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Unanticipated influence of coordination mechanisms on physician workstyles and ED operational efficiency

David A. Tilson
University of Rochester, david.tilson@simon.rochester.edu

Vera Tilson
University of Rochester, vera.tilson@simon.rochester.edu

Vicken Y. Totten
Case Western Reserve Univ. School of Medicine, vicken.totten@uhhospitals.org

Edward A. Michelson
Case Western Reserve Univ. School of Medicine, Edward.Michelson@uhhospitals.org

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Vicken Y. Totten
Case Western Reserve Univ. School of Medicine
vicken.totten@uhhospitals.org

Edward A. Michelson
Case Western Reserve Univ. School of Medicine
edward.michelson@uhhospitals.org

ABSTRACT (REQUIRED)

The coordination of activities in a work context has been examined by many disciplines and in recent years the role of information systems and other artifacts has become increasingly prominent. The emergency department (ED) of a hospital in a large US city is used to study how information systems and other coordinating mechanisms affect how physicians choose to perform their work and how such choices can impact the ED's overall operational performance. The study used direct observation of the work performed in the ED, interviews of physicians, nurses and other ED staff members, and the analysis of historical performance data. The key findings were that the existing coordination mechanisms are a mix of fixed and mobile, computer and paper-based information systems, and other artifacts. The workstyles adopted by physicians were shaped by incidental characteristics of these coordination mechanisms. Some workstyles appear to have adverse, albeit unintended, effects on aspects of the department's operational performance.

Keywords (Required)

Coordination Mechanisms, Hospital Emergency Department, Health Information Systems, Operational Efficiency

INTRODUCTION

In 2004 the US Bureau of Labor Statistics classified healthcare as the country's largest industry, providing 13.5 million jobs. The industry is projected to get even bigger as the baby boom generation ages and national healthcare expenditures are forecast to increase to 20% of GDP by 2015 (up from 12% in 1990) (Bureau of Labor Statistics 2006-07). The demographic shift and increasing population is felt particularly strongly in Emergency Departments (ED). From 1992 to 2002 there was a 23% increase in annual emergency room visits (Nawar et al. 2007).

Any casual observer of the US healthcare industry notes that customer encounters are fraught with operational inefficiencies: starting with multiple registration forms asking for the same seemingly unnecessary information, long waits, complicated (and frequently erroneous) invoices, etc. As early as 1967 the Regenstrief Foundation sought to promote the application of engineering and production concepts to healthcare delivery. More recently the 2006 IOM report on the Future of Emergency Medicine called on hospital leaders to learn from the experiences of other industries and recommended training in operations management and related approaches. Emergency physicians have proposed standardized measures for quantifying and comparing the operational ED performance (Welch et al. 2006). To improve customer satisfaction many EDs instituted "fast tracking" for patients with minor problems, similar to the "express lanes" of large supermarkets. Some hospitals now utilize queuing theory tools to match staffing levels to predicted demand (Green et al. 2006). The EDs and, hospitals in general, are adopting information systems to increase efficiency, improve coordination, and reduce errors.

Coordination of the dependencies among activities has been examined in several fields including organization theory (e.g. Duncan 1971; Galbraith 1973; Lawrence et al. 1967) and economics (e.g. Brynfolfsson et al. 1994; Malone et al. 1987). More recently the coordinating role of information systems has been studied in the multidisciplinary field of Computer Supported Cooperative Work (CSCW), and by adherents of Coordination Theory (Malone et al. 1994).

The proximity (collocated, nearby, or remote) and mobility of coworkers, or relevant artifacts (Luff et al. 1998), uncertainty around the arrival of work, and the level of uncertainty associated with how the work should be competed (Lee et al. 2002) have been identified as key variables in identifying the roles that information systems, and other artifacts can play in assisting coordination. The sometimes subtle roles of non-IT artifacts have been studied in restaurants, air-traffic control, print shops, ship navigation, and healthcare settings among others – see (Xiao 2005) for an overview.

This paper examines how physicians adapt their workstyles to the coordinating mechanisms in the ED, and how, in turn, physician workstyles affect the department's overall operational performance. We provide empirical evidence for the existence of workstyle differences using direct observation and analysis of historical data. We conclude with a discussion of administrative and policy implications of coordination system design in the ED setting.

ED OBSERVATIONS AND INTERVIEWS

One author spent several days and nights directly observing the work in a US ED, "shadowing" several physicians and nurses. The same author also interviewed 4 physicians, 3 nurses, and several other hospital employees involved with the ED[1].

