Published in final edited form as:
Int J Med Inform. 2012 May ; 81(5): 314–319. doi:10.1016/j.ijmedinf.2011.12.007.

Prospective Pilot Study of a Tablet Computer in an Emergency Department

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Abstract

Background—The recent availability of low-cost tablet computers can facilitate bedside information retrieval by clinicians.

Objective—To evaluate the effect of physician tablet use in the emergency department.

Design—Prospective cohort study comparing physician workstation usage with and without a tablet.

Setting—55,000 visits/year Level 1 Emergency Department at a tertiary academic teaching hospital.

Participants—13 emergency physicians (7 Attendings, 4 EM3s, and 2 EM1s) worked a total of 168 scheduled shifts (130 without and 38 with tablets) during the study period.

Intervention—Physician use of a tablet computer while delivering direct patient care in the Emergency Department.

Main Outcome Measures—The primary outcome measure was the time spent using the Emergency Department Information System (EDIS) at a computer workstation per shift. The secondary outcome measure was the number of EDIS logins at a computer workstation per shift.

Results—Clinician use of a tablet was associated with a 38-minute (17-59) decrease in time spent per shift using the EDIS at a computer workstation ($p<0.001$) after adjusting for clinical role, location, and shift length. The number of logins was also associated with a 5-login (2.2-7.9) decrease per shift ($p<0.001$) after adjusting for other covariates.

Conclusion—Clinical use of a tablet computer was associated with a reduction in the number of times physicians logged into a computer workstation and a reduction in the amount of time they

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Author Contributions: SH and LAN conceived the study. All authors designed the study. SH collected the data and performed the statistical analysis. SH, LAN, and FRG wrote the article, and all authors contributed substantially to its revision. SH and LAN take responsibility for the paper as a whole.

Disclosure: None of the authors have any conflicts of interest to disclose.

spent there using the EDIS. The presumed benefit is that decreasing time at a computer workstation increases physician availability at the bedside. However, this association will require further investigation.

Keywords (MESH)

Computers; Handheld; Emergency Medicine; Clinical Informatics; Bedside Computing; Medical Informatics Applications; Attitude Towards Computers; Workflow

Introduction

Background

Mobile healthcare technology has become increasingly popular, both in clinical care and research [1, 2]. Adoption rates among physicians of handheld computers are between 45-85% [3] and upwards of 60-70% by medical students and residents [4]. Survey studies show current adopters of handheld medical references use them frequently and perceive that their use improved patient care [5].

A recent systemic review identified supporting evidence for the ability of mobile technology to positively impact rapid response, error prevention, information accessibility, and data management [6].

The second generation of tablet computers represent a novel form factor for mobile computing. In comparison to its predecessor, this generation has a larger screen size, longer battery life, and slimmer profile that make it better suited for the medical environment. Patients' perceptions of computer-related technology have been largely positive including a recent study evaluating tablet computers at the bedside[7, 8].

Importance

Emergency department workflow requires emergency physicians to simultaneously evaluate patients, enter orders, review results, monitor ED operations, and communicate with consultants quickly and efficiently. Modern medical care in the US is extremely data driven, leading emergency physicians to spend the majority of their time at workstations performing indirect patient care tasks, compared with physicians in other specialties [9]. The use of mobile computing permits completion of information-based tasks such as order entry and record review while at the bedside.

Performing information-based tasks in real-time at the bedside could lead to fewer interruptions, decreased errors of omission, increased time with patients and increased patient satisfaction. Emergency physicians are interrupted more often than physicians of other specialties, with interruptions occurring most frequently at a workstation [10, 11]. Interruptions can negatively impact the physicians' working memory, increase cognitive load, and lead to medical error [12, 13].

The recent availability of low-cost tablet computers provides an opportunity to streamline physician workflow, better engage patients in shared decision-making, and unshackle emergency physicians from the physical computer workstation.

