

# HARVARD health policy REVIEW

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# Personal Digital Assistants and the Reduction of Medical Error

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and Edith C. Ramsdell, MD, MPH*

Studies support that medical error is responsible for patient suffering, loss of life and billions of dollars in healthcare costs. New technology, particularly the “Personal Digital Assistant” (PDA), is able to provide accessible point-of-care medical information. While definitive studies are still necessary, the use of PDAs equipped with relevant, reliable and accurate drug and medical references, and calculator software will likely reduce the frequency of medical error.

A concise definition of “error” may help to understand how the point-of-care use of PDAs can reduce the frequency of medical error. Medical error is defined by the Institute of Medicine (IOM) as the “failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim.”<sup>1</sup> It has been further defined as “a mistake, inadvertent occurrence, or unintended event in healthcare delivery which may, or may not, result in

patient injury.”<sup>2</sup> Medical error can be classified into three distinct types, illustrating the extent to which they affect the everyday practice of medicine (Table 1).

Type 1 medical error occurs when the provider has established a reasonable plan that is poorly executed and results in a flawed outcome. Healthcare professionals undergo some of the most extensive education and hands-on training of any profession, yet this kind of error frequently occurs. Competent physicians often implement sound decisions in the wrong manner. Examples of Type 1 medical error include miscalculating a drug dose, overlooking a serious “adverse drug event” (ADE) or “adverse drug interaction” (ADI), confusing similar drug names, and mechanical or incidental occurrences during medical procedures or surgery.

Considering the typically overwhelming caseload and stress level of most physicians, otherwise simple exercises in arith-

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Medical Error Types	Definitions	Causes
Type 1	Good Plan, Flawed Execution	Miscalculations
Type 2	Flawed Plan, Good Execution 1. "Classic-Flaw" - Never Correct 2. "Fashionable Flaw" - Currently Obsolete	Misinformation
Type 3	Inefficient Plan or Execution 1. "Fear-Flawed"	System Inefficiencies

**Table 1. Summary of Medical Errors.**

metic, memory, phonetics or hand-eye coordination may prove problematic without additional assistance (from a PDA, for example). Drug dosing error often results from simple miscalculation, including mistaken conversions between Imperial and Metric units, frequency of weight-based doses and proper drug concentrations. A single decimal place error can result in a ten-fold difference in the calculation of a drug dosage.

Pediatrics is particularly susceptible to Type 1 error. Children's weights can vary greatly from day to day, especially in the neonatal intensive care unit, and most children and young infants cannot communicate the nature or extent of their illnesses. It is not surprising that the pediatric population experiences a 300% higher likelihood for dosing errors than adults.<sup>3</sup> Since doses can vary as much as 400-fold, errors in weight-based dosing calculations may be easily missed.

Two more examples of Type 1 error are preventable ADI and medication name confusion. There are tens of thousands of chemical constituents in the foods, drugs and remedies we ingest. The possibility of adverse drug-drug, drug-food and drug-herbal reactions is foreseeable. It is virtually impossible to be aware of all the chemicals patients have in their systems and their possibly lethal interactions or ADEs. Similarly, name confusion between some

of the over 10,000 drugs available can also prove fatal. Prescription translation error combined with the increasing number of similar names such as Celebrex, Cerebyx and Celexa can lead to patient morbidity and mortality.

Procedural or surgical flaws are also Type 1 medical error. Incidental surgical error, mismatched blood types and wrong site surgery are examples of situations where highly trained professionals using state-of-the-art equipment establish a good plan and execute it poorly.

Type 2 medical error occurs when a provider initiates a flawed plan irrespective of execution. There are two sub-categories of Type 2 medical error: "classic-flaw" and "fashionable-flaw." Because most Type 2 medical error is a result of faulty planning based on incomplete or insufficient knowledge, most can be prevented with improved information and protocols.

