physicians studied previously in conventional EDs. Interruptions interrupted direct patient care tasks less than other clinical activities. Temporary interruptions appear to be a major source of inefficiency in the ED, and likely a major threat to patient safety. Face-to-face interruptions persist even in the presence of advanced IT systems, such as the electronic whiteboard. Faculty physicians exhibited

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doi:10.1016/j.ijmedinf.2005.03.015

lower workload scores than resident physicians. Frustration was a significant contributing factor to workload in resident physicians. All physicians ranked temporal demands and mental demands as major contributing factors to workload.
Conclusion: The results indicate that the electronic whiteboard improves the efficiency of work and communication in the ED. IT solutions may have great utility in improving provider situational awareness and distributing workload among ED providers. The results also demonstrate that IT solutions alone will not solve all problems in the ED. IT solutions will probably be most effective in improving efficiency and safety outcomes when paired with human-based interventions, such as crew resource management. Future studies must investigate team interaction, workload and situational awareness, and the association of these factors to patient and provider outcomes.

1. Introduction

Data published in the Centers for Disease Control and Prevention's 2004 report *National Hospital Ambulatory Medical Care Survey: 2002 Emergency Department Summary* indicate that emergency departments (ED) in the U.S. are approaching a boiling point in terms of increasing patient demand and shrinking bed capacity. The report estimates between 1992 and 2002 ED visits increased 15% while the number of EDs decreased 22% [1]. U.S. EDs receive more than 100 million patient visits (80 million adults and 20 million children) per year. ED overcrowding often causes hospital diversion (i.e., ambulances diverted from hospital), increased patient wait times, increased length of stays and decreased patient satisfaction [1—5]. The crisis is only expected to worsen as increases in nonurgent ED visits drive demand upward and growing financial pressures cause more hospitals to close their EDs. EDs in use today were not designed to handle the volume of patients they are now seeing. For example, the adult ED central to our study, was designed in the 1970's to handle an annual volume of 20,000 patients, but today receives approximately 43,000 patient visits per year.

Just prior to the time that popular media outlets began publishing reports on ED overcrowding in the U.S. (e.g., ''ER Conditions Critical'', USA TODAY), the Institute of Medicine (IOM) released its sobering report on medical errors and adverse events in healthcare [6,7]. In *To Err is Human: Building A Safer Health System*, the IOM estimated that between 44,000 and 98,000 patients die of iatrogenic injury each year. The emergency department has specifically been identified as a location where adverse events are highly likely to be attributable to error. Studies estimate that the proportion of ED adverse events deemed preventable range from 53 to 82%, compared with overall estimates of 27 to 51% for hospital-based adverse events [8].

Other outcomes, such as patient satisfaction are also suffering in the ED, as demonstrated by recent research findings and increasing rates of patient complaints [9—11]. Although researchers have reported inconsistent findings concerning which factors lead to patient dissatisfaction in the ED they overwhelmingly agree on two general findings: (1) patients dissatisfaction is on the rise and (2) failures or breakdowns in provider-to-provider and provider-to-patient communications are the primary cause [12]. Communication failures have also been implicated and associated with medical errors and preventable adverse events in the ED [13—19]. A retrospective review of ED closed claims revealed that teamwork behaviors would have prevented or mitigated the adverse event in 43% of the cases reviewed [20].

In light of the poor outcomes (i.e., safety and satisfaction) associated with acute patient encounters with the ED system, it is evident that there are serious implications for the professionals who work in this environment on a daily basis. In fact, research has shown that emergency physicians and staff experience high rates of stress, depression and career burnout [21—32]. Three sets of factors have been shown to contribute to these outcomes in ED personnel: (1) organizational characteristics, (2) patient care and (3) the interpersonal environment.

As the demands on emergency medicine (EM) continue to increase, improvements in the organization of work and the access to timely clinical and system information will be required for providers to manage their workload in a safe and efficient manner. Advances in medical informatics are beginning to facilitate clinical improvements in the ED aimed at addressing these needs.

For example, emergency department information systems (EDIS) are being developed that integrate, either in part or in full, the following systems: electronic tracking bed board displays; electronic medical records (EMR); computerized order entry (CPOE) and laboratory and radiology systems. EDIS have great potential to significantly streamline conventional paper-based ED work processes.

The study presented here applied observational methodologies previously employed in the ED and other clinical areas to study and describe provider work and communication processes in an ED equipped with a distributed electronic whiteboard (eWB) [19,33—39]. The results of the study are compared and contrasted with results from previously published observational studies performed in EDs unsupported by integrated informatics systems.

2. Methods

2.1. Sample population

The study was conducted in the adult emergency department at Vanderbilt University Medical Center (VUMC) in Nashville, Tennessee between September 8, 2003 and May 14, 2004. VUMC is a Level 1 Trauma Center and the adult ED receives over 43,000 patient visits annually. A convenience sample of 10 faculty EM physicians, 5 post-graduate year-three (PGY-3) resident physicians and 5 PGY-2 resident physicians were observed during this period. This sample was selected from the 22 faculty physicians, 8 PGY-3 residents and 8 PGY-2 residents that staff the adult ED. The study was approved by Vanderbilt University's institutional review board, and all participating subjects provided verbal consent prior to their observational sessions.

2.2. Design

Time-in-motion, primary task analyses lasting approximately 180 min in duration were conducted on individual EM faculty and resident physicians [33]. All observations were performed on weekdays (Monday—Friday) between 3:00 and 6:30 p.m.). A single trained observer used a standardized data collection form to continuously record the type and duration of all primary tasks and work interruptions. The data collection form was installed on a wireless handheld computer to facilitate mobile data collection. The observer shadowed EM physicians throughout the entire observational period except when patients or physicians requested privacy for patient care or other personal reasons.

