Review Article

Medical Error Reduction and PDAs

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Abstract

Numerous studies have revealed that medical errors are responsible for tremendous patient suffering, loss of life, and billions of dollars in costs. Research also suggests that children are at much higher risk of these errors than adults. New information technologies, particularly personal digital assistants (PDAs), are able to provide readily accessible medical information at the point-of-care. Although definitive studies are still necessary, the bedside use of these portable electronic devices, equipped with relevant, reliable and accurate drug, medical reference and calculator software, can help reduce the prevalence of medical errors, particularly for children. *Int Pediatr. 2003;18(2):69-77.*

Key words: drug diary errors, medical errors, medical reference, medication errors, personal digital assistant (PDA), pocket PC

Introduction

Americans spend more on healthcare than any other country, and have created the most technologically advanced care in the world. Beneath the surface, however, the infrastructure is plagued by core problems, including fragmented care, non-standardized procedures, soaring costs and millions of patients lacking even the most basic insurance coverage.[1] Most alarmingly, the system continues to produce an unacceptably high rate of medical error.

A National Academy of Sciences Institute of Medicine report *To Err Is Human*[2] brought the American medical error problem to the forefront of national debate in 1999. The now often-cited study estimated the prevalence and severity of these medical errors by asserting that between 44,000 and 98,000 people die in U.S. hospitals annually as a result of medical mistakes — more than half of them preventable. Such a surprisingly high number of estimated fatalities are particularly shocking since the figure amounts to an average of 270 deaths per day, equivalent to the number of passengers on a fully-loaded 757 aircraft. The figure also far exceeds the annual number of deaths due to AIDS, vehicular accidents, and breast cancer, problems that have clearly elicited far greater national attention and funding.

Personal Digital Assistant (PDA)

The fiscal burden is proportionately staggering: Preventable medical errors have been estimated to cost the American economy (in the form of additional healthcare costs, lost income and household production, and disability) from $17 to 29 billion annually.[3] These expenses come indirectly out of most Americans' pockets through increased billing and insurance premiums: As these medical costs continue to rise, every dollar spent fixing or compensating for these mistakes is a dollar not spent on preventive care,

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or even on other crucial medical care. The opportunity costs are no doubt similarly vast and incalculable.

Medication dosage errors, perhaps the most preventable of medical mistakes, continue to contribute heavily to this ongoing healthcare crisis, particularly for children. Responsible for more than 7,000 deaths a year, mostly preventable adverse drug reactions cost the average 700-bed hospital an added $2.8 million in billing.[4] Extrapolating these statistics to the nation as a whole, preventable *in-patient drug mistakes alone* cost the American economy more than $2 billion a year, and result in untold, mostly avoidable adult and pediatric suffering.

If these figures would not be telling enough, they merely scratch the surface of the overall American healthcare dilemma. Since the majority of medical interactions occur outside an acute care hospital, medical errors in nursing homes, surgical centers, physician offices and home care significantly add to the overall cost and suffering. Although other researchers have asserted that the Institute of Medicine's report exaggerated their statistics by not sufficiently accounting for terminally ill patients,[5] few industry professionals doubt the overall severity of this medical error crisis, or the urgent need for system-wide reform.

The reputation of the entire American healthcare industry is at stake, as patient confidence continues to proportionately erode. After all, the fragile patient-doctor relationship is a bond of trust around which any healthcare system must revolve. Physical harm done to a patient, regardless of intent, can have deep and lasting effects, many of them emotional. As errors have risen, faith in the system has plummeted[6]; as costs have steadily increased to pay for these mistakes, patient disillusionment has reached an all-time high. Americans are understandably concerned about a healthcare system that seems unable to control either costs or safety concerns.

From the opposite side of the bed, healthcare professionals are often equally frustrated. To err is indeed human, yet physicians, more so than most professionals, are expected to make no mistakes. Pressures mount as ongoing medical research and technological advances produce a virtual mountain of information for healthcare professionals to incessantly monitor. As a result, fragmented and varied care can produce inconsistencies in healthcare emphasis and service, to which medical professionals are held accountable. Combine this avalanche of information with the day-to-day stress of a working medical environment, and mistakes, regardless of intent, become inevitable. We as physicians undergo exhaustive training, tireless devotion to craft and use state-of-the-art technologies and drug therapies; what a tragedy to see an otherwise perfect care plan fail due to a flaw as banal as a misread prescription or hospital chart.