The "classic-flaw" is Type 2 error caused by medical practice that is never correct, yet nonetheless seen within the medical community. Examples of "classic-flaw" include EKG misinterpretation resulting in the inappropriate administration of thrombolytic therapy to a patient complaining of chest pain, or sending a comatose diabetic patient to radiology prior to checking glucose levels.

The "fashionable-flaw" is medical error resulting from fluctuating medical

guidelines where practices fall in and out of favor. Failing to adapt to practice patterns quickly enough can result in error. It is important to remember a “fashionable-flaw” is a medical practice that was not always considered error. For example, a physician may use full tidal volumes rather than “permissive hypercapnia” to treat an intubated asthmatic patient. While this used to be standard care for such a patient, it would now be considered Type 2 medical error, because this practice can result in over-inflated lungs, which will require a protracted ICU recovery if they collapse.

Simple problems should not demand complex solutions. However, over-worked, over-litigated physicians often employ an inefficient “shotgun” approach to treating patients that leads to unintentional secondary events, known as Type 3 error. Such extraneous actions involve ordering unnecessary diagnostics that may result in a “false positive.” This leads to additional testing and unnecessary treatment. In a “systems” approach, these errors are a consequence of organizational or situational pressure and are considered “forced errors.” An otherwise healthy patient may present to the emergency department (ED) with a sprained ankle, only to have the attending physician initiate treatment for high blood pressure and heart rate. Or, a physician might order a complete cardiac work-up for every patient seen with any type of chest pain. Obvious symptoms demanding attention may be temporarily ignored to follow time-consuming measures (e.g., insurance pre-certification, non-vital lab work, physical exam maneuvers). While most physicians find these practices medically unnecessary, they admit that this procedural inefficiency is the only way they can protect themselves from subse-

quent litigation.

Inefficient execution is also a function of cumbersome documentation systems operating within healthcare facilities. Ineffective systems result in the loss of a critical element of clinical medicine – time. Physicians have less time to spend with their patients when they are forced from the bedside to complete the large volume of documentation necessary to process patient records and complete orders. Nurse direct patient time is similarly compromised when diagnostics and treatments are delayed while paperwork is completed.

## Prevalence

The IOM report, *To Err Is Human*, brought the medical error problem to the forefront of national debate in 1999.<sup>1</sup> This study estimated the prevalence of medical error in the U.S. healthcare system. It reported that 44-98 thousand people die annually (~270/day) in U.S. hospitals as a result of error. They further estimated that more than half were preventable. This figure far exceeds annual mortality rates due to AIDS, vehicular accidents and breast cancer – issues that have clearly elicited far greater national attention and funding. While some researchers assert that the IOM report exaggerated statistics by not sufficiently accounting for terminally ill patients, few professionals doubt the severity of the medical error crisis or the need for system-wide reform.<sup>4</sup>

Americans are increasingly concerned about a healthcare system that is not able to control either costs or preventable error. It has been estimated that additional healthcare expenditures, lost income and disability from preventable medical error

costs the U.S. economy \$17-29 billion annually.<sup>5</sup> These expenses come indirectly out of Americans' pockets as increased medical charges and insurance premiums. While medical costs continue to rise, every dollar spent on correcting error is a dollar not spent on preventative or general medical care.

While a majority of medical encounters occur outside the acute care setting, in places such as nursing homes, surgical centers, physician offices and the home, statistics indicate that ambulatory and hospitalized patients are at equal risk for Type 1 medical error. Over 55% of ambulatory care patients are at risk for a preventable ADE.<sup>6</sup> Further studies report that more than 50% of hospitalized children may be subject to medication dosing error.<sup>3</sup>

Quantifying Type 2 medical error is more difficult. Review of the literature suggests few studies have been conducted to determine patient morbidity and mortality from physicians' ignorance of current "best practices" and protocols. Studies suggest 1) physician lack of awareness, 2) protocol non-compliance and 3) protocol obsolescence as the causes of significant preventable injury.