System workload metrics were collected concurrently from the EDIS. Central to the EDIS is a 60 in. plasma touch-sensitive electronic whiteboard that serves as the command and control center of the ED. EDIS display screens are also accessible from any networked computer in the ED. The eWB displays and records patient data and a number of system workload metrics including chief complaint, patient wait time, patient length of stay (LOS), patient acuity, managing physician, number of patients in the waiting room, ED occupancy, diversion status, average wait times and LOS for all patients. The eWB also monitors and displays ED bed status for providers and cleaning staff. These parameters are recorded and stored in the central EDIS database at a sampling rate of once per minute. System workload metrics were collected for both observed and randomly selected unobserved periods (i.e., 180 min bocks of time), and compared to determine if the observed periods were truly representative of the overall ED work picture.

Observers administered the NASA-Task Load Index (TLX) to EM physicians at the end of each observational session to measure subjective workload associated with the clinical activities performed during the preceding 180 min work period. The NASA-TLX is a ''multi-dimensional rating that provides an overall workload score based on a weighted average of ratings on six subscales: mental demands; physical demands; temporal demands; own performance; effort and frustration [40,41]''.

Finally, observers wore a pedometer during each observational session to approximate the amount of walking performed by each study subject [37].

2.3. Instrument development and statistical analysis

Prior to initiating the full study, a pilot study was performed on three volunteers to develop the observational data collection form. The two observers achieved an interrater reliability of 0.81 (Kappa statistic) for task classification after two 3 h observation sessions. Thirteen clinical activities or tasks were determined to represent the majority of the work activities undertaken by EM faculty and residents during typical work shifts (see Table 1). The investigators adopted Chisholm's convention for categorizing the outcomes of tasks performed [34]. That is, tasks could have any one of

Table 1 Categorization of tasks

Task name	Description
Charting	Written charting
Dictating	Verbal charting
Direct patient care	Physician at patient's bedside
Electronic whiteboard view	Physician views or scans eWB for information
Electronic whiteboard interaction	Physician uses touch-screen to pull or add information from the eWB
Exchanging patient information	Provider-to-provider verbal exchange of patient-specific clinical information
Getting charts/records/documents	Physician retrieves paper charts, records, or documents
Phone calls and consults	Phone consultation with another provider
Supervising	Supervision (observation) of a junior physician or resident
Teaching/learning	Formal interactive clinical teaching or learning
View diagnostic test results	Viewing laboratory results or radiology
Answering EMS calls	Physician responding to phone call from EMS
Verbal orders to a provider	Physician gives verbal orders to a resident, nurse or other clinical staff member

Table 2 Categorization of Interruptions

Interruption name	Description
Face-to-face physician	Another physicians interrupts task with verbal communication
Face-to-face nurse	Nurse interrupts physician task with verbal communication
Face-to-face other	Another provider interrupts physician task with verbal communication
Lost chart, form or document	Lost chart or documentation interrupts task
Page	Alpha-numeric page alert interrupts task
Direct patient care	Urgent patient care interrupts current task
Phone call	Phone call (clinical or non-clinical) interrupts task
Equipment malfunction	Computer or diagnostic equipment malfunction interrupts task
Other	Any other event that interrupts physician tasks

the following outcomes: (1) task completed without interruption (i.e., ''end task''); (2) task interrupted and new task started (i.e., ''break-in-task'') or (3) task temporarily interrupted but completed before new task started (i.e., ''temporary interruption''). Table 2 summarizes the nine major types of interruptions recorded during the observations.

An interruption was defined as an event that diverted the physician's attention from the task at hand. An ''end task'' denoted a task proceeded without interruption. A ''break-in-task'' was a type of interruption that pre-empted one task, resulting in another task being performed. A temporary interruption was an interruption that momentarily diverted the physician's attention away from the task at hand but did not result in a break-in-task [34].

Descriptive statistics (i.e., mean ± standard deviation) were used to characterize physician work activity, interruption patterns, workload and eWB activity in the ED. Mann—Whitney *U*-tests were used to compare continuous variables between EM faculty physicians and resident physicians (i.e., PGY-3 and PGY-2 pooled). A significance level 0.05 was used for all analyses.

3. Results

3.1. Work and interruption patterns

In aggregate, 50 h of work activity were observed and recorded for 20 EM physicians working in the VUMC adult emergency department during the study period. Physicians performed 2053 tasks during this time and averaged 103.0 tasks (95% CI, 94.7—111.3) per 180 min observational period. Three-hundred and three interruptions, comprising breaks-in-tasks ($N = 93$) and temporary interruptions ($N = 210$), were recorded. On average, PGY-3 residents performed the most tasks (108.0; 95% CI, 99.2—116.8) and experienced the most interruptions (17.6; 95% CI, 12.8—22.4) per observational. PGY-2 residents completed the least number of tasks (97.8; 95% CI, 86.4—109.2) and experienced the fewest interruptions (11.0; 95% CI, 9.3—12.8).