Goals of this Investigation

Our goal in this pilot study was to determine the effect of physician tablet use in the Emergency Department. We hypothesized that physician tablet use during a shift would be

associated with a change in time spent at a computer workstation. We also sought to understand perceptions of physicians using these tablet computers while on a shift in the ED.

Materials and Methods

Study Design

In this prospective cohort pilot study, we used a combined quantitative and qualitative study design to determine the effect of physician tablet use in the ED. We compared the total session time as well as total number of sessions per shift using an EDIS on a computer workstation when physicians used a tablet versus when they did not use a tablet during a shift. In addition, we collected qualitative data about physician perception of tablet use in the ED to better understand the results from the quantitative aspects of the study. The study was submitted to our institutional review board and a determination was made that no further review was required.

Setting and Selection of Participants

The study was performed in a 55,000 visits/year Level 1 tertiary academic teaching hospital in Massachusetts, USA. We asked physicians to volunteer to use a tablet computer to access an Emergency Department Information System (EDIS) while delivering direct patient care in the ED. Only emergency medicine residents and attendings scheduled for at least one shift during the study period were eligible. During the study period, physicians were assigned a tablet for a 7-21 day period. The range of scheduling durations reflects our scheduling preference to both maximize the number of potential shifts users would have to use the tablet as well as the number of study participants.

The EDIS used in this study is a custom web-based dashboard built on the hospital-wide InterSystems Cache infrastructure. It utilizes a thin-client architecture that is accessible from any web browser. A thin-client architecture uses a web browser as a client, rather than dedicated client software that must be installed on individual computer workstations.

Interventions

During their assigned period, physicians could elect to use or not to use a tablet during their shift. Surveys were completed before and after the study to assess perceptions of physician users.

Methods of Measurements

Detailed usage data of our EDIS is automatically captured and stored in a central database for security auditing purposes. This detailed usage data includes browser type, login time for each session, and total session time. Using the browser type, we were able to determine if a physician was using a computer workstation or a tablet. A session is defined as the time a user logins to the EDIS until they logout. Users are automatically logged out after 3 minutes of inactivity at a computer workstation. We believe total session time at a workstation serves as a good estimate of total time spent at a workstation.

Scheduling data is stored on the Tangier Physician Scheduling system (Peake Software Labs, Hunt Valley MD) for Attending Physicians and Amion Physician Scheduling (Spiral Software, Norwich VT) for Resident Physicians. Shift location and time was extracted for each clinician during the time period and entered into an Excel spreadsheet.

Pre and Post intervention survey instruments were developed using a modified Delphi Consensus process by the four study authors who are all emergency physicians with expertise in clinical informatics. Survey conceptual domains, items, and responses were

developed using four Delphi rounds. The Pre survey consisted of fifteen questions which included two open ended, two categorical, and eleven 5-point Likert scale questions. The Post survey included three open ended and thirty-two 5-point Likert scale questions.

Data Collection and Processing

EDIS usage data was electronically collected for study participants for all scheduled shifts during the study period. Total session time and number of sessions were aggregated per shift for each clinician. Sessions were included in a shift if the time of login occurred during the scheduled shift. Clinicians were counted as having used a tablet if they used a tablet for at least 5 minutes during that shift.

Pre and Post intervention surveys were electronically collected using the Forms feature of Google Documents. The form was set to enforce completion of all survey items. Responses were kept confidential, but not anonymous in order to track survey completion. Repeat requests to complete surveys were completed using a modified Dillman method. [14]

Outcome Measures

The primary outcome measure was the total session time in minutes on the EDIS while at a computer workstation per shift. This sum is the aggregate of all session durations occurring on a computer workstation during a scheduled shift.

The secondary outcome measure was the number of sessions on an EDIS while at a computer workstation per shift. This is defined as the number of sessions during a scheduled shift.

Primary Data Analysis

Statistical analysis was performed using JMP (JMP, Version 8. SAS Institute Inc., Cary, NC, 1989-2009.)