Cranney et al. reported many family practice physicians were not aware of the existence of evidence-based guidelines.<sup>7</sup> The study further stated that physicians reported 1) that available protocols were outdated or 2) limited access to protocols in settings where computers were not available. Cabana et al. support this finding.<sup>6</sup> The authors cited lack of awareness, familiarity, time, required resources, protocol accessibility and excessive volume of information as barriers to successful protocol use.

In their study, Cline et al. reported

that physicians deviated from accepted Advanced Cardiac Life Support (ACLS) guidelines in 35.2% of emergency resuscitations meaning one-third of all resuscitations were flawed based on Type 2 medical error.<sup>8</sup> Other research indicates 71.2% of physicians caring for adults with severe pneumonia did not follow American Thoracic Society (ATS) guidelines in their treatment plans.<sup>9</sup> The study concluded that guideline non-compliance increased mortality 450%. Conversely, Suchyta et al. reported that protocol adherence decreased hospital admissions over 56%, reduced outpatient antibiotic costs \$45 per treatment and reduced in-house patient cost more than \$4,400.<sup>10</sup>

Accepted pediatric guidelines are similarly ignored. Young reported that primary care physicians treating febrile neonates chose treatment strategies differing from accepted guidelines in 60-89% of cases.<sup>11</sup> Another study stated that, 92.4% of the time, pediatricians, emergency physicians, family practice doctors and nurse practitioners chose the wrong management strategies when presented with a child suffering from a minor head injury.<sup>12</sup>

Many protocols are outdated. Shekelle et al. suggested that 50% of guidelines are obsolete within 6 years of development, and that many are out-of-date within 4 years.<sup>13</sup> This is significant as the typical cycle for textbook updates is 4-5 years, making many textbooks obsolete by the time they are published.

"Forced error" is prevalent throughout the entire medical establishment, as statistics show. During the course of ten years, the typical emergency room physician will see an average of 50,000 patients. Odds are 1 in 10,000 will suffer a myocardial infarction within the subsequent 30 days, ir-

respective of any diagnostics the attending physician does or does not perform at the initial encounter.<sup>14</sup> The reality that five lawsuits await every ER physician who does not fully “work up” every patient with remote chest or cardiac symptoms explains why physicians order diagnostics and treatments unnecessarily. Unfortunately, these actions expose patients to Type 3 medical error that would otherwise be avoided.

### **Managing Medical Error: A Solution**

In practice, the management of medical error typically begins with “shame and blame” where physicians are held personally responsible for mistakes. “Bad outcome” is automatically associated with malpractice. Ongoing fears of legal reprisal and public disclosure serve to discourage accurate error reporting. As every patient record is subject to legal discovery, this destructive, finger-pointing approach necessitates the creation and utilization of new risk-management systems. Given the ongoing medical error crisis and its human toll, current obstacles must be addressed before meaningful advances in reducing medical error and promoting patient safety can be realized.

A second IOM report discussed the need for “the efficient and reliable production of goods and services according to the highly personalized needs of individual customers.”<sup>20</sup> While always under review and subject to change by experts in each field as new evidence emerges, evidence-based medicine (EBM) protocols already exist for a variety of healthcare areas including ACLS, ATLS, PALS, APLS, BLS, Asthma, JNC7 and ATS guidelines.

Incorporating EBM protocols into well-designed programs is critical for successful electronic system utilization.