Table 3 Summary statistics from EM physician observations[a]

	Attending ($N=10$)	PGY-3 ($N=5$)	PGY-2 ($N=5$)
Total time observed (hours:minutes:seconds)	25:28:42	12:54:19	11:53:48
Counts of ED system workload metrics (mean and standard deviation)			
Total no. of patients seen	11.4 ± 5.3	12.6 ± 2.7	6.4 ± 5.0
Maximum no. of patients simultaneously managed	9.8 ± 4.0	10.8 ± 1.6	5.6 ± 4.3
Acuity of patients seen	2.6 ± 0.2	2.1 ± 0.2	2.2 ± 0.2
Patient LOS (h)	5.9 ± 2.2	9.8 ± 0.9	6.4 ± 3.7
ED occupancy (%)	92.7 ± 3.8	94.8 ± 11.7	92.0 ± 6.5
Counts of tasks and interruptions (mean and standard deviation)			
Tasks	102.4 ± 23	108.0 ± 10	97.8 ± 13
End tasks	86.4 ± 24.0	90.4 ± 14.6	86.8 ± 12.0
Break-in-tasks	5.3 ± 3.8	5.6 ± 3.0	2.4 ± 1.8
Temporary interrupted	10.7 ± 2.9	12.0 ± 7.9	8.6 ± 2.1
No. of interruptions	16.0 ± 3.4	17.6 ± 5.5	11.0 ± 2.0
Time between interruptions (min)	9.6	8.8	13.0
Duration of tasks and interruptions (mean and standard deviation)			
Uninterrupted task	1:22 ± 1:56	1:17 ± 2:03	1:23 ± 2:16
Broken tasks	0:54 ± 0:52	1:21 ± 1:44	0:56 ± 0:52
Interrupted tasks (excluding duration of interruption)	2:09 ± 1:42	2:03 ± 1:57	1:48 ± 1:35
Task duration preceding temporary interruption	1:00 ± 1:10	0:57 ± 0:59	0:53 ± 0:56
Temporary interruptions	0:33 ± 0:40	0:29 ± 0:32	0:24 ± 0:19
Distance walked (mean and standard deviation)			
Distance walked (miles)	0.8 ± 0.4	0.8 ± 0.3	0.7 ± 0.3

[a] Statistics are per 180 min observation.

Faculty physicians experienced an interruption once every 9.6 min (95% CI, 8.3—10.8), PGY-3 residents every 8.8 min (95% CI, 7.3—10.3) and PGY-2 residents every 13.0 min (95% CI, 12.6—13.4). Table 3 summarizes the observational data by training level.

The tasks performed most frequently by the pooled EM physician group were exchanging patient information, direct patient care and charting. The tasks requiring the greatest time commitment per observation were direct patient care and exchanging patient information. Fig. 1 shows the relationship between the frequency of tasks performed and the amount of time EM physicians spent completing those tasks. As the figure illustrates (see direct patient care and exchanging patient information for examples), the frequency and duration of tasks performed were not always positively correlated. In terms of differences between training levels, faculty physicians and resident physicians differed most on the proportion of work tasks allocated to exchanging patient information and charting, respectively. The proportion of exchanging patient information tasks observed was 8% higher for faculty physicians (29% of all tasks performed) as compared to residents (21%). Faculty performed 26.9 (95% CI, 21.6—32.2) exchanging information tasks and residents performed 19.8 (95% CI, 17.1—22.5) of these tasks per observational period, respectively. Conversely, the proportion of observed charting tasks was 11% greater for residents (20%) than faculty physicians (9%). Residents performed 18.4 (95% CI, 15.5—21.3) charting tasks per observation as compared to 8.6 (95% CI, 5.5—11.7) for faculty. Similar gaps were found to exist in the amount of time faculty and residents spent performing these tasks. In addition, faculty physicians were found to spend nearly 12% of their observed time performing dictation tasks, whereas residents spent virtually no time dictating. Residents performed 58.6% ($N = 173$) of all direct patient care tasks observed.

The mean duration of uninterrupted tasks was 2 min 41 s (95% CI, 02:33—02:49), and the mean duration of tasks temporarily interrupted was 2 min 3 s (95% CI, 01:49—02:17), excluding the duration of the temporary interruption. Breaks-in-tasks and temporary interruptions each occurred about 1 min into the start of a clinical task. The mean duration of observed temporary interruptions was 30 s (95% CI, 00:25—00:35), and there were no statistically significant differences between faculty and resident physicians groups.

Nine percent ($N = 27$) of all direct patient care tasks were interrupted by either breaks-in-tasks or temporary interruptions. The most common

