The Impact of Personal Digital Assistant Devices on Medication Safety in Primary Care

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Abstract

Objectives: This study determines the impact that use of personal digital assistants (PDAs) has on avoiding potential medication prescribing errors in primary care, office-based practices. The specific aims are to (1) measure the occurrence of prescribing-related errors, (2) determine the extent to which medication prescribing errors may be reduced by physicians having improved access to pharmaceutical information at the point of care via the PDA and use of the PDA as a prescription-printing device, and (3) identify perceived barriers to PDA use and successful strategies to overcome these barriers. **Methods:** A prospective, randomized, controlled trial of 78 physicians was conducted in 31 primary care, office-based practices to determine the impact of PDA use on medication prescribing errors. The intervention group was trained by case-simulation to use a PDA-based clinical drug information application at the point of care during the prescribing process, and enter and print prescriptions on a local printer via the PDA. The control group maintained their traditional prescribing practices throughout the study. Qualitative interviews were conducted with the intervention group to identify perceived barriers to PDA use and successful strategies to overcome these barriers. **Results:** The outcome indicates that voluntary use of the PDA results in substantial reductions in errors of legibility, omissions, and use of abbreviations and symbols. Variation in adoption of the PDA as both a prescribing device and a drug information tool was observed. Barriers and successful strategies to overcome the barriers to PDA use are identified. **Conclusion:** The PDA offers an effective method to bring prescribing safety to primary care, office-based practices**.**

Introduction

According to a report by the Institute of Medicine (IOM),[1] hospital patients likely represent only a fraction of the total population at risk of experiencing a medication-related error. This concern was amplified by consumers, 40 percent of whom indicated that they were very concerned about serious errors or mistakes when they received care from the doctor's office.[2] The majority of medication prescribing and use occurs in the ambulatory environment, with 2.5 billion prescriptions dispensed by U.S. pharmacies in 1998.[3] Yet, little research exists to date to inform about prescribing errors in community, office-based physician practices. In early 2000, the Quality Interagency Coordination Task Force (QuIC),

with the Agency for Healthcare Research and Quality (AHRQ) as lead agency, published its report to the President of the United States, *Doing What Counts for Patient Safety: Federal Actions to Reduce Medical Errors and Their Impact*. This report outlined a road map for action, such as identifying and learning from errors, working with providers, and using decision support systems and information technologies to reduce errors and improve care.[4]

Root causes of medication errors usually occur in systems of care delivery.[1] In the medication use system, the first individual who is able to prevent errors is the prescriber.[3] A 1992 study involving 89 community pharmacists in 5 States documented the frequency and type of prescriber errors in the community setting.[5] The results revealed that the pharmacists intervened in 1.9 percent of 33,011 new prescription orders to resolve a prescriber-related problem. Errors of omission, commission, and interactions accounted for 60.5 percent of these prescriber-related problems. Illegibility accounted for 6.4 percent of the errors identified. Expert evaluators concluded that 28.3 percent of the prescribing problems identified during the study could have caused patient harm if the pharmacist had not intervened to correct the problem. Legibility of prescriptions is a widely recognized cause of medication errors.[6–10] Inability to correctly read a medication name, dose, or regimen has resulted in injuries and death. The issue is of such importance that the American Medical Association (AMA) studied the legal implications of poor legibility of medication orders. The AMA publicly reported that misinterpretation of physician prescriptions was the second most prevalent and expensive malpractice claim listed on 90,000 malpractice claims filed over a 7-year period.[11]

These types of errors are potentially correctable at the point of the prescriber through technologies.[12] The personal digital assistant (PDA) provides a technical method to enter data about prescriptions into a format that can be readily printed in the office, thus reducing prescription legibility problems. Early experiences with PDA technology suggest that the PDA's convenience, ease of use, and portability within the physician's office solves several logistical barriers associated with fixed, desktop computer systems.