As professionals and public servants scramble for solutions, lives are lost, hospital stays prolonged, productivity is impeded and costs continue to rise. Although Presidential speeches, Congressional hearings, the introduction of four bills on Capital Hill and much media commotion followed the initial Institute of Medicine report, fresh studies reveal that patients today are no safer than they were in 1999, when the report was first issued.[7] Clearly, the time is long overdue for not only addressing this nationwide crisis in healthcare, but providing tangible and effective solutions at the point-of-care.

The Need for New Approaches

Other complex infrastructures, such as aviation, have adopted "failsafe" routines in the last two decades, and the perception is that they do a much better job of error handling and prevention.[8] The ironic question then becomes: "When will seeing a doctor seem to be as safe as flying in a jet?" Given the ongoing medical error crisis and its human toll, current obstacles must be overcome or in some manner circumvented before meaningful advances in reducing medical error and promoting patient safety can be realized.[9]

Current medical error handling practice in the United States typically begins with the so-called "shame and blame" method, where physicians are held personally responsible for mistakes. Such a potentially destructive, finger-pointing approach markedly discourages error reporting, especially since everything a doctor states for the record is subject to legal discovery. Approaching the medical error problem from a different vantage point, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) has instituted institutional policy reforms requiring accredited hospitals to report all adverse events. Unfortunately, the JCAHO's ability to release all hospital data to third parties (including the media), coupled with the risk of the scrutinized hospital losing

its accreditation in like manner, preclude effective reform.

Given these ongoing fears of legal consequence and public disclosure, new error handling and prevention methods must be utilized.

Medical Error as "Misinformation"

The Agency for Healthcare Research and Quality (AHRQ) has noted that insufficient or erroneous point-of-care treatment information is a frequent and significant cause of medical error.[10] In an address to Congress, AHRQ stated that clinicians must have sufficient evidence and information to close the potentially gaping chasm between medical fact and medical practice. Only by smoothly and efficiently integrating knowledge with craft can healthcare quality improve.

Since communication problems and access to information lie at the heart of most medical errors, new information management technologies must therefore be implemented and smoothly integrated within the existing healthcare infrastructure if effective and ongoing changes can ever take place. Consider the ongoing problem of identifying adverse drug reactions, usually a consequence of an information error occurring at one or several points during the prescription-to-administration process. Improper dosing or incorrect drug choice can lead to a host of complications and even death, particularly for children.

For many reasons, children are three times more likely to experience a preventable adverse drug event than adults.[11] First, the relatively broad range of pediatric and neonatal patients, whose weights can vary from 400g to 120kg, create a 300-fold potential for weight-based dosing error. Since few drugs are available from manufacturers in ready-to-administer pediatric or neonatal unit doses or dosage forms, preparation of stock dilutions, repackaging or compound dosage forms are routinely required. To make matters worse, most drugs on the market in the United States are not labeled with a pediatric indication; many have never been studied for safety or recommended dosages for pediatric or neonatal populations. (The FDA attempted to address this safety discrepancy with their "Pediatric Rule" in 1997, which legally required pharmaceutical companies to study new and marketed drugs and biologics in children to determine their safety, efficacy and dosing.[12] In October 2002, however, the U.S. District Court for the District of Columbia decided that the FDA had no authority to enforce this rule, leaving drugs untested for children.) Secondly, children are less capable of communicating their symptoms, significantly reducing reaction time in the event of drug overdose or adverse reaction. Lastly, children are less able to physically combat the deleterious and potentially lethal effects of a drug overdose or negative interaction, maximizing their risk to these emergencies.[13]