In anesthesiology, the death rate dropped from 1:10,000 to 1:250,000 with the implementation of protocols, standardization of equipment and dependable procedures.<sup>15</sup> In critical care there was a 400% increase in survival of patients with severe respiratory distress after the implementation of computerized protocols.<sup>16</sup> Additional research has shown that accessible bedside resources effectively reduced error. Having a pharmacist on adult ICU rounds, for example, reduced medication order error by as much as 66%.<sup>17</sup> Similarly, a pediatric study predicted that ward-based clinical pharmacists could reduce potential adverse drug events in children by 94%.<sup>18</sup>

To address systemic error, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) instituted widespread policy reform, requiring accredited hospitals to report all adverse events.<sup>19</sup> Fear of revocation of hospital accreditation and the release of all hospital data to third parties, including the media, will likely preclude effective reform. To be successful and feasible, a systemic solution must equally address the three types of medical error prevalent today in health care: miscalculations, misinformation and system inefficiencies.

Programs developed for electronic databases allow for consistent protocol access by clinicians and offer a simple solution for protocol non-compliance. If all system providers have access to the same database, “access” theoretically acts as a “reliability check” to protocol awareness and adherence. Electronic storage and transfer of medical data also allows for more efficient and reliable patient management

by improving the flow of patient orders, facilitating the exchange of diagnostic results and simplifying patient cross-coverage. These point-of-care communication systems have been shown to reduce pediatric medication error.<sup>7</sup>

The challenge is to develop a system that does not secondarily overburden already overworked and inefficient organizations. For the most part, personal computer (PC) based technology lacks the portability and practicality of a point-of-care tool, as the dynamic of the interface often requires more information management. Systems not only remain difficult to use, but are often incapable of communicating with each other. Further, new Health Insurance Portability and Accountability Act (HIPAA) guidelines and other privacy concerns limit data accessibility and transfer. As a result of these secondary issues, several healthcare systems have abandoned electronic solutions.

Consider California's Cedar-Sinai Hospital, where a \$34 million system was recently dismantled.<sup>21</sup> System failure was due to Type 3 medical error that outweighed predicted benefits. Doctors complained that the system, designed to increase efficiency, actually decreased direct patient care, forcing them to devote too much time to data entry and system management. At least six other hospitals have also eliminated their paperless systems due to end-user resistance, system overburden and other communication hurdles.<sup>21</sup>

Medicine has proven that EBM protocols and technology improve outcomes and save lives. The challenge is to identify the best solution for unique demands within specific healthcare environments while delivering these protocols to the practitioner in "real-time." In other words, the

challenge is to create a true point-of-care medical reference. Point-of-care solutions are now available for different specialties that satisfy both the needs of the provider and the system in which they work without increasing the management burden: this is the goal.

Providers will welcome such protocols and technology because the systems can provide customized access to the best sources of up-to-date information. Hospitals and other healthcare systems will also likely welcome the technology because these systems offer 1) net time savings by decreasing inefficiencies while increasing productivity and 2) system wide reliability checks by decreasing medical error, improving risk management and tracking protocol use and compliance.

It has been reported that physicians, including those with pharmacology training, routinely miss over 85% of significant ADIs identified by a simple drug-interaction program.<sup>22</sup> These medication order errors were reduced 83% with an order entry system capable of providing dosing information and calculations, and checking for allergies and interactions.<sup>23</sup> Other studies suggest that computerized order entry can reduce potential ADIs in children by 93%.<sup>18</sup>

Ongoing studies further reinforce the premise that well designed and properly implemented computer protocols are better than humans at rapidly making basic, yet critical, bedside decisions. This is particularly true of PDAs, which can access volumes of information at the bedside in less than 1 minute.<sup>24</sup> Personal Digital Assistants prove ideal for these unique point-of-care demands for a number of reasons (Table 2). David Siegal, MD, JD, wrote in ACEP News: "It is entirely conceivable

that [the PDA] will become, or has become, the standard of care.”<sup>25</sup>

When considering the PDA potential, it is important to describe how the PDA offers a solution for reducing the three types of medical error. Point-of-care patient management software will significantly decrease Type 1 medical error by confirming current medications, allergies, lab values, surgical site and other vital information. Built-in calculators can verify dosing, drip rates, lab abnormalities and key medical parameters. Software can also automatically check for ADI and provide ADE information. Such easy access to patient care information will allow better patient cross-coverage and should decrease the estimated 500% increase of risk of an ADE during patient transfer.<sup>26</sup>