The IOM has identified that professional practice consistent with current medical knowledge is an essential element in achieving safety and quality in health care.[1] As stated by a leader in health care informatics, "Humans are inherently fallible information processors."[13] Reliance on imperfect memory for medical information can lead to compromised patient safety and increased rates of medical errors.[14] Both the complexity of health care and the lack of adequate information lead to humans making multiple errors every day. Rates of error in knowledge-based processes are also known to be higher than those associated with automatic mental processing.[14]

Automated information and decision support systems have been shown to be effective in reducing certain errors, including those associated with drug knowledge and dissemination.[15] However, automated information and decision support systems are generally not found in physician office-based practices. The complexity of health care requires the availability of systems to assist providers in

making the best possible clinical decisions. PDAs serve this purpose by providing immediate access to drug information at the point of patient care. Many respected, credible information sources are now available as electronic media on these devices. Future trends are clearly to move all expert published information resources to electronic media.[16] Traditional community-based systems already in place to protect patients include double checks through other responsible health care professionals, i.e., nurses and pharmacists, at the time of care delivery. Although PDAs will not eliminate the need for this step, the impact on physicians of immediate information access should reduce the workload of pharmacists, who are correcting prescribing errors caused by a lack of appropriate prescribing information availability at the point of care.

This paper focuses on the impact that PDA use has on prescribing errors. PDAs have already contributed to patient safety by improving the accuracy of patient identification in the hospital setting, and in providing immediate information access for use in diagnosis and care decisions.[17, 18] This paper will address the use of PDAs in reducing pharmacist's intervention at the prescribing phase. It is expected that the use of PDA will reduce the rate of errors caused by illegible prescriptions. It is also expected that immediate access to clinical information may be a contributor to reducing errors.[1] However, new technologies do create new demands on the operators. Even introducing devices such as PDAs, a low-level technology, will encounter barriers to acceptance and use because of the human factor principles that must be addressed to account for the human-machine interface.[19, 20] Introduction of the PDA does cause a shift in workload to the physician. This shift occurs at a time when office efficiency is a health business goal, further increasing the strain on providers. PDAs are also associated with systems technology implementation challenges. The electronic prescribing applications must be integrated with routine office functions, including documentation workflow. These devices also need to maintain communication with a Web server on a regular, if not continuous, basis.[21] The overall effect is not entirely predictable, and it is vital to study the impact of these technologies. The best technologies will allow people to do the things best done by people, such as making complex decisions and communicating with each other.[22]

Purpose

The purpose of this study is to determine the impact of the use of PDAs by prescribers on potential prescribing medication errors in primary-care physician office-based practices. It is the hypothesis of this study that bringing drug information and prescription-printing technology to the point of care in physician offices will reduce prescribing errors and advance patient safety.[4] It is also hypothesized that barriers to adoption will be identified by physicians who use PDAs, and they will employ strategies to successfully overcome these barriers to adopt this health information technology for improved patient safety and quality.

The specific aims of this study are to

1. Measure the occurrence of preventable medication prescribing errors in physician office-based practices.

2. Determine the extent to which medication prescribing errors may be reduced by physicians having improved access to pharmaceutical information needed at the point of care via the PDA, and by using the PDA as a prescription-printing device.
3. Identify perceived barriers to PDA use and successful strategies to overcome these barriers.

Methods

Site and subjects

The study was conducted in 31 primary care offices (one rural, by Metropolitan Statistical Area definition). The offices averaged 2.1 primary care practitioners per site (range of 1–7). The study subjects were primary care physicians with an average age of 42 years (range of 31–79); one-fourth were female; and 85 percent of their practices were in family medicine, and 15 percent in internal medicine. No effort was made to either include or exclude any participant based upon age, gender, race, or ethnic background.

Design overview

A prospective, randomized, controlled trial of 78 prescriber physicians was constructed to observe the impact of PDA use on prescriber medication errors and to answer study aims 1 and 2 mentioned above.[23] A qualitative study of the intervention group was conducted to evaluate study aim 3.

Randomized controlled trial to test aims 1 and 2

Using a random number table, office practices were randomly assigned to either an intervention or control group, and all subjects within an office were in the same group (n = 39 subjects in each group). The intervention group was trained via a case-simulation curriculum to use a clinical drug information application installed on the PDA at the point of care during the prescribing process, and to enter and print prescriptions to a local printer via the PDA. The curriculum to teach the intervention group about PDA use was produced using a best-practice prototype system based upon the assessment criteria developed by the Council on Health Care Technology of the Institute of Medicine.[24–27] Instructional design methods were used to prepare the practice-based, case-simulation curriculum and teach the intervention subjects individually, on site in their clinic practice. They were taught to use the prescribing software to produce a complete and accurate prescription. Formative curricular assessment was used to refine the instruction until users demonstrated successful technology use.

Intervention group physicians were encouraged to use the PDA as much as possible. Each intervention group physician was instructed to print two copies of prescriptions using the PDA, one for the patient and one for the field researcher. However, they could choose to handwrite prescriptions when they preferred.