Name confusion during drug processing is frequently the most common cause of drug-related errors.[14] A recent and vivid example: The sound-alike/look-alike names for the antiepileptic drug "Lamictal" and the antifungal drug "Lamisil". Dispensing errors were common enough to warrant the Lamictal manufacturer, Glaxo Wellcome Inc., to launch a campaign warning pharmacists of the potential confusion. Their precautionary efforts were hardly unwarranted, since the possible consequences of prescribing the wrong drug are grave: Epileptic patients receiving the anti-fungal drug Lamisil could experience continuous seizures; conversely, patients erroneously receiving the antiepileptic drug Lamictal might experience a serious rash, blood pressure changes, or a host of other side effects. Along similar lines, imagine handwritten prescriptions for the drugs Celebrex®, Celexa® and Cerebyx®, which are for pain, depression and seizure, respectively. The potential for misidentification is readily evident, and exemplifies the connection between misinformation and medical error.

I can relate my own experience with a potentially devastating drug mix-up: One evening I returned home from work at the hospital to discover my wife unconscious. She had been prescribed "Lorazepam" (Ativan) and was given "Alprazolam" (Xanax). Since the erroneously substituted drug has a potency of 8 times that of what should have been prescribed for her, I was fortunate to arrive at home on time. Unfortunately, countless other patients have not been so lucky, falling victim to preventable dosing or drug name mix-up problems that should never have happened.

The American Hospital Association systematizes and elaborates on these and other types of medication errors,[15] most commonly due to:

- Patient Information Problems: Improper diagnoses, lab values, potential allergies, drug

contraindications, etc. (Incorrect weights also can be a major problem as parents may relate a weight to health care professionals that is inaccurate – or weights poorly estimated in an emergency situation)

- Drug Information Problems: Dosing miscalculations or ignorance of potentially harmful drug interactions

Additional problems include:

- Drug Ordering Problems: Failed communication, including poor handwriting, name confusion, decimal point errors, metric and U.S. conversion factors, inappropriate abbreviations, ambiguous or incomplete orders

- Labeling, Packaging and Drug Nomenclature Problems: Lack of appropriate labeling and errors during transfer

- Environmental Stress: Lighting, heat, noise, and interruptions can distract health professionals from properly handling all the information connected to proper drug prescription and dispensation

The urgency and severity of these and other problems are evident. Consider these general statistics generated by a Commonwealth Fund report[16]:

- 1 of 5 (22%) Americans report that they or a family member had experienced a medical error of some kind

- 1 of 10 adults reported that they or a family member had "gotten sicker" as a result of a mistake in a doctor's office or in the hospital, and about 1/2 of those said the problem was very serious; of 16% reporting a medication error, over 1/5 said the error turned out to be very serious

- Close to 23 million people reported at least 1 family member who experienced a medical mistake; more than 8 million households reported at least 1 family member had a problem that was serious

The Electronic Solution

Installing guidelines for care on electronic databases permits ubiquitous, consistent and timely access by clinicians. The electronic storage and transfer of medical data can also allow for the rapid exchange of clinical laboratory results, and can efficiently handle patient cross-coverage and referrals. In fact, electronic point-of-care communication procedures can actually lower the rate of pediatric medication errors.[17]

The Dana-Farber Cancer Institute, for example, is one of several organizations that have implemented new electronic systems to minimize medical errors. Responding to industry and public outcry after the much-publicized accidental dosing death of *Boston Globe* health columnist Betsy A. Lehman, the institute has installed a $1.7 million information handling and processing system so that doctors no longer have to hand-write prescriptions.[18] As these procedures have taken effect, Dana-Farber has also begun a system of non-punitive error-reporting to encourage the open discussion of medical mistakes among staff. The institute has since described a "dramatic increase" in error reporting, hopefully lifting the taboo from a subject that requires constant and open-ended scrutiny.

The Veterans' Administration (VA), arguably the largest healthcare system in the country, has taken similarly effective measures to prevent medical mistakes through electronic system controls and implementation. Between June 1997 and December 1998, the VA counted almost 3,000 medical errors (with some 700 deaths among them). To help minimize such statistics, the VA has installed a new bar-coding system to prevent and track medical errors.[19] Over a five-year test period at two VA hospitals in Kansas, the medication error rate dropped 70 percent, setting a precedent for new and innovative medical error-prevention systems nationwide.