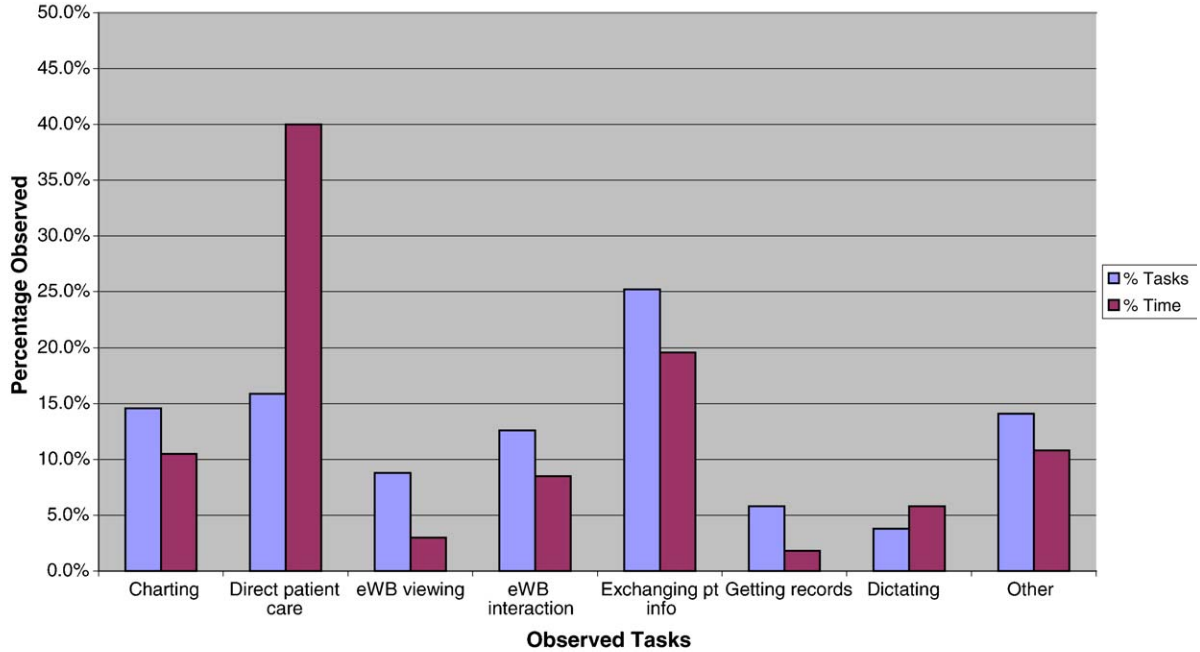

Fig. 1 Distributions of tasks observed—frequency and duration.

interruptions (Fig. 2), across all tasks, were face-to-face physician (47.5%, $N = 144$), face-to-face nursing communications (21.1%, $N = 64$), and phone calls (13.5%, $N = 41$). Face-to-face physician interruptions most frequently interrupted charting (29.2%, $N = 42$), eWB interaction (22.2%, $N = 32$) and exchanging patient information tasks (11.8%, $N = 17$). Face-to-face nursing interruptions most frequently interrupted exchanging patient information tasks (23.4%, $N = 15$), eWB interactions (21.9%, $N = 14$) and charting (15.6%, $N = 10$). Phone interruptions most frequently interrupted exchanging patient information tasks (22.0%, $N = 9$), direct patient care (17.1%, $N = 7$) and charting (14.6%, $N = 6$). The distributions of observed interruptions were consistent in regards to frequency and

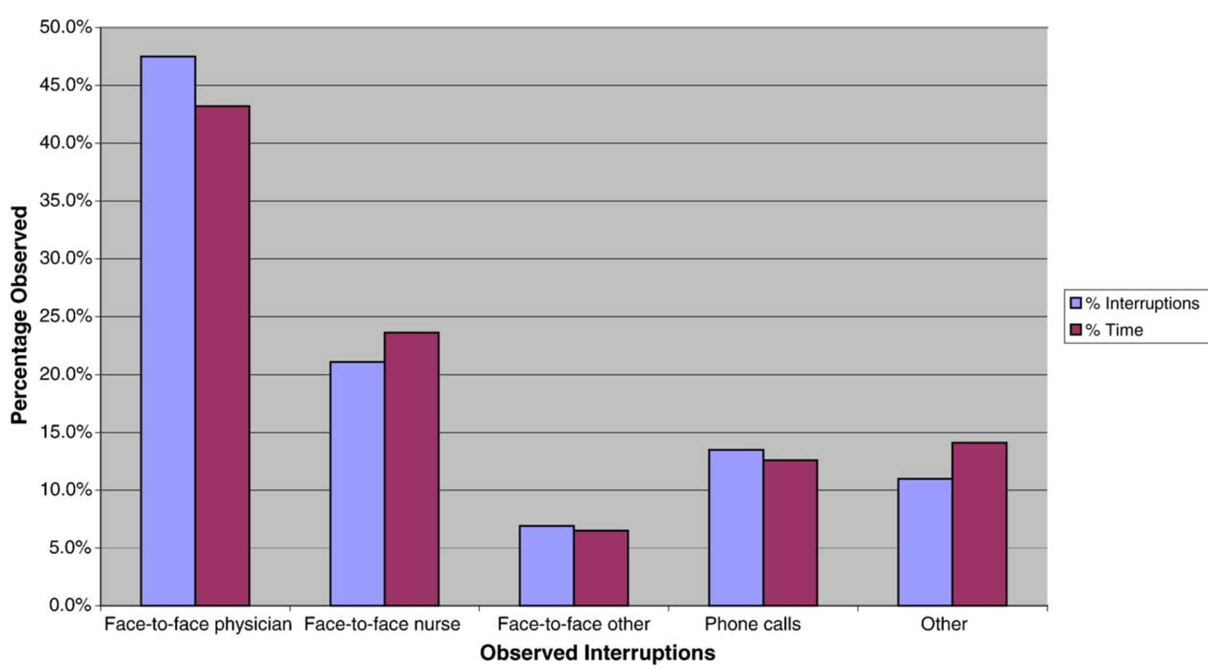

Fig. 2 Distributions of interruptions observed—frequency and duration.

