



A Clinical Trial Evaluation of Pager vs Smart-device Efficacy in an Academic Hospital Setting

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ABSTRACT

Introduction: Health care delivery is contingent on efficient communication among providers. We hypothesized that using smart-device two-way communication would result in faster provider responses when compared with alphanumeric paging among resident physicians in an academic medical center.

Methods: Resident physicians were given an Apple iPad Mini smart device with a Health Insurance Portability and Accountability Act-compliant smart-device two-way communication application. Patient care messages were randomized for transmission via smart-device two-way texting or standard one-way paging. Physician response time was recorded as the primary outcome measure.

Results: The study was halted after participation of the first 24 residents due to safety concerns. A technical glitch was identified in which the smart devices automatically powered off to conserve battery life. The first 72 smart devices to first 37 pager communication response times were similar (8 vs 6 minutes, $p=0.43$). In analysis of responses within 5 minutes of communication (the time smart devices powered off), smart-device responses occurred significantly faster (1 vs 2 minutes, $p<0.05$) but the response frequency was less in the smart-device group (33 vs 62%, $p<0.05$), and thus the study was ended early due to safety concerns.

Discussion: Based on our initial findings, smart devices have potential to improve communication but technical issues must be addressed prior to usage as the sole means of communication.

Keywords: Academic, Communication, Device, Hospital, iPad, Pager, Trial, Smart.

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INTRODUCTION

Health care delivery is highly contingent on accurate, rapid, and efficient communication among health care providers.^{1,2} In most hospital environments, health care staff communicate with one another solely via one-way pagers. In the traditional model employed by most teaching hospitals, physicians, nurses, and trainees page through a central switchboard.³ Thus, when a physician receives a page he/she often leaves his/her clinical activity at that time to either call the page-sender or find a computer with network access in order to return the page. Such workflow interruption among health care professionals has been posited as creating lapses in care which in turn lead to stressful cognitive demands and potential medical errors.⁴⁻⁹ The current method of communication among health care professionals has not only been shown to cause workflow interruption but also communication failure. In the medical community, it has been repeatedly established that communication failure and poor transmission of information among health care personnel lead to delayed delivery of appropriate care and adverse patient outcome.^{1,2,10-13}

Smartphone and smart-device usage has erupted since the introduction of smart technology in the mid-2000s in everyday life and within the health care system. Smartphones allow for instantaneous two-way communication and their ubiquity translates into familiarity to all nearby providers. Multiple studies demonstrate smartphone-based e-mail as effectively facilitating communication between hospital team members, while web-based messaging has resulted in improved user satisfaction and ease of communication.¹⁴⁻¹⁸ In the face of these advances, it is crucial that patient-protected health information (PHI) be transmitted via Health Insurance Portability and Accountability Act (HIPAA)-compliant modalities.

Smart-device applications that guarantee HIPAA compliance for PHI transmission represent a new space in health care technology that is only beginning to gain traction. The adoption of modern tools for communication is imminent and ripe for evaluation. We

hypothesized that using a smart-device-based HIPAA-compliant application would result in more timely provider responses when compared with alphanumeric paging with an equal or greater satisfaction rating among health care providers for ease of use as compared with the current system.

METHODS

Technology and Intervention

Institutional Review Board approval was obtained for data collection at a single, 850-bed teaching hospital with over 650 resident physicians. Resident physicians on inpatient services were participants in this study. Each participant was given an individual Apple iPad Mini smart device (Apple Inc., Cupertino, CA, USA) to use for the study. Each iPad was encrypted per hospital policy and given access to the hospital's wireless network. We utilized Mediprocity, a free HIPAA-compliant smartphone/smart-device application developed for physicians and hospitals (Fig. 1).¹⁹ The application allows two-way encrypted text messaging by registered users over the hospital's wireless network. A noise alert is generated with each text message, alerting the user to a new communication. The Mediprocity application was loaded on each iPad Mini and participants were trained on its use at the beginning of each enrollment. Additionally each participant retained his or her personal alphanumeric pager for comparison to the wireless smart device. Two study coordinators were present each day for message/page transmission and data collection.

Due to the hospital's security measures, all wireless devices must be encrypted with a passcode required when accessing the device. This posed a significant difficulty with residents in the operating rooms who would need to respond to secure text messages via the Mediprocity app. Thus, for this pilot study, we included resident physicians not in the operating rooms.