Descriptive statistics including means with 95% confidence intervals were reported for normally distributed variables and medians with interquartile ranges were reported for non-normal data. Shift distributions were compared using a Chi-squared test. There was no missing data.

We used a multivariate linear regression using total session time and number of sessions as outcome variables. Tablet use, clinical role, shift location, and shift length were used as covariates. Shift time was also entered as a covariate, but was not statistically significant and subsequently removed. Both outcome variables were normally distributed. Regression residuals were also found to have normal distributions and exhibit homoscedasticity. No significant interactions were found between covariates.

The six matched questions in the pre and post surveys were compared using a Wilcoxon signed-rank test. Survey questions were then grouped into disagree, neutral, or agree. A negative response was defined as either (1) Strongly Disagree or (2) Disagree, neutral was defined as (3) Neither Agree nor Disagree, and a positive response was defined as either (4) Agree or (5) Strongly Agree on a 5-point Likert scale. Given the survey sample size, Structured Equation Modeling could not be reliably performed to validate our conceptual domain constructs.

Results

Characteristics of Study Subjects

Eighteen physicians initially volunteered for this study. We were unable to schedule 5 of the volunteers with a tablet during the study period. It took approximately 2 months to schedule 13 clinicians to have a tablet for a minimum of 3 scheduled shifts. We assigned one of 4 tablets to each of the 13 physicians for use during a 7-21 consecutive calendar day period.

Main Results

A total of 168 scheduled shifts (130 without tablets and 38 with tablets) were assigned to 13 physicians (7 Attendings, 4 EM3s, and 2 EM1s) during the study period. Physician demographics and prior experience with tablets is reported in Table 1. Shift distribution with and without tablets is reported in Table 2. Each physician used a tablet for a median of 3 shifts [IQR 1-4].

Clinician use of a tablet when working in the emergency department was associated with a 38-minute (17, 59) decrease in time spent per shift using the EDIS at a computer workstation ($p<0.001$, $R^2 0.64$) after adjusting for clinical role, location, and shift length. The number of logins was also associated with a 5-login (2.2, 7.9) decrease per shift ($p<0.001$, $R^2 0.52$) after adjusting for other covariates.

All 13 physicians responded to both the pre and post surveys yielding a 100% response rate. The six matched questions in the pre and post surveys are reported in Table 3. Overall, physicians found the tablet to be clinically useful and easy to carry around. Physicians held these beliefs before using a tablet and they did not change significantly after using a tablet. The remainder of the survey questions is reported in Table 4.

Physicians unanimously found the tablet easy to get started with. Only 46% of physicians felt that tablet use decreased the number of logins at a computer workstation, a finding which is divergent from our quantitative data. Furthermore, only 31% of physicians felt tablet use was associated with more time at the bedside.

69% of physicians were afraid of losing the tablet and 62% were afraid of dropping it. However all of the devices were returned after the study in working order without visible damage.

Limitations

There are several potential limitations to this pilot study. First, this study occurred at a single institution with a custom built ED information system. These results might not generalize to other systems that are not web-based or tightly integrated into the ED workflow. However, we made no attempt to optimize our system for tablet use, and believe our results reflect a lower bound of tablet utility in clinical practice.

Our study was also an observational study among emergency physicians who volunteered to use the device which could introduce a self selection bias. We do not intend to force reluctant physicians to use mobile computers in the future, and therefore chose to measure the effect among only those physicians who were willing to use the tablet device.

Our study chose the surrogate measure of time spent at a workstation using an EDIS to approximate the actual time a physician spent at a workstation. Another important metric would have been total time spent at any computer, as tablet use could have increased the total time spent at any computer. Unfortunately the architecture of the tablet operating

system prevented us from accurately measuring the time spent on a tablet. The EDIS uses movement of the computer's mouse to detect when a user is physically present and working. After several minutes of inactivity, the system closes the session and creates the log entries we reviewed. Unlike a workstation computer, second generation tablets use a touchscreen instead of a mouse. Because of this difference, we had no reliable method to determine when our specific tablet was actively being used. We instead relied on a device-level lockout instead of closing the session. This difference made it impossible to accurately compute the time tablets were actively being used. Without this information, we could not compute global time spent at a computer. A formal time-motion study could have captured this data and been more rigorous. However time-motion studies are costly to conduct and should only be considered after promising preliminary research. Our pilot study presents preliminary data to inform and power a future time-motion study.