All these electronic data sources need to be available at the bedside. Clinics and hospitals have varying experience with personal computers in the exam room. Tablet PCs increase the portability of access to data, but have yet to be refined and popularized. Given today's technological environment, the most portable portal for the storage of electronic information is clearly the personal digital assistant, or "PDA".

PDAs: Background

PDAs have indeed revolutionized information management by combining the power of a user-friendly computer with the practicality of a handheld device. Although similar in function to desktop and laptop personal computers, PDAs nonetheless possess several distinguishing, mostly favorable, characteristics: For example, since PDAs utilize "flash memory" (as opposed to more conventional data storage on magnetic and optical media, such as hard disk drives and CDs), PDAs turn on instantly, and tend to crash less frequently. While in operation, they can be moved and handled with some facility, without fear of data corruption or mechanical breakdown. In addition, PDAs use a stylus on a touch-sensitive screen for text input and handwriting recognition, which tend to be much more practical and less cumbersome than the standard computer keyboard interface. (Tablet PCs provide similar functions with an even larger screen area, but the technology has yet to prove itself in the marketplace.)

PDAs operate with different software yet can easily exchange programs and data with their PC counterparts. Accomplished by a process referred to as "hot-syncing," such data transfer routinely involves establishing a PDA-PC connection via a "cradle" device through a USB or serial port. Many PDAs can also wirelessly "beam" data to compatible PDAs and printers using infrared transceiver ports. Newer PDA models even have the capability to use compact flash, secure digital or memory sticks for expandable direct data storage and exchange.

In terms of software functionality, PDAs not only offer built-in appointment, memo and address books, but can also provide numerous personal data management services. PDAs can run a vast range of programs, including document readers, databases and calculators. In fact, many PDA-compatible software programs and data files can be readily found on the Internet, and available at no charge ("freeware"), nominal charge ("shareware") or retail. These software resources continually allow PDAs to function as sophisticated, transportable and eminently interactive reference and organizational devices.

Two major PDA operating systems (OS) exist: Microsoft Pocket PC (Windows CE) and Palm. Although Windows CE is a scaled down version of the PC operating system, the PDA version cannot run any Windows 95/98/2000/NT software. Windows CE nonetheless allows efficient file transfer between many Windows programs, such as Microsoft Word and Excel, and is therefore popular within the business community. In contrast, Palm OS is relatively incompatible with Microsoft products, and has instead become the standard for medical professionals. Currently, thousands of Palm OS medical programs, databases, textbooks and web sites are available to students and professionals worldwide.

PDA Information Services

PDAs for medical tasking have already been implemented in the corporate world. For example, General Motors Corporation (GM) has distributed handheld wireless devices to 5,000 doctors who treat GM employees in conjunction with Medscape.[20] Using this new approach, GM hopes to reduce inaccurate insurance billing information and poor penmanship by physicians which together have caused more than 360,000 prescriptions to be re-examined annually.

Meanwhile, expansive PDA drug databases, complete with adult and pediatric dosing, indications and contraindications, mechanism of action, adverse drug reactions and other vital categories of information have been developed by "ePocrates" (www.epocrates.com; capable of delivering clinical drug information on Palm OS), "PEPID" (www.pepid.com; usable on both Palm OS, Windows CE and desktop platforms), and LexiDrugs (www.lexi.com; Palm OS and Windows CE). Several major American teaching hospitals, such as those affiliated with Stanford Medical School, Duke Medical School, Harvard Medical School and Northwestern routinely supply PDAs preloaded with drug and medical referencing software to their physicians in the hope of improving prescribing practices and reducing adverse drug events through the virtually instantaneous access of drug information at bedside. Empirically, such an initiative was supported by a survey of 870 drug-reference software users, of which 50% believed that using this software prevented at least one adverse drug event per user per week. Additional perceived benefits included improved physician drug knowledge, and a reduction in drug selection time.[21]

The market leader in drug databases with the most users is ePocrates. Their free drug information program is used by over 500,000 health-care professionals

worldwide, but comes at a different kind of price: Physician usage information is sold to drug companies for analysis. Their newest version (ePocrates Pro), has just been released with many more features, but this software is no longer without cost.