Because they had the option of reverting back to the traditional handwritten prescription, the intervention group was given carbon copy duplicate prescription blanks in addition to the PDA, so that the data related to both their PDA and handwritten prescribing were collected.

The physicians in the control group maintained their traditional handwritten prescribing practices throughout the study. Each control group physician was provided prescription pads with carbon copy prescription backs. The original was given to the patient, and the carbon copy was set aside for field researchers to collect.

The PDA device and applications selected for this study were the Sony Clie' PEG-SJ30™ (Sony Corporation), and Lexi-Drugs™ Platinum Drug Information (Lexi-Comp Corporation) software.[28] The prescribing software was developed through a contract with a software vendor.

Prescribing errors

This paper reports on errors observed by evaluation of the face of a prescription, including legibility errors, errors of omission, errors of commission, and errors of interpretation. Table 1 displays the error types included in this research, and the application (drug information, electronic prescribing [e-prescribing], or both) that was responsible for influencing the error.

The field researchers were prepared to consistently and reliably identify and classify errors through a case-based curriculum. They were instructed to follow a standard method of review and provided with large-print, easy-to-read checklists with criteria for evaluation and determination of prescription errors to document their observations. The criteria were based on the National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP) Taxonomy of Medication Errors.[29] Interrater reliability was determined using chance-corrected kappa or intraclass correlation coefficient, when appropriate. Kappa was interpreted following the suggested guidelines of Landis and Koch: excellent agreement beyond chance is attributed to a kappa ≥ 0.75, fair to good agreement as 0.4 to < 0.75, and poor agreement beyond chance at < 0.4.[30] When interrater reliability was observed to be < 0.4, the field researchers were retrained and reliability reevaluated to achieve minimally fair-to-good agreement.

Baseline and postintervention assessment of potential prescribing errors was conducted for both the intervention and the control groups. Field researchers visited the practice sites and evaluated the medication prescription orders written by each participating physician prior to randomization until approximately 500 prescriptions were studied for each physician. The quantity of 500 exceeds the required sample size by 2.5-fold, allowing for an actual minimum sample per physician of 200. After the practices were randomly assigned, researchers evaluated another estimated 500 prescriptions for each participating physician in each group post-PDA implementation.

Table 1. Potential impact of PDA application on type of prescribing error

Provides opportunity to reduce error		Type of error application may impact
Drug information application	**E-prescribing application**	
	X*	Illegible prescriber signature
	X	Unclear prescriber identity
	X	Illegible patient name
	X	Illegible prescription overall
	X	Omission of patient name
	X	Omission of patient age or birthdate
	X	Omission of patient address
	X	Omission of date prescription written
	X	Omission of prescriber signature
	X	Omission of indication for medication
	X	Omission of prescription refill status
X	X	Omission of drug name
X	X	Omission of drug strength
X	X	Omission of dosage form
X	X	Omission of quantity to dispense or duration of treatment
X	X	Omission of drug dose
X	X	Omission of route of administration
X	X	Omission of schedule for administration
	X	Use of an abbreviation for the drug name
	X	Use of an abbreviation for the dose amount
	X	Use of an abbreviation for the quantity
	X	Use of an abbreviation for the route of administration
	X	Use of an abbreviation for frequency of administration
	X	Use of symbols on face of prescription
	X	Use of a trailing zero after a decimal point
	X	No use of a leading zero before a decimal point
	X	Vagueness of instructions on prescription
	X	Wrong route of drug administration on prescription

* If electronic signature allowed.

Sample size. The physician sample size was determined to test the hypothesis that a 50 percent reduction in errors as a result of the PDA intervention would be achieved.[1] Published observations of 1.9 prescribing errors for every 100 new prescriptions written was used to estimate the physician sample size needed.[5] This study determined the number of errors using the dispensing-error-detection technique, a technique known to substantially underestimate the number of errors that actually occur.[31, 32] Therefore, this is a conservative estimate of prescriber-related error. To estimate the number of physicians, we assumed a pooled standard deviation for all physicians that equaled the difference in the mean number of prescribing errors between the intervention group (observed mean) and control group (expected mean). Based upon this assumption, a significance level