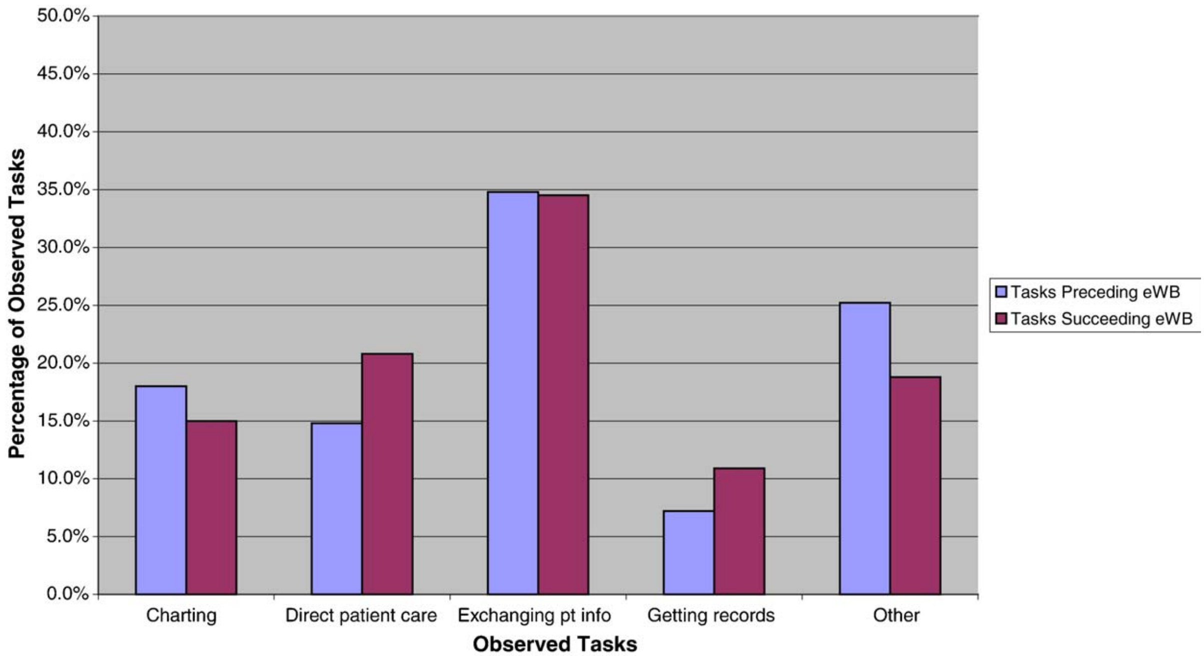

Fig. 3 Distribution of tasks preceding and succeeding physician electronic whiteboard activity (viewing or interaction).

duration (Fig. 2). That is, the interruptions that occurred the most consumed the most clinical time.

3.2. Use of the electronic whiteboard

Physician viewing of and interaction with (i.e., touch-screen) the eWB represented 19.3% (N = 396) of all clinical tasks observed. Faculty physicians and PGY-2 residents viewed the eWB 9 times (95% CI, 6.7—11.7) and interacted with it 11 times (95% CI, 8.2—13.8) per observational session. PGY-3 residents viewed the eWB five times (95% CI, 2.3—7.7) and interacted with it 14 times (95% CI, 7.2—20.0) per session. The tasks that most frequently preceded eWB viewing or interaction were (see Fig. 3): exchanging patient information (34.8%), miscellaneous other tasks (25.3%), charting (18.0%) and direct patient care (14.8%). Exchanging patient information (34.5%), direct patient care (20.8%) and charting (15.0%) most frequently succeeded eWB viewing or interaction.

3.3. Physician patient load, physical activity and subjective workload

A comparative analysis of system workload metrics during observed and unobserved periods revealed no significant differences between periods for average number of patients managed, maximum number of patient managed, average patient acuity, average LOS or average occupancy (see Table 4).

Faculty and PGY-3 resident physicians managed approximately twice as many patients (i.e., 12 patients) per observational session than did PGY-2 residents (i.e., 6 patients). Statistically significant differences were not found among the mean distances each physician group walked (i.e., 0.8 miles) per observational period (Table 3).

Table 4 Comparison of system workload metrics during observed and unobserved periods[a]

	Observed (N = 20), mean (95% CI)	Unobserved (N = 30), mean (95% CI)
Total no. of patients managed	10.1 (7.6—12.7)	8.8 (7.5—10.2)
Maximum no. of patients simultaneously managed	8.7 (6.7—10.8)	7.9 (6.6—9.1)
Acuity of patients seen	2.3 (2.2—2.4)	2.3 (2.2—2.4)
Patient LOS (h)	7.4 (5.9—8.9)	7.8 (6.7—8.9)
ED occupancy (%)	91.4 (80.7—102.1)[b]	88.2 (84.7—91.8)

[a] Statistics are per 180 min periods.
[b] ED occupancy can exceed 100% if the number of patients admitted exceeds the number of exam rooms.

Table 5 Mean subjective workload scores by task and training level[a]

Task	Attending ($N=10$)	PGY-3 ($N=5$)	PGY-2 ($N=5$)
Answering EMS	26.0 ± 18.9	39.6 ± 25.8	28.5 ± 22.9
Charting	52.7 ± 15.7	59.8 ± 13.5	67.5 ± 11.5
Direct patient care	53.7 ± 18.8	71.8 ± 8.9	61.5 ± 13.5
Electronic whiteboard interaction	35.5 ± 18.2	42.0 ± 19.7	48.8 ± 4.6
Exchanging patient information	53.8 ± 11.7	66.2 ± 22.4	58.8 ± 13.3
Getting old records	30.2 ± 25.2	46.2 ± 32.6	40.8 ± 28.7
Phone call/consults	51.0 ± 15.4	65.2 ± 21.4	65.8 ± 13.6
Supervising	54.8 ± 12.8	41.3 ± 25.5	20.5 ± 41.0
Teaching/learning	54.6 ± 11.9	55.6 ± 15.9	57.5 ± 19.0
Viewing diagnostic results	43.6 ± 20.9	52.8 ± 15.1	54.0 ± 20.0

[a] Viewing eWB data and eWB Interaction were combined into a single category for workload assessment; two tasks, dictating and verbal orders, were excluded from the assessment because attending physicians performed nearly all these tasks.