Discussion

Clinical use of a tablet computer was associated with a reduction in the amount of time physicians spent using an EDIS at a computer workstation and a reduction in the number of times physicians logged into a computer workstation. Reducing time at a workstation increases the amount of potential time for a physician to spend at the bedside. This could potentially lead to increased patient satisfaction [15, 16], reduced number of interruptions, decreased cognitive load, and improved clinical workflow. However, this association will require further investigation.

Although our quantitative data showed a clear decrease in both the duration and number of times clinicians spent at a computer workstation, only 46% of clinicians agreed with this statement. As our qualitative data is reflective, it is possible this discrepancy can be secondary to measurement error. It is also possible that clinicians found the 38-minute and 5-login decrease to not be perceptible, given that only 8% explicitly disagreed with the statement. Interestingly, only 31% of physicians felt that a tablet allowed them to spend more time at the bedside. It is possible that potential free time made available by the tablet was redistributed to perform other clinical tasks rather than spend time at the bedside. It is also possible that a non-optimized tablet interface could have distracted clinicians at the bedside and decreased the quality of the patient-physician interaction at the bedside. A time-motion study is needed to further characterize this association.

Prior to the intervention, 100% of surveyed clinicians agreed that the tablet would be clinically useful. After the intervention, only 54% agreed with this statement, but none disagreed with this statement. Although this finding did not reach statistical significance, in a group of early adopters, this is an important result. Participant free text responses state a need for a user interface customized to the tablet that would expedite bedside charting and order entry. Participants overwhelmingly cited the lack of efficient documentation and order entry as the reason they felt it was not as clinically useful as they had expected. Study participants did however find that it was useful during bedside rounds and bedside encounters to look up labs and previous medical records.

Security of mobile devices is of substantial concern in the hospital enterprise. 85% of our physicians did not express any privacy or security concern and could easily log into their accounts. Use of a thin-client to access the EDIS ensures that no private information is persistently stored on the mobile device. Furthermore, most of the tablets on the market contain mechanisms to remotely track, deactivate and erase data if needed. On iOS devices, MobileMe (Apple Computer, Cupertino, Ca) allows units to be tracked via either their carrier network or wireless network signal. There are similar third party solutions available on the Android tablet operating system.

Infection control with mobile devices is much the same as with other handheld objects. A recent review recommended a handheld device, like any other piece of equipment, be considered contaminated if comes in contact with any environment of the patients room [17]. After using the intervention, users felt the device was easy to disinfect. Our standard procedure is to use hand disinfection at a minimum upon entering and leaving the room. Disinfection of equipment, including the tablet is carried out by use of Steris Coverage Plus wipes (PDI, Orangeburg NY), an isopropyl alcohol and quaternary ammonium chloride-based disinfectant. While the tablet vendor does not recommend the use of these types of agents, we did not notice any appreciable effect on the devices during the study period.

This pilot study provides rationale to undertake further studies to determine the impact of tablet computing on both providers and their patients. Formal time-motion studies will be needed to unequivocally demonstrate changes in physician workflow. Such a study design would track physician time delivering bedside care, information retrieval, documentation, communication, and other clinical tasks. Data could also be collected on the number of patients evaluated by physicians, revenue generated, and other metrics of productivity. In addition to its effect on providers, it would also be important to measure patient-oriented outcomes. Such metrics should include patient satisfaction as well as previously validated quality of care metrics. These metrics could include time to evaluation by a physician, time to antibiotic, and ED length of stay. Further study is warranted to evaluate how tablet computing impacts physician workflow, physician productivity, patient satisfaction, as well as the quality and safety of care.