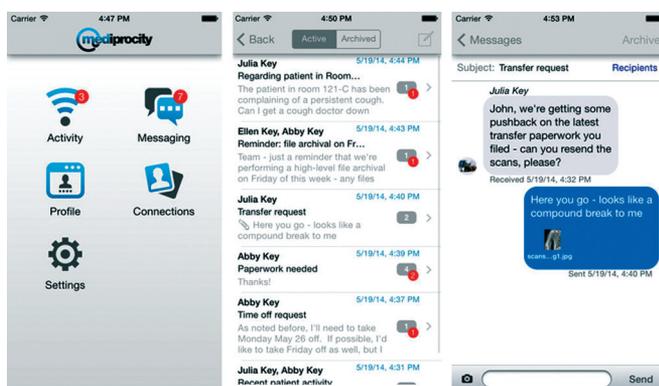


Fig. 1: Mediprocity Health Insurance Portability and Accountability Act-compliant app sample screenshots¹⁹

Power Calculation

We hypothesized *a priori* that the smart-device group will be noninferior to the pager group, and without historical data from which to estimate standard errors, the study group determined that as long as the smart-device group is no worse than 10 seconds longer than the pager group the trial will be successful in demonstrating that the new method does not increase response time in a clinically important way. With this in mind, for comparing 60 smart-device and 60 pager resident communications, a two-group, 0.05 one-sided t test will have 97% power to reject the null hypothesis that the pager and smartphone groups are not equivalent (the difference in means is 5.0 seconds or longer) in favor of the alternative hypothesis that the means of the two groups are equivalent, assuming that the expected difference in means is -5.0 seconds and the common standard deviation is 15.0 seconds. Thus, the experiment was designed for 60 participants although only 24 were ultimately enrolled before the study was halted for safety concerns.

Study Design

A total of 24 residents were enrolled in the study and consent was obtained from each participant. All enrollees were given an iPad Mini for approximately 9 hours, during which data were collected. Each day, a new group of residents was included in the study, depending on their current floor assignment. Nurses were instructed to relay nursing care messages to study coordinators who then contacted the appropriate resident, via alphanumeric paging system or Mediprocity app. Patient care messages were randomly sent to the appropriate resident by the study coordinators using either the Mediprocity smart-device application or the existing hospital web-based alphanumeric paging system.

Physician response time was recorded by the study coordinator from the time the message was sent to the time response was obtained, either text via Mediprocity or telephone call following alphanumeric page. Times were recorded in seconds. Exit surveys were distributed at the end of each session to the participants that assessed their level of satisfaction and device utility, especially as it compared with each participant's existing pager. A standard 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) was used for this survey (Table 1). Free response questions allowed participants to list most positive and negative aspects of the smart device.

Table 1: Seven-point Likert scale for smart device satisfaction and usability survey questions

Strongly disagree	Disagree	Disagree somewhat	Neutral	Agree somewhat	Agree	Strongly agree
1	2	3	4	5	6	7

Analysis

The *a priori* statistical plan for primary comparisons was to compare the smart-device group with the pager group using two sample t tests. For secondary outcomes, we planned to use either t tests or chi-squared tests to compare groups depending on whether the outcome measure is continuous or categorical. If any of the continuous outcome measures are found to be non-normal, we would first see if an appropriate transformation (i.e., log transformation) can bring the variable to a normal distribution. If no transformation is identified, then comparisons would be made using a nonparametric test, such as the Kruskal–Wallis test.

All data collection was done utilizing REDcap database collection software. Data analysis was performed with SAS version 9.3 software (SAS Institute Inc., Cary, NC, USA). All p values were two-sided and p values less than 0.05 were considered significant.

RESULTS

Sample size estimation for a noninferiority study necessitated 60 residents to be enrolled in the study; however, after participation of the first 24 residents, the study was halted due to safety concerns. A technical glitch was identified in which the smart devices automatically powered off to conserve battery life and subsequently disconnected from Wi-Fi service. For the sake of parsimony, response times were ultimately converted to minutes instead of seconds owing to the long response times in both groups. As a result of this technical impediment, interim analysis was conducted comparing the first 72 smart-device communications to the first 37 pager communications, demonstrating noninferiority (8 vs 6 minutes response time, $p=0.43$). In subset analysis of responses occurring within 5 minutes of pager transmission (approximately the time smart devices powered off), smart-device responses occurred significantly faster than pager responses (1 vs 2 minutes, $p<0.05$). However, the response frequency under 5 minutes was significantly less in the smart device group as compared with the pager group (33 vs 62%, $p<0.05$), and thus the study was ended prior to reaching the precalculated sample size due to safety concerns by the investigators.