Table 6 Mean subjective workload scores by dimension and training level

Workload dimension	Attending ($N=10$)	PGY-3 ($N=5$)	PGY-2 ($N=5$)
Mental demand	56.3 ± 19.5	59.9 ± 19.8	44.9 ± 17.2
Physical demand	24.8 ± 12.9	20.4 ± 17.9	46.2 ± 15.2
Temporal demand	62.8 ± 17.7	74.4 ± 13.2	63.5 ± 25.8
Effort	50.8 ± 22.0	61.1 ± 22.7	63.8 ± 5.6
Performance	45.6 ± 20.9	41.4 ± 19.8	45.8 ± 14.1
Frustration	45.3 ± 14.2	65.8 ± 18.1	61.2 ± 18.9
Weighted workload	50.6 ± 12.7	61.9 ± 12.8	61.0 ± 7.7

Faculty physicians exhibited lower subject workload scores than residents for all tasks, except supervising (Table 5). Residents performed only one supervisory task during the observational period. PGY-3 residents reported a mean workload score of 71.8 (95% CI, 64.0—79.6) for patient care tasks, and this represented the highest mean workload score reported for all groups. PGY-3 residents also scored for exchanging patient information tasks (66.2; 95% CI, 46.6—85.8) higher than either faculty (53.8; 95% CI, 46.5—61.0) or PGY-2 resident physicians (58.8; 95% CI, 47.1—70.5). PGY-2 residents assigned their highest workload score (67.5; 95% CI, 57.4—77.6) to charting, a task they spent more observed time (20%) performing than any other group.

Analysis of the six dimensions of subjective workload revealed relatively balanced scoring behaviors across physician training levels (Table 6). However, two dimensions—temporal demand (TD) and frustration—drove the mean weighted workload scores approximately 10 points higher ($p=0.054$) for residents (61.5; 95% CI, 54.9—68.1) than faculty physicians (50.6; 95% CI, 42.7—58.5). The difference in frustration scores between faculty (45.3; 95% CI, 36.5—54.1) and residents (63.7; 95% CI, 52.3—75.1) was statistically significant ($p=0.02$) despite the small sample size. Nearly, 40% of all physicians observed scored TD as the highest overall contributor to workload. The majority (86%) of physicians had an average TD workload score that exceeded their overall weighted workload score. Physicians ranked TD the strongest contributor to workload for the following tasks: direct patient care; charting; exchanging patient information and eWB interaction. For the study period, these tasks represented 68.2% of all tasks performed and 78.4% of all clinical time observed.

4. Discussion

This study replicated and expanded the methodology of several previously published observational studies in the ED and other clinical areas to gain some insight on the effects of implementing an integrated electronic whiteboard on physician work, communication and workload in the ED. The results of this study would have been greatly strengthened by using an increased sample size and either a pre—post (i.e., eWB implementation) study design or a randomized clinical trial (RCT). These changes were not feasible for this study due to various organizational and resource constraints. This study also did not use real-time audio recordings of the observations or observer notes to supplement the computer-assisted primary task analysis. This methodology has been shown to add rich contextual information to observational studies in the ED [35]. Despite these limitations, a number of important insights have been gained regarding the behavior of physicians in a complex clinical setting supported by an advanced informatics infrastructure. Information garnered from the study provides some important feedback regarding the benefits of the eWB and future improvements.

The most striking differences in our results compared to previously published results relate to work efficiency and interruption rates in the ED. We report that EM physicians performed 102.6 (95% CI, 94.3—110.9) tasks and were interrupted 14.9 (95% CI, 13.3—16.5) times per 180 min observational period. Chisholm et al. reported that EM physicians performed 67.6 (95% CI, 62.2—73.0) tasks and experienced 30.9 (95% CI, 27.4—34.4) interruptions per 180 min period in a conventional ED [33]. Similarly, we found that, on average, EM physicians are interrupted every 9.5 min, or 6.3 times per hour. Chisholm and Coiera reported interruption rates of 9.7 and 11.5 interruptions per hour, respectively [19,33,34]. Spencer et al. reported 23.5 and 8.3 interruptions per hour for attending ED physicians and interns and residents, respectively [42]. However, Hymel and Severyn reported a lower rate (4.8 interruption per hour) in an urban teaching ED [38]. Finally, we report that our pooled EM physician group spent approximately 40% of all observed time on direct patient care tasks. This result is 10% higher than previously reported by Hollingsworth et al. who studied a similar sample in a city teaching hospital. In an analysis of communication events in the ED, Spencer found that 71% of total event time observed was related to patient management. Although unproven by the current study, the results suggest that distributed and accessible clinical information improves work and communication efficiency.

Our results are consistent with those previously reported by Hollingsworth et al. regarding the time faculty and residents allocate to different tasks [37]. Faculty, PGY-3 and PGY-2 physicians each spent the greatest percentage of their clinical time on direct patient care. Similarly, we found that resident physicians perform the majority of charting tasks in the ED. PGY-3 resident physicians were determined to be the workhorses of the ED in our study, performing the most tasks and experiencing the most interruptions. Our results did not support Hollingsworth's finding that faculty walked less than resident physicians [37]. We found no difference in the distance walked between our physician groups.

As previously reported by Chisholm et al., we found temporary interruptions occurred at nearly twice the rate that breaks-in-tasks occurred [33,34]. We found that temporary interruptions lasted approximately 30 s in duration which is consistent with results previously reported by Spencer (i.e., 38 s) [42]. We also found that tasks temporarily interrupted, excluding the duration of the interruption, were approximately 38 s shorter in duration than uninterrupted tasks. This finding calls into question the quality of clinical work completed in highly interruptive environments and has important implications related to efficiency and patient safety [43]. The results suggest that, upon resuming temporarily interrupted tasks, physicians accelerate or rush the completion of these tasks, perhaps to make up for lost time created by the interruption. The effects of time constraints created by interruptions may disrupt the pace or rhythm of work. The relationships between interruptions, work pace, quality of work and re-work will require further study before solid conclusions can be made.