Acknowledgments

Funding Support: Foster Goss was supported by a T15 LM007092 NLM training grant.

References

1. Lane SJ, et al. A review of randomized controlled trials comparing the effectiveness of hand held computers with paper methods for data collection. BMC Med Inform Decis Mak. 2006:23. [PubMed: 16737535]
2. Haller G, et al. Handheld vs. laptop computers for electronic data collection in clinical research: a crossover randomized trial. Journal of the American Medical Informatics Association. 2009:651–9. [PubMed: 19567799]
3. Garritty C, El Emam K. Who's Using PDAs? Estimates of PDA Use by Health Care Providers: A Systematic Review of Surveys. J Med Internet Res. 2006:e7. [PubMed: 16867970]
4. Kho A, et al. Use of Handheld Computers in Medical Education. A Systematic Review. J GEN INTERN MED. 2006:531–537. [PubMed: 16704405]
5. Rothschild JM, et al. Use and perceived benefits of handheld computer-based clinical references. J Am Med Inform Assoc. 2006:619–26. [PubMed: 16929041]
6. Prgomet M, Georgiou A, Westbrook JI. The impact of mobile handheld technology on hospital physicians' work practices and patient care: a systematic review. J Am Med Inform Assoc. 2009:792–801. [PubMed: 19717793]
7. Strayer SM, et al. Patient attitudes toward physician use of tablet computers in the exam room. Fam Med. 2010; 42(9):643–7. [PubMed: 20927673]
8. Hsu J, et al. Health information technology and physician-patient interactions: impact of computers on communication during outpatient primary care visits. J Am Med Inform Assoc. 2005; 12(4):474–80. [PubMed: 15802484]
9. Hollingsworth JC, et al. How do physicians and nurses spend their time in the emergency department? Annals of Emergency Medicine. 1998:87–91. [PubMed: 9437348]
10. Chisholm C. Work interrupted: A comparison of workplace interruptions in emergency departments and primary care offices. Annals of Emergency Medicine. 2001:146–151. [PubMed: 11468609]

11. Jeanmonod R, et al. The nature of emergency department interruptions and their impact on patient satisfaction. Emerg Med J. 2010:376–9. [PubMed: 20442168]
12. Spencer R, Coiera E, Logan P. Variation in communication loads on clinical staff in the emergency department. Ann Emerg Med. 2004:268–73. [PubMed: 15332070]
13. Parker J, Coiera E. Improving clinical communication: a view from psychology. J Am Med Inform Assoc. 2000:453–61. [PubMed: 10984464]
14. Dillman, DA. Mail and Telephone Surveys, The Total Design Method. New York: John Wiley and Sons; 1978.
15. Gross DA, et al. Patient satisfaction with time spent with their physician. J Fam Pract. 1998; 47(2): 133–7. [PubMed: 9722801]
16. Lin CT, et al. Is patients' perception of time spent with the physician a determinant of ambulatory patient satisfaction? Arch Intern Med. 2001; 161(11):1437–42. [PubMed: 11386893]
17. Neely AN, Sittig DF. Basic microbiologic and infection control information to reduce the potential transmission of pathogens to patients via computer hardware. J Am Med Inform Assoc. 2002:500–8. [PubMed: 12223502]

Highlights

- Using a tablet computer can decrease time spent at a computer
- Clinician's felt the tablet was easy to disinfect
- Clinician expectations can not be met by a change in form factor alone

What is already known

- Mobile computing can positively impact error prevention, information accessibility, and data management
- Newer generation tablets have longer battery lives, larger screens, and slimmer profiles that make them more suitable for clinical use
- These new tablets have the potential to facilitate clinical computing at the bedside

What this study adds

- Using a tablet computer can decrease time spent at a computer, increasing available time to spend at the bedside
- Clinician's felt the tablet was easy to disinfect
- Clinician expectations for mobile computing can not be met by a change in form factor alone