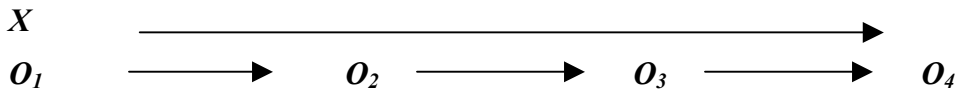
of 0.05, and a power established at 0.80, the total number of physicians exceeds the minimum sample size required.[32]

Qualitative study to meet aim 3

Identification of barriers and strategies to overcome barriers was studied using a qualitative approach employing direct observation and semistructured interviews of individual physicians.[29, 33–36] Interviews were conducted with the intervention group physicians to determine environmental and system factors they believe contribute to increased error risk.[34] The semistructured individual interviews were conducted face-to-face with physicians in their office settings, audio recorded, and converted to written transcripts for purposes of analysis.[36, 37] Onsite observations were conducted using the observer-as-participant approach. Following are the structured questions used to conduct the interview:

- Would you tell me how you have incorporated the use of the PDA into your practice?
- What have you tried to do with your PDA?
- What has worked?
- What has not worked?
- Are there situations that you can recall that have stopped you from using the PDA?
- When you've encountered difficulty with using the PDA, what have you done to solve it?
- Are there any barriers in your immediate work environment that you have encountered when trying to use the PDA? What actions did you take to overcome them?

Once the physicians who had been introduced to the PDA began using it, they were studied to determine what barriers they identified, the solutions they employed to overcome these barriers, and which barriers did not have a solution. The time course of data collection in relationship to the introduction of the intervention to the subjects can be represented as



Where,

X = Introduction of the intervention.

O_1 = Baseline criteria-based performance of PDA use assessment using direct observation by a field researcher and subject interview information documented. All intervention group physicians were required to perform all case simulations competently (accurate and complete prescriptions).

O_2 = Criteria-based subject self-assessment of PDA use and performance 4–7 days postintervention. All intervention group physicians were required to perform competently.

O_3 = Semistructured interview of subject about barriers and solutions to performance at 2–4 weeks postintroduction of the intervention.

O_4 = Direct observation and followup interview with subjects upon completion of intervention.

Analysis

Occurrence of prescribing errors

All prescriptions were handwritten at baseline by all physicians. The frequency of medication errors was determined by counting the total number of errors attributed to the written prescriptions, as evaluated by the trained field researchers, within each classification according to the NCCMERP Taxonomy of Medication Errors. No differences were observed between the control and intervention groups at baseline ($P < 0.05$).

Impact of PDA use on prescribing errors

The frequency of medication errors was compared between pre- and postintervention in the intervention group to determine the impact of PDA use on medication prescribing errors within each NCCMERP classification. For the intervention group, the total number of prescriptions evaluated was 19,372 at baseline and 14,378 postintervention. We reduced the target prescription volume postintervention, while remaining well above the minimum sample size necessary, to reduce unnecessary additional cost and time to complete the data collection.

Use of PDA

To determine the extent of PDA use for prescribing, we examined each prescriber by looking at the relative frequency of PDA-generated prescriptions for each physician against the date the prescriptions were written. We evaluated the entire intervention group by studying patterns of adoption for prescribing in two overarching ways: (1) total proportion of prescriptions generated by PDA versus handwriting, and (2) patterns of PDA-generated prescriptions versus handwritten prescriptions over time. By examining the PDA/handwritten prescription ratio per day per physician, we could examine the patterns generated by each individual. By studying this voluntary adoption, we improve our accuracy in projecting what the impact of PDA prescribing would actually be in the private office setting. Therefore, we retained all physicians in the intervention group, regardless of the volume of prescriptions they generated on the PDA.

The self-reported use of the drug information application was completed post-PDA intervention. Individuals responded to the question “How frequently do you

use the PDA as a source of drug information?" with a behaviorally anchored Likert scale of 1 = never use; 2 = quarterly or less often; 3 = at least monthly; 4 = at least weekly; and 5 = at least daily.

Barriers to PDA use and strategies to overcome them

Semistructured interviews were conducted on the intervention group physicians (n = 39) at 2 weeks after PDA introduction. Training had been completed and the physicians had some experience using the device. A qualitative analysis, evaluating the observations and interviews by coding and organizing observations through content analysis and question analysis of the semistructured interview, was conducted. Observations were organized into barriers identified and strategies used to overcome barriers.[34] An evaluation of the findings regarding barriers and solutions was conducted through a reflective process of the research group and a determination of the contribution of new or unique information.