A PDA can address both the “classic-flaw” and “fashionable-flaw” Type 2 medical errors by suggesting diagnostic and therapeutic plans based on EBM guidelines and protocols. Physicians, other health professionals and healthcare systems will be able to confirm orders and protocol use and compliance. Immediate access to peer-reviewed protocols can help change standards of care and eliminate inefficient plans based on system overburden, decreasing the fear of litigation and reducing Type 3 medical error.

To fully understand the impact that the electronic age (specifically PDA technology) will have on healthcare systems, the practice of medicine and the elimination of medical error, consider a “real-world” scenario using three methods of patient management: “old school” (non-technological), an electronic database and the PDA.

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|---|
| <ol style="list-style-type: none"><li>1. Compact</li><li>2. Fast Processors</li><li>3. Abundant Inexpensive Memory</li><li>4. Easy Interface with PC</li><li>5. Excellent Battery Life</li><li>6. Excellent Readability</li><li>7. Wireless Capabilities</li><li>8. Phone/Camera/Video/Audio Capability</li></ol> |
|---|

**Table 2. PDA Features.**

### “Real-world” scenario

A 7-year-old child with a penicillin allergy presents to the ED with a fever of 103oF and a severe headache. The child has a known history of Tourette’s syndrome and takes the antipsychotic medication pimozide to control the symptoms. The attending physician suspects a case of acute sinusitis.

In a non-technological system, the physician must rely on and trust memory (Type 2 medical error), or review a textbook to determine the best diagnostic strategy. This process is time-consuming (Type 3 medical error) and the available information may prove outdated or incomplete (Type 2 medical error). The physician may consult a pediatric ENT specialist, which also demands extra time and additional resources (Type 3 medical error).

Given the child’s penicillin allergy, the physician must know to not use the commonly administered amoxicillin (Type 1 medical error), and must review a text (Type 2 medical error), or place a call to a pharmacist to determine a reasonable alternative medication (Type 3 medical error) and possible drug-drug interactions (Type 1 medical error). Once an appropriate, non-interacting antibiotic is identified, multiple calculations to determine dose and concentration must be performed (Type 1 medical error). Only after this

Patient Specific Programs	Patient Tracker
Medication Information	ePocrates Lexidrug & Interact Apothecarium Davis's Drug Guide Pocket PDR PEPID PDC
Calculators	MedCalc PEPID MC
Diagnostic & Treatment	Five Minute Clinical Consult Series (5MCC) Harrison's Manual of Medicine Washington Manual Up-to Date InfoPOEMS PEPID ED

**Table 3. Selected Available PDA-Based Software Solutions.**

time-consuming, possibly erroneous and “fear-flawed” scenario, can our physician safely write a prescription and send the child home.

Currently, good resources for disease and drug information are available on the Internet (e.g., eMedicine and Up-to-Date) and creditable software (e.g., PDR and LexiDrug) is also available for the PC or laptop. Unfortunately, none are designed for quick access and instantaneous point-of-care decision-support. The inefficient use of physician time required to leave a patient’s bedside, log onto a PC or Internet site, search for desired information, review lengthy “text-book” format and decipher inconsistencies creates significant Type 3 as well as potential Type 2 medical error.

There are several PDA-based software solutions available (Table 3). At present the software for PDA systems is either integrated or non-integrated (Table 4). In the non-integrated software, several separate PDA programs must be used in sequence to obtain the needed information, while integrated software allows for paral-

lel access to the same data.