Table 1

Shift Distribution

	Number of Shifts		P value[a]
	Tablet used (n=38)	No tablet used (n=130)	
Location, No. (%)			
Acute	26 (68%)	61 (47%)	
Urgent	10 (26%)	60 (46%)	0.06
Critical	2 (5%)	9 (7%)	
Role, No. (%)			
EM1	4 (11%)	40 (31%)	
EM3	12 (32%)	22 (17%)	0.01
Attending	22 (58%)	68 (52%)	
Shift Length, No. (%)			
11 hour	1 (3%)	25 (19%)	
9 hour	8 (21%)	13 (10%)	0.02
8 hour	27 (71%)	83 (64%)	
6 hour	2 (5%)	9 (7%)	

[a] Significance tested using a Chi-squared Test. $\alpha < 0.05$

Table 2
Physician Demographics and Experience

	Physicians (n=13)
Age, mean (95% CI), y	34.5 (30.6, 38.3)
Male gender, No. (%)	10 (77%)
Role, No. (%)	
EM1	2 (15%)
EM2	0 (0%)
EM3	4 (31%)
Attending	7 (54%)
Experience, median (IQR)[a]	
Computers in General	4 [3-4.5]
Smartphone	3 [3-5]
[First Generation] Tablet	2 [1-3]
[Second Generation Tablet]	2 [1-2.5]

[a] 5 point Likert scale – 1) No experience, 2) Some experience, 3) Moderately experienced, 4) Highly experienced, 5) Very highly experienced

Table 3

Comparison of physician perceptions

	Pre Survey[a] (n=13)		Post Survey[a] (n=13)		P value[b]
	Disagree	**Agree**	**Disagree**	**Agree**	
Clinically useful	0%	100%	0%	54%	0.11
Improve care	0%	54%	15%	31%	0.23
More efficient	0%	85%	15%	31%	0.10
Improve Patient Satisfaction	8%	38%	15%	23%	0.45
Easy to carry around	0%	54%	23%	62%	0.99
Easy to disinfect	31%	38%	0%	54%	0.17

[a] **Disagree** defined as either 1) Strongly Disagree or 2) Disagree and **Agree** defined as either 4) Agree or 5) Strongly Agree on a 5-point Likert scale

[b] Significance tested using a Paired Wilcoxon Sign-Rank Test. $\alpha < 0.05$

Table 4
Physician attitudes regarding tablet use at the bedside

Post Survey Questions	Physician Response[a] (n=13)	
	Disagree	Agree
Getting Started		
It was easy getting started with the [tablet]	0%	100%
The [tablet] was fast to learn	0%	100%
It was easy to find what I was looking for	0%	100%
Workflow		
The [tablet] allowed me to spend more time at the bedside	23%	31%
I felt the [tablet] allowed me to better monitor ED operations	15%	54%
I felt the [tablet] allowed me to multitask	8%	31%
I felt the [tablet] decreased the number of times I needed to use a desktop computer	8%	46%
Communication		
The [tablet] allowed me to better communicate results to patients	15%	62%
The [tablet] allowed me to recognize critical lab values earlier	15%	31%
The [tablet] improved my communication with other staff and consultants	8%	31%
The [tablet] allowed me to better engage patients in shared decision making	23%	31%
Portability		
I found the [tablet] battery life adequate	8%	85%
I was not afraid of losing the [tablet]	69%	31%
I was not afraid of dropping the [tablet]	62%	31%
Infection, Reliability, and Security		
The [tablet] worked reliably	0%	92%
I have no privacy or security concerns when using the [tablet]	8%	85%
I felt the [tablet] made it easy for me to log in to my accounts	8%	62%

[a] **Disagree** defined as either 1) Strongly Disagree or 2) Disagree and **Agree** defined as either 4) Agree or 5) Strongly Agree on a 5-point Likert scale