Results

All physicians in the intervention group were trained and demonstrated successful use of the PDA prior to the intervention. Physicians in the intervention group generated 43 percent of their prescriptions with the PDA. The extent to which individual physicians used the PDA for e-prescribing under the circumstances of voluntary use ranged from 0 to 100 percent of the prescriptions they wrote. There were only two physicians who did not generate any prescriptions on the PDA.

Occurrence of prescribing-related errors

Problems of illegibility, omissions, and use of abbreviations and symbols all were observed in high frequency on the baseline prescriptions (all handwritten). The frequency of these prescribing-related errors is shown in Table 2.

Impact of PDA on prescriber medication errors

The results of the impact of PDA use on prescribing errors are also shown in Table 2. These results reflect the impact of PDA use when partially adopted by users, so both PDA-generated and handwritten prescriptions were analyzed postintervention. Errors associated with legibility were greatly reduced by the implementation of the e-prescribing application on the PDA. Overall illegibility of the prescriptions decreased from 9.1 percent to 2.7 percent. Illegibility was not eliminated because not all prescriptions were generated using the PDA. All types of error attributable to omission on the prescription were reduced, with the exception of the patient's address (no change). There was a remarkable drop in the omission of the patient's age or birthdate, from a 95.5 percent omission rate at baseline to a 59.2 percent omission rate after PDA introduction. This is a desirable change, because knowing the patient's age improves correct dosing verification and patient identity. All types of errors of omission related directly to

Table 2. Impact of partial adoption of PDA intervention on prescription errors*

% Error in intervention group (baseline) (n = 19,372 Rx's)	% Error in intervention group (post-PDA use) (n = 14,378 Rx's)	Type of error
76.6	17.7	Illegible prescriber signature
55.9	27.6	Unclear prescriber identity
18.7	9.8	Illegible patient name
9.1	2.7	Illegible prescription overall
0.6	0.1	Omission of patient name
95.5	59.2	Omission of patient age or birthdate
99.8	99.7	Omission of patient address
1.4	0.6	Omission of date prescription written
1.3	1.3	Omission of prescriber signature†
89.9	78.5	Omission of indication for medication
18.5	12.1	Omission of prescription refill status
0.5	0.2	Omission of drug name
20.9	17.0	Omission of drug strength
84.7	51.7	Omission of dosage form
6.2	4.5	Omission of quantity to dispense or duration of treatment
13.4	11.7	Omission of drug dose
30.8	19.5	Omission of route of administration
5.3	4.8	Omission of schedule for administration
3.4	2.3	Use of an abbreviation for the drug name
61	70.5	Use of an abbreviation for the dose amount‡
1.6	0.5	Use of an abbreviation for the quantity
63.2	36.7	Use of an abbreviation for the route of administration
85.8	50.7	Use of an abbreviation for frequency of administration
76.7	47.4	Use of symbols on face of prescription
0.4	0.3	Use of a trailing zero after a decimal point
0.5	0.4	No use of a leading zero before a decimal point
9.4	11.1	Vagueness of instructions on prescription
0	0.3	Wrong route of drug administration on prescription

* 43% of prescriptions were generated through the PDA.
† No electronic signature in this study.
‡ E-prescribing application used abbreviations for some dose amounts.

the drug or regimen itself were also reduced. A remarkable improvement in dosage form omission was observed. Use of the e-prescribing package showed a substantial reduction in use of abbreviations. Abbreviation use was not eliminated because physicians were allowed to make natural choices and follow their prescribing method preferences during the study. There was also a decrease in the omission of indication for medication use on the prescription, from 89.9 percent to 78.5 percent. This is valuable information to have available on a prescription for pharmacists and patients to enhance patient education and safety. Two types

of errors increased after introduction of the PDA: vagueness of instructions on the prescription and identification of the wrong route of drug administration.

Use of PDA

Prescribing function. Three patterns of prescription generation via the PDA emerged when the PDA-to-handwritten ratio was identified for each individual: (1) adopters, i.e., high-volume use with a sustained pattern of PDA prescription generation over time; (2) nonadopters, i.e., no PDA prescription generation or early, short-term use tapering to no use for a consistent time period; and (3) potential adopters, i.e., sustained use with varying patterns over time. Nine prescribers were identified as adopters. These individuals wrote between 88 and 100 percent of their prescriptions via the PDA and displayed a sustained pattern of use over time. Seventeen individuals were identified as nonadopters. They generated between 0 and 19 percent of their prescriptions from the PDA and demonstrated use only at the beginning of the time period. The 13 remaining prescribers were identified as potential adopters. These individuals generated between 16 and 61 percent of their prescriptions via the PDA; their pattern of use was either sustained throughout the study period or they had a higher volume early in the study with a downward but continued-use trend by the end of the study period. We identify these individuals as potential adopters because the patterns of use indicate they did not give up using the technology, despite the lower use than individuals who are clear adopters.