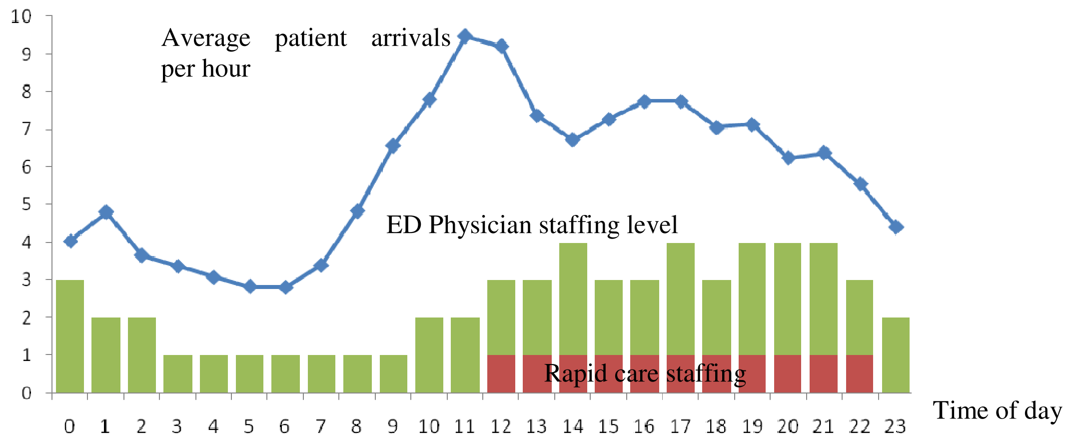

Figure 1. Typical physician staffing of the main ED over a 24-hours

Patient Arrivals and Physician Schedules

The department studied treats, on average, 130 patients per day in its adult, pediatric and rapid care clinics. There are daily and weekly patterns associated with patient arrivals and staffing levels also vary. A Rapid Care (RC) center, open from noon to 11:00 pm daily, specializes in fast tracking the treatment of minor complaints. Figure 1 illustrates typical physician coverage in the non-pediatric part of the ED over the course of a day. "Bumps" in coverage are due to overlaps in shifts.

Some physicians are employed full-time (2000 hours per year), while others are contracted to work some fraction of this. Work schedules must satisfy the terms of the physicians' contracts, and are made-up of combinations of four, six, seven, eight, nine, eleven and twelve-hour morning, daytime, and evening shifts in the regular ED or RC.

Workflow

Most patients arrive into a waiting room. There they are examined by a triage nurse, who assigns them to one of three priority groups according to the acuity of their condition. When the RC center is open, patients with the most easily treated conditions are directed there. At other times these low-acuity patients are treated in the main ED. Thus, whether or not the RC center is open has a large impact upon the mix of patients dealt with by the main ED.

After triage patients are registered - this involves collecting their billing information and assigning an ID number. This ID number is used in tracking the services provided by various hospital departments, in billing, and in accessing electronic patient records.

As beds become available patients are moved from the waiting room to the ED, according to acuity priority. In this ED one of the most important mechanisms for tracking patients is a whiteboard mounted on a wall at the center of the department. Each row on the whiteboard contains information about the patient assigned to a particular bed. As a patient is allocated to a bed

[1] The authors sought and obtained IRB approval of this study.

the patient's name, time-of-arrival, and chief complaint are posted in the corresponding row of the whiteboard. The whiteboard is visible not only to all personnel within the ED, but also to the triage nurse and to the ED administrator, who can monitor the whiteboard remotely via a webcam. ED nurses are responsible for providing care to patients in a set of co-located beds (an approach referred to as "zone staffing"). The charge nurse assigns areas of responsibility to nurses and other non-physician personnel, coordinates lunch breaks, and expedites procedures for patients who have spent a long time in the ED.

After a patient is placed in a bed, the ED secretary creates a patient chart (a one-inch thick three-ring binder labeled with the bed number). The nurse assigned to the bed records his/her initial observations in the chart. After these initial observations have been recorded, charts are placed next to the whiteboard. The charts are grouped by acuity and are visible to all ED staff. One look at a stack of charts is sufficient to inform a physician of how many new patients of each acuity level are in the ED (but not in the waiting room). Generally, priority is given to more acute patients, but first-in-first-out prioritization of patients of the same acuity is not enforced. For example, a physician may pick up several charts of patients located close together – thus minimizing walking from one bed to another. At the end of a shift, a physician may decide to take on a simple case that can be completed by the end of the shift. Selecting a more complex case risks having to pass the patient to another physician, breaking continuity of care, incurring additional coordination overhead, and possible handover errors. Once a physician takes on a patient, he/she writes his/her initials next to the patient's name on the whiteboard.