Despite the technical issues, resident physician surveys demonstrated overall positivity toward handheld devices in their usage for patient communication (Table 2). When asked whether the usage of smart devices could ultimately be feasible in the academic medical system, 100% of respondents answered “yes.” While the one overarching negative theme was the unreliability of connectivity at unpredictable times, several positive

Table 2: Responses to poststudy physician satisfaction survey questions

Survey question	Mean score on 1–7 Likert scale (SD)
1. Overall, I am satisfied with how easy it was to use this wireless handheld device in the work environment	5.4 (1.2)
2. I feel comfortable using this wireless handheld device	6.3 (0.9)
3. It was easy to learn this system	6.3 (1.0)
4. Compared with using my pager, I am able to complete my work more effectively using this handheld device	5.5 (1.5)
5. I believe I became more productive using this wireless handheld device	5.2 (1.4)
6. I was able to quickly learn how to use this device	6.4 (0.8)
7. Whenever I make a mistake using the wireless handheld device, I recover easily and quickly	6.0 (1.2)
8. The instructional information (such as on-screen messages and other documentation) provided with this system is clear	6.0 (1.1)
9. The wireless handheld device is effective in helping me complete clinical tasks and scenarios	5.4 (1.5)
10. The organization of information on the wireless handheld device is clear	6.0 (1.2)
11. The interface of this system is pleasant	6.0 (1.1)
12. This wireless device has all the functions and capabilities I expect it to have	5.3 (1.6)
13. I would be interested in utilizing a wireless handheld device that incorporated more multimedia capabilities	6.3 (1.1)
14. Overall, I am satisfied with this system	5.7 (1.5)

SD: Standard deviation

themes from free responses pervaded, including ease of use, seamless transitioning between electronic medical record and messages on the device, and enhanced communication with nursing staff without disrupting patient interactions and team rounds.

DISCUSSION

In the past few decades, the use of modern technology in health care has burgeoned but the formal methods of communication among academic health care personnel have lagged behind. Health care experts are beginning to understand that the adoption of modern tools for communication could potentially facilitate more efficient decision-making while improving workflow schemes for the average physician. Prior to 2008, there was a surprising dearth of literature reporting on the use of mobile phone communication by health care personnel in the work environment.

Most notably, a 2005 study by Aziz et al²⁰ looked at a heterogeneous team of doctors ($n=9$) working in a busy

surgical setting at St Mary's Hospital in London and compared the use of mobile phones with the existing pager system. In the study, the authors found that doctors equipped with mobile phones rather than pagers responded more quickly to attempted communications and also had a lower failure-to-respond rate (relative risk: 0.44; 95% confidence interval 0.20–0.93). Clinicians also found this technology easy to adopt as seen by a significant reduction in perceptions of nervousness to the technology over the 6-week study period (week 1: mean 4.10 (standard deviation 1.69) *vs* week 6: 2.20 (1.99); $p=0.04$). Based on the encouraging results of this seminal study, the authors called for a larger scale clinical trial, further comparing these two technologies. As far as we are aware, there has yet to be a clinical trial that makes this comparison. As delineated below however, there has been a small amount of literature relevant to mobile phone and pager technologies since Aziz et al's study.

In 2008, Locke et al reported on the results of a survey given after the implementation of a web-based system to triage urgent and nonurgent pager messages in a tertiary care center in Canada. These authors found via their postimplementation surveys that there was a high degree of uptake of the new practice and their focus groups showed a high level of satisfaction and a perceived decrease in interruptions to the workflow of both nurses and physicians using the new system.²¹

In 2009, Ighani et al²² conducted a crossover prospective study comparing physician perceptions of a two-way text paging system to conventional one-way alphanumeric pagers. The authors found that the two-way text pagers were perceived as significantly more helpful to participants for increasing daily efficiency, facilitating patient care and overall helpfulness. When compared with the alphanumeric pager, the two-way text pager was found to subjectively decrease the need for callbacks, reduce interruptions of learning activities, and enabled better patient care.²²