Drug information function. Self-reported use of the drug information application via the PDA was highly variable in the PDA intervention group. The most frequent postintervention response to the question asking individuals to assess their use of the drug information application was "at least monthly," representing 24 percent of the users, followed by 21 percent reporting daily use and 18 percent reporting weekly use. Thirty-seven percent reported using it quarterly or less.

We also examined the relationship between PDA-prescribing adopters with use of the drug information application. Almost all of the adopters (seven of nine) reported daily use of the drug information application, one adopter reported weekly usage, and one reported no use. In contrast, the 17 nonadopters all reported monthly use or less of the drug information application.

Barriers to PDA use and strategies to overcome them

The quantitative data about prescribing demonstrates that when given the opportunity to use traditional prescribing or e-prescribing applications on the PDA, the PDA is not universally selected. New technologies do create new demands on operators. When use of the technology was optional, some operators opted out.

We identified four major themes reported by physicians that inhibited full PDA adoption. These include technology, time, environment, and personal views. Figure 1 provides further details of representative responses reported by

physicians as they encountered difficulties with use of the PDA. These problems included the technology itself, the influence of the physician's patient volume and time on learning the technology for use in daily practice, the clinic's capability to support the technology, and the physician's perception of the PDA's usefulness and fit in his or her daily practice.

Figure 1. Physician-reported barriers and solutions themes

Barriers themes	Solutions themes
Technology • *Hardware* – the time it took for the prescription to print perceived to be increased. • *Software* – the prescription-generation tool perceived to be cumbersome. Time • *Learning time* – the time needed to learn how to use the PDA. • *Prescription generation* – the time need to write and print the prescription using the PDA. • *Workload* – the perceived patient volume of the physician that day. Environment • *Technology ready* – offices are not ready or equipped properly to support prescribing and printing system. • *Printer location* – printers were not conveniently located so as not to disrupt workflow. Personal views • *Patient centeredness* – the use of the PDA or its software was not appropriate for the patient mix of the clinic. • *Slow to adapt* – interest level or fear of technology slowed adoption.	Individual level • *Self help* – physician takes an active role in solving the problem and continues to try using the PDA. • *Partial adoption* – physician incorporates and continues to use only the applications of the PDA that work best for his or her practice. • *Avoidance* – physician essentially gives up on using the PDA partly because the perceived workload does not allow him or her to seek a solution. System level • *System redesign* – physician proposes the solution requires an organizational commitment and investment to improving the clinic environment to promote use of the PDA. • *Organizational development* – physician proposes the solution requires the organization to recognize the need for and support the necessary training and development.

Figure 1 also shows the solutions devised by the individual physicians in reaction to these barriers at the individual and system levels. At the individual level, physicians may have sought help on their own, chose to use the technology application they felt added value, or simply decided not to use the PDA. Note that only the first option is a "real" solution associated with full adoption. The other "solutions" allow physicians to only accept what easily works or return to what has worked in the past. System-level solutions referred to solutions identified by physicians that necessitated interventions beyond that of the individual physician (e.g., organizational intervention). This intervention may include a need to improve the technology capabilities of the clinic or support additional training.

Barriers and solutions to PDA use exist on both individual and systems levels. From a systems perspective, the interviews clearly showed the necessity to

customize PDAs to the physician's practice, thus contributing to the office's efficiency. On an individual level, physicians need to spend the time to learn the technology so it is an asset and not an inhibitor to their daily practice. Adaptation requires successful learning and application by the user, incorporation of the technology into the physical space, and incorporation into the workflow itself.

Discussion

The frequency of prescribing errors in traditional handwritten prescriptions is substantial. The existing knowledge of prescriber-related errors in physician office-based practices is limited. This study demonstrates the frequency and types of prescriber-related errors in primary care, office-based practices and targets solutions to the problem. This study also assists decisionmakers about technology investments in office-based practices. The costs associated with hardware and software investment, start-up training, and maintenance of systems must be weighed against the value gained.