From the point of view of an ED physician the process of treating a patient typically consists of two main phases. In the initial phase the doctor takes the patient's history and performs a physical examination (H&P) after which a series of tests and treatments are usually ordered. In the second phase the physician reviews the results of tests and treatments, and decides whether further treatments or observation in the ED are required. Alternatively the physician can decide to admit the patient to the hospital, transfer the patient to another healthcare facility, or discharge the patient. This phase is typically performed in the 'back office' with decisions communicated to the patient by a nurse.

Coordination of tests, treatments, and consultations

In addition to the whiteboard and paper charts other coordinating mechanisms are used in the ED. These mechanisms evolved over time to address workflow and coordination issues that emerged from practice. For example, after initially examining a patient, a physician enters orders for medication and diagnostic tests. These orders are recorded in the chart and also entered into a computerized order entry system (using terminals located either in the nurses' area or the physicians' cubicles). In addition, the nurses are alerted either verbally or by placing an "RX" magnet next to the patient's name on the whiteboard[2]. Thus, one request for a test can require the physician to utilize four coordination mechanisms, some of which can be time-consuming, but at the same time provides redundancy.

The whiteboard is also occasionally used to coordinate equipment needs. If a physician needs to perform a pelvic exam, he/she places a magnet on the whiteboard indicating that the particular bed area needs to be prepared for a pelvic exam. When the equipment needs are more complicated or the physical presence of a nurse is required during a procedure, the physician must locate the nurse and coordinate face-to-face.

During the time a patient spends in the ED, nurses use the paper chart to record vital signs and the fulfillment of physician orders. The chart is also used by physicians to review status, as a reference for dictating the notes that will appear in the electronic medical record (EMR), or to assess whether all the tests and treatments have been completed. The chart thus plays an important coordinating role. Its physical characteristics have some beneficial coordinating effects (e.g. the stack of charts awaiting physicians' attention acts as an indicator of ED load) but can also have negative effects. These include contention for simultaneous access to a chart, or charts being temporarily misplaced (e.g. if a physician is interrupted while working with a chart). To reduce the incidence of misplaced charts a shelf at the nurses' station serves as a holding place for charts. The shelf is separated into 'mail slots', with a slot dedicated to each bed in which the corresponding chart is usually kept. When the chart is not available, any paperwork that should be placed in the chart is left in the mail slot.

After a physician enters treatment/lab orders using the computerized systems, orders are printed directly to a printer in the ED. Printed orders are placed into the mail slot dedicated to a particular bed. Sorting of orders into the mail slots is an ad-hoc process, done by whomever has a few free moments. The sorter looks at the printout, reads off the patient's name, and then looks at the whiteboard to determine which bed the patient is in so that the order can be placed into the correct mail slot.

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[2] It is not uncommon for several ED patients to have the same last name. A mechanism was developed from practice to deal with this situation: an asterisk is placed next to each instance of the name on the whiteboard to remind providers to be careful.

Sometimes the mail slots serve as temporary placeholders for blood or culture samples waiting to be sent to the lab. Copies of printed test orders together with samples are sent by nurses to a hospital lab using a pneumatic tube system. A label with information about the sample sent is affixed into a log book and the time the sample is sent recorded. The pneumatic tube system is not always reliable, and occasionally tubes get jammed. There is no automatic mechanism for immediate verification that a sample sent from the ED was received in the lab. A lab coordinator in the ED checks on tests that take unreasonably long. The coordinator is also alerted by the lab when poor quality samples need to be retaken.

Patients' test results become part of the patient record in the EMR database. Physicians access these results via computers in the physicians' area. Lab reports are also printed directly to a printer in the ED and sorted into the mail slots just like physicians' orders are sorted.

Unlike lab tests, imaging studies require the patient's presence. When diagnosis requires imaging, the physician alerts the ED secretary, who contacts the appropriate department. When the department is ready an orderly brings the patient to X-ray, CAT Scan, etc. The orderly notes the patient's destination on the whiteboard and the time he/she was taken from the ED.

In addition to lab tests and imaging studies physicians occasionally need to consult specialists: cardiologists, orthopedic surgeons, neurologists, pharmacists, social workers, etc. ED physicians alert the ED secretary when they need such a consultation. The secretary pages the consultant, and, when the latter returns the call, the secretary forwards the call to the appropriate wireless phone[3]. In the current process there are multiple steps in connecting ED physicians with a consultant.

When all tests, treatments, and consultations are complete it should be possible for physicians to make decisions about the discharge, admission, or further treatment of the patient. There is no systematic way in which the physician is made aware that all the test results are available and the treatments completed. In some cases the nurse may check the status and inform the physician that all the orders have been completed. In others the physician requests a status update or personally checks the chart. The lack of a systematic coordination mechanism results in some patients spending longer in the ED than necessary.