In the recent past, there have been two notable studies assessing communications technologies of interest. Wu et al¹⁴ assessed a pilot program at Toronto General Hospital that equipped internal medicine residents with mobile phones. As part of the pilot program, all internal medicine residents were equipped with mobile phones, which they retained for the duration of their rotation. These mobile phones were a supplement to the traditional pagers, which the residents retained. In addition to this intervention, the hospital created a "master smartphone" (which they termed Team Blackberry) given to the senior resident of each medical team. This phone received critical medication and laboratory alerts, and nurses could also send web-based pages to this phone. The outcome measures of the study were residents' use of

smartphones and perceptions of residents and nurses on the new communication process. Resident use of the smartphones was measured by the volume and frequency of communications over a 3-month period. Residents' perceptions were measured by a survey administered prior to the start of their clinical rotation and at the end of their rotation. The investigators of the study found that there were an average of 9.1 incoming calls, 6.6 outgoing calls, 14.3 received e-mails, and 2.8 sent e-mails per day to each Team Blackberry device; residents strongly preferred the smartphones over conventional paging with perceived improvements in all items measured and felt that it improved efficiency and communication. However, they did not find any improvement in the overall satisfaction of the nurses with physician's response time for urgent issues. Wu et al¹⁴ admit that their study is limited by the fact that residents retain their traditional pager device, thereby creating confounders that make it difficult to properly assess the efficacy of their primary intervention.

Haroon et al found that among the 60 junior physicians surveyed at their institution, 100% of participants used personal mobile phones while at work, and also for hospital-related work. For 98.3% the personal mobile phone was their main mode of communication while in the hospital. A total of 62% ($n=37$) made 6 to 10 calls daily purely for work-related business, and this comprised of $\geq 80\%$ of their daily usage of mobile phones. For 98% of participants, most phone calls were work-related. Regarding reasons for using mobile phones, all reported that using mobile phones is quicker for communication. Thus, the authors concluded that, despite the current paradigm of institutional pager communication, physicians still preferred and actually predominantly used mobile phone technology for work-related communication.¹⁵

Although investigators in the field of health care communication and innovation have called for clinical trials comparing mobile phone *vs* pager communication, our review of prior work revealed a gap in this area of the literature. There have been a fair number of qualitative assessments performed predominantly in the form of postimplementation survey studies that look to assess attitudes and perceptions after the implementation of a new means of health care communication. However, there has been no large-scale head-to-head comparison proving the superiority of one means of communication over another. Furthermore, while it has been established that physicians and other health care personnel prefer the use of modern communication tools in the workplace, no study has proposed a feasible workflow paradigm to replace pagers with mobile phones or smart devices. Without an applicable/workable scheme, investigators

have not had the opportunity to assess pager *vs* smart-device use by physicians in a randomized controlled fashion while measuring tangible workflow metrics, health care personnel satisfaction/technology uptake, and measures of health care quality and outcomes.

In our proposed trial, we intended to fill the gaps in the research identified above. Despite overcoming numerous political and logistical hurdles to make the study a reality, we ultimately found that in our academic center, the technical issues of a Wi-Fi-based HIPAA-compliant smart-device communication system were overwhelming and that the constraints imposed upon our system could not overcome these issues. In prior iterations of the study, cellular technology was to be utilized for communication – which could potentially have avoided the technical issues of Wi-Fi – but the large wireless carrier fees for purchasing minimum 1- to 2-year contracts with monthly service rates along with inconsistent reception requiring further cellular tower infrastructure at our institution made this plan a costly endeavor outside the realm of possibility with the grant funding available and economic climate of our institution at the time.

Limitations of this study are the unfortunate necessity to end the study early as well as questionable external validity to many community hospitals and private practice groups which are transitioning to cellular communication with the provider's personal smartphone often being written off for tax purposes as a business expense. Nonetheless, we believe there are important lessons to be learned for the academic tertiary care centers that have held steadfast to pager communication modalities. For those communications that occurred less than 5 minutes after nursing communication (which we empirically hypothesized to be the point at which our devices entered "hibernation" mode), smart devices proved themselves useful for rapid exchanges of information. Furthermore, the enhancement of physician satisfaction and its downstream effects on team functioning and patient care should be taken into consideration by medical centers when deciding on modalities of communication. While we believe that further clinical investigation is warranted, the next study to be undertaken may be better served at an institution with robust cellular capacity to obviate the hindrances of pure Wi-Fi-based communication.

CONCLUSION

We found that smart-device communications occurred faster than pager interactions when the response time was under 5 minutes from the initial nursing page. Although technical issues with Wi-Fi connectivity

ultimately limited reliable communication in this study, physician satisfaction is still high with modern modes of communication. Smart-device use is increasing exponentially and becoming commonly accepted in the health care setting; maximizing the communication potential of smart devices and smartphones will be paramount in the constantly evolving face of health care. Academic medical centers should consider these findings when developing future institutional communication systems.

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