Physician acceptance of technology and the associated applications and routine adoption in daily practice are the key indicators of success. If such investment results in physician acceptance, quality improvement, and systematic efficiencies, the investment is worthwhile. This study demonstrates these endpoints are achieved within the typical small to medium primary care office-based practice when PDA technology is introduced into this patient care environment, even with partial adoption.

This work also reveals the barriers to achieving success from the individual physician's point of view within the practice environment, and solutions devised by the individual physicians in reaction to these barriers. A detailed understanding of the physician experience when introduced to this technology, the information sources, and the prescribing applications was attained by the researchers. Full implementation of the hand-held applications did not occur in this study of voluntary PDA adoption. Knowledge of the barriers should assist decisionmakers in choosing technologies and applications that are supportable by the local environment and processes before making an investment decision.

Adoption of these technologies may also lead to an indirect benefit for pharmacists and patients. Workload in pharmacies is a substantial concern. Pharmacists constantly balance time required to accurately dispense medications, monitor medications, and educate patients. A reduction in time spent by pharmacists solving potential prescribing errors could directly contribute to improving the time available to monitor the effectiveness of medications and provide education. Were office-based practices to incorporate error-reduction strategies systematically, substantial time spent on problem-solving by pharmacists could be reduced.

Employing information technology (IT) strategies and systems to prescribe drugs holds substantial additional potential for reducing the number of drug-related injuries in the ambulatory setting.[36] Physicians will need to be competent

and confident with the use of PDAs and increasingly receptive to their use as a daily practice tool.

The Centers for Medicare and Medicaid Services has made the adoption of electronic medical records and electronic prescribing a top priority.[39] The Medicare Prescription Drug, Improvement and Modernization Act of 2003 mandates that standards be in place by 2009 for writing and transmitting electronic prescriptions. A recent study[40] documented that of 1,200 physicians, 25 percent were PDA users at work, and more had a substantial interest in becoming users. Of the physicians in the study already using PDAs, 58 percent indicated they used them for drug and clinical information retrieval and 12.1 percent for e-prescribing. Between 39 and 53.4 percent were interested in starting PDA use for clinical decision support, medical records, prescribing medications, and viewing laboratory results. In April 2004, the President's Information Technology Advisory Committee issued draft IT recommendations that call for electronic order entry for both inpatient and outpatient care, clinical decision support tools to aid compliance with evidence-based medical practices, and electronic health records to increase information available to caregivers without creating new workflow requirements or costs.[41]

The data in our research support the notion that adoption of clinical information support and e-prescribing will improve patient safety related to prescribing. Future reports will include an analysis of the impact of the PDA on errors attributed to inadequate clinical decision support, including drug interactions; contraindicated use; and errors in the selection, dosing, and duration of therapy.

Limitations

This study is limited to physician prescriptions in adult primary care practices; it does not study physicians of all medical and surgical specialties. However, the sample is representative of typical primary care, office-based practices around the country. The majority of physicians in the United States practice in independent, small groups of five or fewer[21] (our clinic sites averaged 2.1 physicians/clinic). This study is not designed to detect variations in medication errors that may be caused by characteristics of group practice environments or dynamics. We recognize there may be differences observable between physicians, which in part are attributable to the clinic environment they practice in. Use of the checklist and rater training substantially reduces the variability introduced with varying taxonomies for error classification and multiple raters. This improves our ability to understand and compare data from error studies.

This paper does not address the contribution of the PDA to improved clinical decision support at the point of care to improve prescribing safety. Additional work is presently being completed that will describe the impact of PDA use on detection and avoidance of drug-drug and drug-disease interactions, dosing outside of the acceptable range, and other clinical decisions that can be optimized to improve safety in the primary care office setting.

Finally, the use of the PDA in the prescribing model in this study does not represent order entry integrated with the medical chart. This study represents the lowest cost, lowest level of sophistication for drug information access and electronic prescribing. Despite these technical limitations, the impact of this voluntary use of the PDA on potential prescription errors is substantial.

Conclusion

Voluntary use of the PDA as a prescribing tool results in substantial reductions in errors of legibility, omissions, and use of abbreviations and symbols on prescriptions. Variation in adoption of the PDA as both a prescribing device and a drug information tool occurs when use is voluntary. The PDA offers an effective method to bring prescribing safety to primary care, office-based practices.

Acknowledgments

This study was supported in part by Grant Number R18HS11808-1, Agency for Healthcare Research and Quality.

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