In addition to the EMR and the test and medication ordering system, other technological systems are used to coordinate and perform activities. Physicians use fixed telephones located in their shared office to dictate notes about the examination and treatment of patients. The dictations are transcribed and become a part of the patient's electronic medical record. A single centrally located terminal, donated by a pharmaceutical company, is used to print out discharge instructions and prescriptions.

Batching Workstyle

Physicians are the most expensive human resource in an ED and are scheduled for maximum utilization. Staffing for high utilization, combined with random patient arrivals and service times, means that when a physician is ready to examine a new patient there are usually several waiting to be seen. Physicians are faced with a choice, (a) to pick up several charts at once, examine the patients, return to the physicians' area, log on and enter orders for tests and treatments for all patients in the batch, or (b) pick up a single chart and carry-out all of these tasks for one patient. Those physicians who pick up several charts are adopting a "batching" workstyle. Several factors encourage a "batching" workstyle: (1) layout of the ED and location of the computer terminals, (2) login requirements for each of the information systems in the ED, (3) view of the whiteboard as a barometer of productivity – a physician taking care of more patients at once is viewed as more productive. It could be argued that the batching workstyle increases physician productivity by decreasing the time spent on coordination overhead per patient. This workstyle reduces the time physicians spend on certain coordination tasks i.e. going to/from the whiteboard to select which, and how many, patients to take on as well as going to/from and logging-on to terminals to place orders Figure 2 illustrates the ED layout). On the other hand, the orders for the first patient in the batch are not entered until after the last patient in the batch is examined, and the last patient is only examined after all the previous patients are examined. By taking the patient's chart, a physician "locks in" the patient, since the chart is not available to other physicians while other patients in batch are being examined.

The nature of the work processes in the ED is such that physicians usually have multiple patients under their care. Several studies have suggested that having more patients under care simultaneously results in inefficiency due to increased interruptions (Chisolm et al. 2000; Speier et al. 1999; Zijlstra et al. 1999). If these prior researchers are correct the reduced

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[3] Physicians, the charge nurse, and selected other personnel are provided with wireless phones for the duration of their shifts. The wireless phone numbers associated with each member of staff are recorded on the whiteboard.

coordination costs of batching is likely to be more than offset by the increased coordination costs of having to deal with more interruptions that come with caring for more patients simultaneously.

Interviews of physicians and other ED staff also revealed that some physicians adopted a batching workstyle as they believed that they would be perceived as being more productive by "having their initials all over the whiteboard." Physicians who adopted a more "steady" workstyle argued that even though they were perceived as less productive, they completed all their work during their shift, while their colleagues who appeared busier ended up passing many incomplete cases to the next shift – which one would expect to require significant coordination overhead. Thus, the high visibility of the information on the whiteboard appears to promote the adoption of the batching workstyle.