Overall, 14.8% of all observed tasks were interrupted (e.g., temporary or breaks-in-tasks). Coiera et al. previously reported 30.8% of all communication events were interruptions [19]. Face-to-face interruptions, by physician or nurse, were determined to be the most common type of interruption (68.6%) in our study. This result is supportive of recent findings by Spencer et al. [42]. Although interruption rates appear to be reduced in an ED equipped with an eWB, it is clear that such synchronous communications are still commonplace. This is not a surprising or unsatisfactory result since the ED is a dynamic, team-oriented environment. These results tend to support Coiera's earlier conclusion that ''excessive emphasis on communication technology may be misguided since much may be gained from information exchange through information technology'' [35].

In fact, only 9% of all interruptions directly interrupted patient care. Therefore, safety interventions, such as crew resource management, that focus on provide—provider interactions outside the patient's room may produce the greatest improvements in patient safety outcomes. The results support or encourage a dual approach to clinical improvement in complex environments, one that finds a balance between information technology and team training (e.g., crew resource management, Med-Teams, etc.). It is hypothesized that the safest, most efficient and reliable socio-technological systems will find this balance between human—human and human—technology interaction. That is, IT solutions will facilitate the efficient and safe communication of clinical data to all members of a care team.

The eWB appeared to function as the command and control center of the ED. One-fifth of all clinical activities recorded in our study were either eWB viewing or interaction. By comparison, Spencer et al. reported that residents and attending physicians used a conventional EDIS for 3—5% of communications events in a large metropolitan teaching hospital [42]. Provider-to-provider communication (i.e., exchanging patient information) was the most common task preceding and succeeding eWB activity. This result re-emphasizes the importance of team communication and feedback in the ED. Only direct patient care and retrieving records occurred more often after eWB activity than before. Although resident physicians reported higher overall workload scores and workload scores across most tasks, including eWB usage, than faculty physicians, the workload scores were well-distributed. The workload differences observed across physician training level suggest that physicians with more experience have acclimated to the work environment and have achieved a greater sense of control over job demands. This is supported by the finding that residents ranked frustration as major contributor to their workload while faculty physicians did not. All physicians ranked temporal demands and mental demands as major contributing factors to workload, a result that is expected in the fast-paced ED environment.

These results appear to have important human factors and safety implications. The eWB appears to improve the distribution of workload among team members and improve provider situational awareness. However, these results must be viewed as preliminary due to limitations in the study design and analysis. First, additional studies using local controls (i.e., pre—post study design) are needed to evaluate the true impact of the eWB on provider outcomes and performance. Secondly, although the investigators tried to replicate previously published methodologies to enable comparisons of results across studies, differences remained and must be acknowledged in evaluating the results and conclusions.

Future research must focus on the relationships among task load factors, communication factors, and information technology factors and patient and provider safety outcomes. Research methodologies from human factors engineering are well-suited for examining the specific linkages among ED work state, EM provide state (i.e., psychological and physical well-being), efficiency and safety in the emergency department. Finally, observational studies must be continued in the ED, but extended to provider teams rather than isolated EM providers.

References

[1] L. McCraig, C.W. Burt, National Hospital Ambulatory Medical Care Survey: 2002 Emergency Department Summary, National Center for Health Statistics, Hyattsville, MD, Advance Data 340, March 2002, 2004.
[2] S. Trzeciak, E.P. Rivers, E.N. Barthell, S.L. Foldy, et al., Emergency department overcrowding in the United States: an emerging threat to patient safety and public health, Emerg. Med. J. 20 (2003) 402—405.
[3] A. Forster, I. Stiell, G. Wells, A.J. Lee, C. van Walraven, The effect of hospital occupancy on emergency department length of stay and patient disposition, Acad. Emerg. Med. 10 (2003) 127—133.
[4] Reasons for crowded EDs vary among hopsital, communities, GAO says, Qual Letter Healtc Lead, 15 (2003) 12—13.
[5] F. Zwemer, Emergency department overcrowding, Ann. Emerg. Med. 36 (2000) 279—280.
[6] J. Appleby, ER Conditions: Critical, in USA Today, Crystal City, 2001.
[7] To Err is Human: Building A Safer Health System, National Academy Press, Washington, DC, 1999.
[8] J. Fordyce, F.S. Blank, P. Pekow, H.A. Smithline, G. Ritter, G. Gehlbach, E. Benjamin, P.L. Henneman, Errors in a busy emergency department, Ann. Emerg. Med. 42 (2003) 324—333.
[9] D.M. Taylor, R. Wolfe, P.A. Cameron, Complaints from emergency department patients largely result from treatment and communication problems, Emerg. Med. (Fremantle) 14 (2002) 43—49.
[10] J. Vinen, Doctors beware: why a patient complains is not always what it seems, Emerg. Med. (Fremantle) 14 (2002) 9—11.
[11] L.R. Schwartz, D.T. Overton, Emergency department complaints: a one-year analysis, Ann. Emerg. Med. 16 (1987) 857—861.
[12] E.D. Boudreaux, C.V. Mandry, K. Wood, Patient satisfaction data as a quality indicator: a tale of two emergency departments, Acad. Emerg. Med. 10 (2003) 261—268.
[13] J.G. Adams, J.S. Bohan, System contributions to error, Acad. Emerg. Med. 7 (2000) 1189—1193.
[14] J. Allard, J. Carthey, J. Cope, M. Pitt, S. Woodward, Medication errors: causes, prevention and reduction, Br. J. Haematol. 116 (2002) 255—265.
[15] T. Hamilton, Communication in the emergency department, Med. J. Aust. 177 (2002) 334, author reply 334—5.
[16] R. Knopp, S. Rosenzweig, E. Bernstein, V. Totten, Physician-patient communication in the emergency department, part 1, Acad. Emerg. Med. 3 (1996) 1065—1069.
[17] C.A. Vincent, R.L. Wears, Communication in the emergency department: separating the signal from the noise, Med. J. Aust. 176 (2002) 409—410.
[18] S. Williams, J. Weinman, J. Dale, Doctor-patient communication and patient satisfaction: a review, Fam. Pract. 15 (1998) 480—492.
[19] E.W. Coiera, R.A. Jayasuriya, J. Hardy, A. Bannan, M.E. Thorpe, Communication loads on clinical staff in the emergency department, Med. J. Aust. 176 (2002) 415—418.