In the above scenario, the physician could use a medical information program (e.g., 5 Minute Emergency Consult) to review disease presentation, diagnostic criteria and appropriate treatment strategies. Then a separate pharmacological reference (e.g., ePocrates) must be accessed to determine appropriate medication and to assess potential drug-drug interaction. A medical calculator is then needed to compute dosing conversions. Finally, a traditional calculator is needed to compute the specific patient medication dose. While there is less chance for medical error using non-integrated PDA software than in the methods described above, the system is not fluid and leaves room for error, especially Type 3 medical error.

In an integrated software solution all diagnosis, treatment, medication choice, dose and calculations are nested within a single, seamless program. The program allows for easy access between diagnostic and pharmacological information, drug-drug interactions, and medical conversions

<b>Non-Integrated Software</b>	<b>Open Medical Reference</b> <i>Eg. 5MCC</i>	<ul style="list-style-type: none"> <li>• Go to index</li> <li>• Locate "Sinusitis"</li> <li>• Go to diagnostic criteria</li> <li>• Go to treatment</li> <li>• First line treatment: Amoxicillin (patient allergic)</li> <li>• Find alternative: Macrolide-Clarythromycin</li> <li>• Close medical reference</li> </ul>
	<b>Open Pharmacological Reference</b> <i>Eg. ePocrates</i>	<ul style="list-style-type: none"> <li>• Go to drug interactions</li> <li>• Enter Clarithromycin</li> <li>• Enter other patient medications: Pimozide</li> <li>• Note dangerous interaction</li> <li>• Consider another Macrolide-Azithromycin</li> <li>• No interaction noted</li> <li>• Go to drug information</li> <li>• Enter Azithromycin</li> <li>• Note dosing information</li> <li>• Write it down</li> <li>• Close the drug reference</li> </ul>
	<b>Open Medical Calculator</b> <i>Eg. MedCalc</i>	<ul style="list-style-type: none"> <li>• Find a metric converter</li> <li>• Enter patient's weight in pounds - convert to kilograms</li> <li>• Note result</li> <li>• Close metric converter</li> </ul>
	<b>Open Traditional Calculator</b>	<ul style="list-style-type: none"> <li>• Multiply weight in kilograms by daily dose in milligrams</li> <li>• Divide by frequency of administration</li> <li>• Divide does by antibiotic concentration</li> <li>• Record correct dose</li> </ul>
<b>Integrated Software</b>	<i>Eg. PEPID</i>	<ul style="list-style-type: none"> <li>• Go to index</li> <li>• Enter "Sinusitis"</li> <li>• Go to diagnostic criteria</li> <li>• Go to first line treatment: Amoxicillin (patient allergic)</li> <li>• Find alternative: Macrolide-Clarythromycin</li> <li>• Check for interactions</li> <li>• Enter Clarithromycin/Pimozide - Note: "dangerous interaction"</li> <li>• Choose another Macrolide: Azythromycin</li> <li>• Recheck interaction - None noted</li> <li>• Go to Azithromycin drug dosing and dosing calculator</li> <li>• Enter weight in pounds</li> <li>• Correct dose displayed in milligrams and milliliters</li> </ul>


**Table 4. Non-Integrated vs. Integrated PDA Software.**

and calculations. This method decreases Type 1 medical error by eliminating medication name confusion, ADIs, ADEs and dosing miscalculations; Type 2 medical error by containing up-to-date peer reviewed treatment plans, protocols and appropriate medication choices; and Type 3 medical error by improving efficiency and decreasing “fear-flawed” plans.

**Conclusion**

As professionals and public servants scramble for solutions, lives are lost, hos-

pital stays are prolonged, productivity is impeded and healthcare costs continue to rise due to ongoing medical error. Despite presidential speeches, congressional hearings, the introduction of legislation and media attention to the initial IOM report, studies reveal that today patients are no safer than they were in 1999 when the report was first published.<sup>27</sup> It is imperative that physicians and healthcare systems address the medical error crisis. Given today’s advances in technology and the need for effective and efficient point-of-care solutions, PDA and integrated software solutions are clear choices to decrease medical

error and cost, and improve overall patient care. 

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