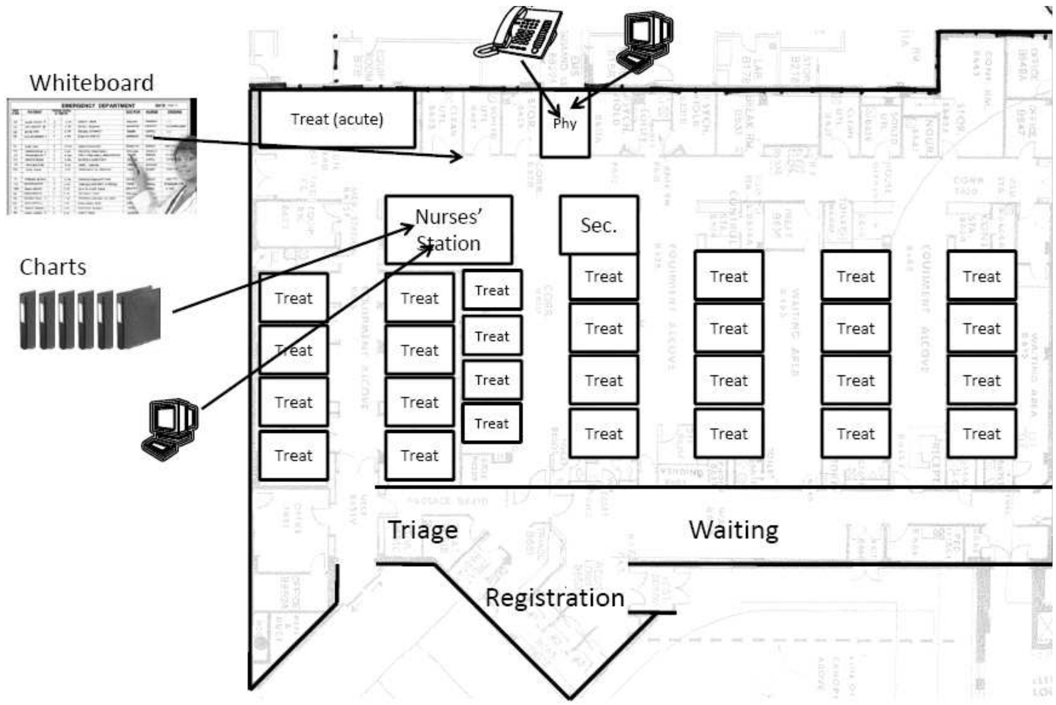

Figure 2. Layout of Emergency Department

ANALYSIS OF QUANTITATIVE DATA

Data Analysis – Initial Attempt

Among the benchmarking measures proposed by experts in ED operations (Welch et al. 2006) are median length of stay time for different types of patients, door-to-doctor time, doctor-to-decision time, etc. We sought to quantify the impact of physician adaptation mechanisms on the efficiency of the ED in terms of such measures. We created an Institutional Review Board (IRB) protocol that allowed us to collect the time stamps defined in (Welch et al. 2006). The sort of data sought is outlined in Table 1.

The data was to be collected manually and captured in a database. Some of the time stamps were to be collected from charts, while others needed to be recorded by physicians or clerks on a separate form. Unfortunately, this approach was not successful. Physicians would not consistently enter "first seen by physician" time stamp on charts, to say nothing of the additional time stamps we asked them to record. Collecting enough data for statistically significant observations by shadowing physicians would have been unduly expensive.

Our initial experience with data analysis strengthened our observation that physicians have considerable discretion over how they do their work and designers of any system (including a data collection system) need to be mindful of the incentive structure. Our data collection offered only extra work to already heavily utilized employees, so perhaps we should have expected low compliance.

Data Analysis – using what was available

The emergency department provided us with an alternate data set to investigate physician workstyles. The data had been extracted from an operational database and included: (a) patient registration time, (b) the ID of attending physician, (c) the time the patient left the department, and (d) a disposition code, indicating whether the patient was discharged, admitted to the hospital, or transferred to another facility, etc. The electronic record was created when the patient was registered after triage. The registration time, item (a), was recorded automatically at registration. An ED secretary manually entered items (b), (c), and (d) at a later time. In addition to this patient data, we had access to seven months of ED physician schedules.

Table 1. Ideal patient level and physician level data for understanding ED physician workstyles

Patient Level Data:	**Key events (timestamps):**	**Physician Level Data:**
Patient_ID (anon) Acuity Diagnosis	Patient arrives (door time) Triage Bed allocation First seen by physician Test/treatments ordered Tests/treatments completion Disposition decision time Time left the ED Physician-to-physician handover	Provider_ID (anon) Role (physician, PA) Shift start/end Demographic information

This is not an ideal data set since there is no information about the patient's acuity level or the time of other important actions, such as when the patient is first seen by a physician, or when all orders are entered and completed. There is no data on whether the patient is treated by the same physician throughout or by different physicians. Three out of four fields are entered manually and there were a number of data entry errors (e.g. departure times before arrival times). Despite the limitations of the available data set we spent considerable time becoming familiar with the data to understand just what insight could be gained and what analyses were possible. We identified five variables that we believe provide some evidence that there are indeed operationally significant differences in the workstyles of the ED physicians. The variables are:

i. The number of newly arrived patients taken on by a physician per hour. This allowed us to examine whether some physicians take on more patients than others
ii. Percentage of patients discharged after the end of the shift. This is used as a proxy to investigate whether the physicians pass much of their work onto the next shift[4]
iii. Average total time in the ED for patients who are eventually discharged. Thus we can determine whether physicians workstyles significantly impact the total time patients spend in the ED
iv. Standard deviation of the total time in the ED for patients who are eventually discharged. We tentatively use this measure as a proxy for physicians batching their work.
v. Patient admission rates. This was readily available in the dataset and provided another measure of the differences in the physician workstyles.

These five variables are dependent on physician work schedules, since both patient arrival rates and staffing levels (Figure 1) varied throughout the day. Consequently, it was difficult to directly compare them across physicians. To overcome this difficulty we computed predicted values[5] for each variable given the physician's schedules, and compared them with the actual values. The Δ columns in Table 2 provide the percentage differences between the actual and predicted values. The variation in these Δ columns shows that there is indeed variability in the key output variables across physicians. While there may be a number of explanations for this variability the interview data and observations suggest that at least some of it is due to differences in the way that the physicians coordinate with other hospital staff and use the ED's coordination mechanisms.