[20] D.T. Risser, M.M. Rice, M.L. Salisbury, R. Simon, G.D. Jay, S.D. Berns, The potential for improved teamwork to reduce medical errors in the emergency department. The MedTeams Research Consortium, Ann. Emerg. Med. 34 (1999) 373—383.
[21] P. Bennett, R. Lowe, V. Matthews, M. Dourali, A. Tattersall, Stress in nurse: coping, managerial support and work demand, Stress Health 17 (2001) 55—63.
[22] V. Cassar, A. Tattersall, Occupational stress and negative affectivity in Maltese nurses: testing moderating influences, Work Stress 12 (1998) 85—94.
[23] J.M. Laposa, L.E. Alden, L.M. Fullerton, Work stress and posttraumatic stress disorder in ED nurses/personnel, J. Emerg. Nurs. 29 (2003) 23—28.
[24] M. Levitt, An evaluation of physiological stress in the emergency department, Am. J. Emerg. Med. 9 (1991) 217—219.
[25] J. Losek, Characteristics, workload, and job satisfaction of attending physicians from pediatric emergency medicine fellowship programs, Pediatric Emerg. Care 10 (1994) 256—259.
[26] S. Lloyd, D. Streiner, S. Shannon, Burnout, depression, life and job satisfaction among Canadian emergency physicians, J. Emerg. Med. 12 (1994) 559—565.
[27] G. Lum, R.M. Goldberg, W.K. Mallon, B. Lew, J. Margulies, A survey of wellness issues in emergency medicine (part 2), Ann. Emerg. Med. 25 (1995) 242—248.
[28] M. Reinhart, B.S. Munger, D.A. Rund, American board of emergency medicine longitudinal study of emergency physicians, Ann. Emerg. Med. 33 (1999) 22—32.
[29] T.W. Whitley, E.J. Allison, M.E. Gallery, J. Heyworth, R.A. Cockington, P. Gaudry, D.A. Revicki, Work-related stress and depression among physicians pursuing postgraduate training in emergency medicine: an international study, Ann. Emerg. Med. 20 (1991) 992—996.
[30] S. Williams, J. Dale, E. Glucksman, A. Wellesley, Senior house officers' work related stressors, psychological distress, and confidence in performing clinical tasks in accident and emergency: a questionnaire study, BMJ 314 (1997) 713—718.
[31] M.E. Gallery, T.W. Whitley, E.J. Allison Jr., D.A. Revicki, Factors associated with stress among emergency medicine residents, Ann. Emerg. Med. 18 (1989) 1157—1161.
[32] J. Zautcke, V.D. Neylan, R.G. Hart, Stress in the emergency department clerical staff, J. Emerg. Med. 14 (1996) 247—249.
[33] C.D. Chisholm, E.K. Collison, D.R. Nelson, W.H. Cordell, Emergency department workplace interruptions: are emergency physicians ''interrupt-driven'' and ''multitasking''? Acad. Emerg. Med. 7 (2000) 1239—1243.
[34] C.D. Chisholm, A.M. Dornfeld, D.R. Nelson, W.H. Cordell, Work interrupted: a comparison of workplace interruptions in emergency departments and primary care offices, Ann. Emerg. Med. 38 (2001) 146—151.
[35] E. Coiera, V. Tombs, Communication behaviours in a hospital setting: an observational study, BMJ 316 (1998) 673—676.
[36] L.G. Graff, S. Wolf, R. Dinwoodie, D. Buono, D. Mucci, Emergency physician workload: a time study, Ann. Emerg. Med. 22 (1993) 1156—1163.
[37] J.C. Hollingsworth, C.D. Chisholm, B.K. Giles, W.H. Cordell, D.R. Nelson, How do physicians and nurses spend their time in the emergency department? Ann. Emerg. Med. 31 (1998) 87—91.
[38] G. Hymel, F. Severyn, Typical shiftwork interruptions faced by supervising EM faculty in an EM residency setting, in: Presented at Society for Academic Emergency Medicine Midwest Regional Meeting, Ann Arbor, Michigan, 1999.
[39] Y. Xiao, C. Lasome, J. Moss, C.F. Mackenzie, S. Faraj, Cognitive properties of a whiteboard: a case study in a trauma centre, in: Presented at Seventh European Conference on Computer-Supported Cooperative Work, Bonn, Germany, 2001.
[40] NASA Task Load Index (TLX) V 1.0 Users Manual, Human Systems Information Analysis Center, 1988.
[41] S.G. Hart, L.E. Staveland, Development of NASA-TLX (Task Load Index): results of experimental and theoretical research, in: P.A. Hancock, N. Meshkati (Eds.), Human Mental Workload, North Holland, Amsterdam, 1988, pp. 139—183.
[42] R. Spencer, E.W. Coiera, P. Logan, Variation in communiction loads on clinical staff in the emergency department, Ann. Emerg. Med. 44 (2004) 268—273.
[43] J. Parker, E. Coiera, Improving clinical communication: a view from psychology, J. Am. Med. Informatics Assoc. 7 (2000) 453—461.