[4] This is an imperfect proxy, since we do not have data to determine whether a physician works past the end of his/her shift to complete the work on a patient, or if the work is completed by a different physician during the next shift. We observed both behaviors in practice.

[5] Of 15 physicians who worked during the 7 month period examined, we focused on 9 who worked a wider variety of shifts. Expected values are based on the data from all 15 physicians.

One of the expected effects of the batching workstyle is variability in the time patients spend in the ED. This is captured in Table 2 by the standard deviation of the time in ED for discharged patients. Physicians H and I exhibit greater variability than would be expected while physicians A, B and E exhibit less. The findings provide some support for our observations and interviewee's perceptions that different workstyles exist. However, the support would be much stronger if we had been able to observe the workstyles of these specific physicians and correlated them with the numerical results.

Some physicians' patients are discharged after the end of the shift more frequently than would be expected (e.g. physicians G, H, and I) while others' are discharged after the end of the shift less than would be expected (e.g. B and C). Interviewees suggested that this was characteristic of some physicians' wish to have their names "all over the board." The data is consistent with some physicians passing on more of their patients to the next shift than others. However, we need to be careful in our interpretation since the numerical result is also consistent with physicians choosing to stay past the end of their shift to complete work on their patients, something that we also saw in practice.

The time that patients spend in the ED is seen as an important measure because it is a factor in determining the physical facilities (e.g. number of beds) required, and is perceived as having a large impact on patient satisfaction. The analysis of the dataset reveals that there are striking differences across physicians in the average times until patients are discharged. Similarly there are differences in the variation (measured with standard deviation) of time spent in the ED. Physicians A and H offer a fairly striking contrast. Despite taking on the same number of patients per hour physician A tends to discharge patients much earlier than physician H. Furthermore the variability of discharge times for physician A is also markedly lower than for physician H. Physician H's patients spend 9% longer in the ED than patients of an "average" physician. This difference implies that physician H's patients require, on average, 9% more capacity in terms of beds, nurses, and other supporting personnel. In contrast physician A's patients, on average, require 13% less capacity. The dataset does not allow us to determine the extent to which different patterns of coordination with other professionals and different ways of using the coordination mechanism influences these disparities. Alternative explanations include the differences in experience levels, 'cherry picking' of easier cases, and individual differences in medical proficiency. However, it does seem that developing a deeper understanding of how theses physicians perform their work would be worthwhile. It may be beneficial if physician A's patterns of coordination, and other work practices, were more widely adopted.

An unexpected result came from examining admission rates. Differences in admission rates were difficult to observe by shadowing physicians. However, examination of historical data showed that physicians differ significantly in their admission decisions. In our small sample the difference in admission rates is correlated (R^2=0.62) with physician experience, with the more experienced physicians admitting fewer patients than their less experienced colleagues. While we believe the most likely explanation to be superior diagnostic skills of experienced physicians, we would require more data to eliminate alternative hypotheses such as 'cherry picking' easier cases.

The analysis of the data set provided by the emergency department shows that there are variations across physicians in terms of productivity, patient admission rate, the time patients spend in the ED, and the proportion of their patients that are discharged after the end of their shift (see Figure 3). While there are severe limitations in the data these results are consistent with the different workstyles that were observed and with those reported by the interviewees.

DISCUSSION AND CONCLUSIONS

Direct observations and interviews showed that working in the ED is a complex process that requires physicians to coordinate not only with patients but also with many other members of staff. ED physicians are professional employees with broad discretion over how they perform their duties. Since the actions of physicians initiate many other work processes, the way in which physicians prioritize and organize their tasks can affect the ED's overall operational productivity.

Our analysis of an historical dataset from an emergency department in a major US city highlights variability in performance measures across physicians, including those proposed in (Welch et al. 2006). Our direct observations of the work performed in the ED and our interviews with physicians and other ED staff lead us to believe that a significant portion of that variability is accounted for by differences in the workstyles adopted by individual physicians. Some elements of these workstyles are clearly undesirable from an operational efficiency perspective, e.g. passing a large portion of the workload onto the next shift, and having patients spend a long time in the ED. Other aspects involve tradeoffs (e.g. variability in the time patients spend in the ED versus door-to-doctor time).

The work performed in the ED requires coordination of tasks performed by physicians, medics, nurses, lab technicians, and others. Several mobile and fixed, electronic and paper-based information systems, as well as other artifacts are used to coordinate the dependencies among these tasks. The mobility, physicality, visibility, and other characteristics of these coordination mechanisms shape the ways in which physicians and others choose to perform their work and coordinate with others. The technologies created to aid coordination changed over time. New information systems were adopted, new mechanisms were created to cope with problems encountered in practice (e.g. patients with the same name), or were imposed because of changing regulations. The ways in which the coordination mechanisms were used evolved over time as well, and physicians have adapted to the coordination mechanisms in differing ways. We observed that some of the ways that the coordination mechanisms were used had adverse effects on efficiency. The location of order-entry computer terminals and a perception of lengthy log-on procedures encouraged the adoption of a batching workstyle. Furthermore, having one's initials against many rows on the whiteboard was perceived as a sign of productivity. In the terminology of the operations field this can be considered a snapshot of the "inventory level" and the operations literature tells us this is a misleading proxy for productivity. A physician with a lower average "inventory" level could in fact be treating, on average, more patients per shift while utilizing fewer resources. The perception that high inventory, as displayed on the white board, implies high productivity may be leading to "hoarding" of patients and results in inefficient use of ED resources. The adoption of the batching workstyle also increases the variability in the time patients spend in the ED. This workstyle can lead to a significant number of patients being dissatisfied and negatively impact customer satisfaction surveys – even if the average stay in the ED is below industry benchmarks.

Table 2. Physician Summary Data

Physician ID	Experience [yrs]	New Patients Per Hour		Patients discharged after end of shift		Average time in ED for discharged patients (hrs)		Stdev of time in ED for discharged patients		Admission Rates	
		Act.	Δ	Act.	Δ	Act. (hrs)	Δ	Act. (hrs)	Δ	Act.	Δ
A	>7	1.57	14%	9%	-8%	3.2	-13%	2.1	-5%	26%	-26%
B	>7	1.47	9%	8%	-13%	3.7	-3%	2	-8%	40%	4%
C	<7	1.51	3%	8%	-19%	3.6	1%	2.1	-4%	34%	4%
D	>7	1.41	1%	9%	2%	3.7	-1%	2.2	-1%	35%	-5%
E	<7	1.35	11%	10%	9%	3.7	-3%	2.3	3%	46%	19%
F	>7	1.01	-6%	9%	6%	4.2	6%	2.1	-5%	34%	-21%
G	<7	1.39	7%	12%	24%	3.8	1%	2.2	1%	40%	6%
H	<7	1.6	12%	12%	20%	4.1	9%	2.5	12%	41%	16%
I	>7	1.25	-1%	11%	20%	3.6	0%	2.3	7%	26%	-20%

Improving the operational performance of the ED could be accomplished in several ways. In the short run the coordination and other work practices of the most effective physicians could be studied and shared with their colleagues. ED managers observed that the variation in demand and staffing levels made it extremely difficult to assess ED physician productivity. The adoption of long-term performance metrics that take account of the different staffing levels and workloads of different shifts, such as those used to analyze the historical dataset, could be put in place to counter the perception that have one's initials 'all over the whiteboard' is viewed positively.

In the longer term better coordination mechanisms and standardized patterns of coordination could provide improved performance. Improving these mechanisms undoubtedly requires a multidisciplinary approach. The design of workflows, coordination protocols, and information systems require medical, operational and information systems expertise. System designers and architects would benefit from being familiar with theoretical work on the coordination of the dependencies among tasks (Malone et al. 1994), as well as the central roles of spatiality, temporality, and mobility (Tilson 2007) in the coordination of different types of work. Advances in wireless mobile computing devices and RFID technology ought to be able to eradicate many of the features of existing solutions that promote less effective workstyles. It is important that the design of information systems in a highly collaborative environment such as an ED, incorporates findings from the field of computer supported cooperative work (Pratt et al. 2004; Xiao 2005). Central among these findings are the recognition of the importance of incentives and of the roles played by non-technical artifacts. For example, in the ED environment the physical size of a patient chart limits batching behavior: a physician cannot comfortably carry around more than three or four charts. The number of patient charts waiting to be seen gives physicians a quick indication of the ED load. If physical charts are to be replaced by electronic ones, other functionality must be added to limit batching, and to allow physicians a quick visual guide to ED loading. The importance of incentives was clear from our physician interviews. Most did not like having to use the computerized ordering system or dictating notes via telephone. They told us of their previous experiences in other hospitals where they could request orders using paper forms, or had a scribe follow them during H&P taking notes. They argued that such systems are more efficient. While, the physicians did not have the power to force the ED to abandon computerized order entry, some turned to batching to minimize the annoyances they associated with working with these systems.

While standardizing the ways that coordination mechanisms are used is important, designers should be sensitive to the variety of ways that coordination mechanisms and technologies are adopted by users. Unintended adverse side effects, or limitations of the mechanisms, could be designed out during the next iteration of the system. Conversely, any improved mechanisms identified by the users of the mechanism could be supported in later systems iterations. However, it can become more difficult to experiment as coordination mechanisms are inscribed in software.

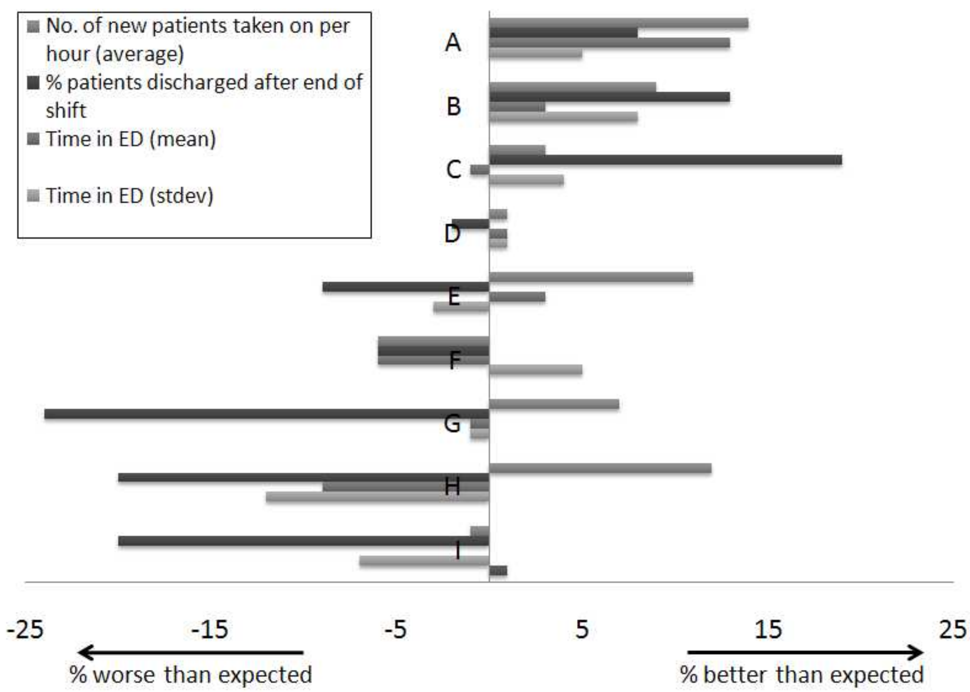

Figure 3. Plot of key performance metrics illustrates variation among physicians

The limitations in the data set used for analysis meant that we could not identify definitive correlations between workstyles and performance outcomes. We hope some of these deficiencies will be addressed by the introduction of new information systems, which will also provide a contrasting context for on-going research. We have to be careful about generalizing our findings beyond the particular ED where we performed our observations, interviews, and historical data analysis. Nevertheless we believe that coordination in settings where there is uncertainty about what work is required and about when work will arrive is particularly difficult (Faraj et al. 2006). Observations at another ED in a different US city highlighted similar coordination difficulties although differing in the specifics.

Measurable improvement cannot be achieved without performance data. Together with the expert defined measurements required for industry benchmarking (Welch et al. 2006) there needs to be a discussion of the mechanisms for practically collecting consistent data suitable for benchmarking among hospitals. “Door-to-doctor” for example, is considered an important measure – but we observed in two EDs (and other clinics) a lack of an automatic process for capturing the “door” time. However, even where such validated measures have not been put in place internal process improvement is possible with internally developed albeit imperfect measures.

Both of the emergency departments we observed had plans to expand the size of their facilities and increase the number of beds. If the coordination mechanisms are not improved the departments could find that the adverse effects of existing coordination mechanism exacerbated by staff members trying to coordinated their work over larger physical spaces.

Finally, the implications for the designers of information systems for emergency rooms include making systems easier and quicker to access. Possible practical changes include the use of mobile devices, ubiquitous bedside devices, or simply more terminals in more places to remove some of the incentives to batch work. More rapid authentication mechanisms to replace multiple passwords (e.g. retina scanning) could also help. In the short term the batching incented by the perceived need to have one's name all over the white board could be ameliorated by removing physicians' names from some views of electronic white boards. Longer term, the reliable and automatic measurement of relevant productivity metrics could help address this directly as well as provide a platform for continuous improvement where the impact of process changes and individual approaches can be objectively measured.

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