In contrast, drug reference software such as PEPID's Portable Drug Companion (PDC) and LexiDrugs rely on purchases from the end user, and do not participate in any such information sharing programs with drug companies — nor do they accept advertising.

Generally, all drug reference programs cover dosing, prescribing, indications, contraindications, pregnancy and lactation categories, kinetics, adverse drug reactions and basic interaction data very well. What differentiates one program from another, however, is their additional features and coverage, which may include:

1. Active Interactions Identification: Basic interactions information is presented in all drug programs. However, ePocrates Pro (at $49.95 but not the free ePocrates) has an interactions generator that will identify all interactions from a list of up to 30 drugs and/or herbal remedies; LexiDrugs has an additional program (Interact, at $75) that will do the same, but is not integrated into their basic drug information product (also at $75, but the two purchased together are $115). PEPID:PDC (at $49.95) has an integrated product like ePocrates Pro, and generates interactions for a list of up to 40 drugs. Given the many serious drug interactions that occur and the significant morbidity and mortality that often result, this kind of program is essential to reduce some of the preventable medication errors.

2. Dosing Assistance/Calculators: One major source of dosing errors, as described above, is simply miscalculating the dose. Such errors remain a major problem in pediatrics, where all dosing is either weight-based or body-surface-area-based. Having to convert pounds to kilograms and then multiply by a daily dose, only to then divide by the frequency administered, adds many steps, and can and does lead to significant dosing errors. (Especially at 4AM!) PEPID:PDC contains approximately 1600 automatic dosing calculators that eliminate all potential dosage calculating errors. The user simply enters a weight (or height or age if the weight is not known) and the exact dose and mls to administer at differing concentrations is presented. (Please see the Amoxicillin example presented in Figs 1-6.)

3. Overdose Management: Overdose management is generally beyond the scope of most drug reference programs. All-in-one PDA references include toxicology and overdose management which can help reduce the morbidity associated with drug dosing errors.

Other PDA-supported products include medical electronic textbooks ("e-texts"), usually based on already existing U.S. medical textbooks. The most popular titles include *The 5 Minute Clinical Consultant*, *Harrison's Principles of Internal Medicine Companion Handbook*, *The Merck Index*, *PEPID:MD* and *The Washington Manual of Medical Therapeutics*. Recently, the *Johns Hopkins Manual* was converted to PDA format. All of the titles mentioned above (except PEPID:MD which was created for the PDA format) have taken material originally designed for textbooks and converted them to work on PDAs. Such ad hoc conversion between media platforms generally leads to a format that is not well-suited to the PDA, and creates ongoing difficulties in information search and presentation.

The Next Generation: All-In-One PDA Reference Devices

Recently, a few software publishers for PDAs have begun to combine drug reference information with medical references, dosing calculators, and other equations used in medicine (ie A-a gradient, GFR, pediatric fluid & electrolyte requirements etc). These programs have the potential to significantly impact the point-of-care environment by providing:

- Rapid access to pediatric information (no need to close one reference source or open another, etc.)

Amoxicillin Example

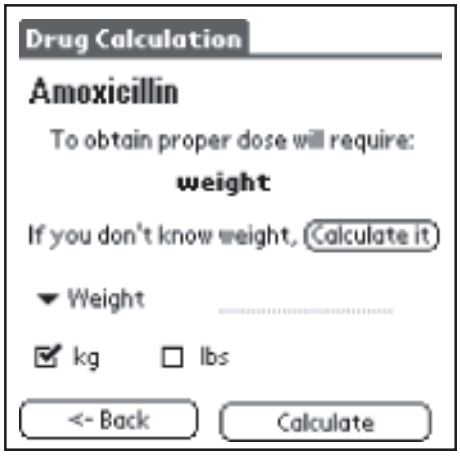

Fig 1 - Calculator starting screen.

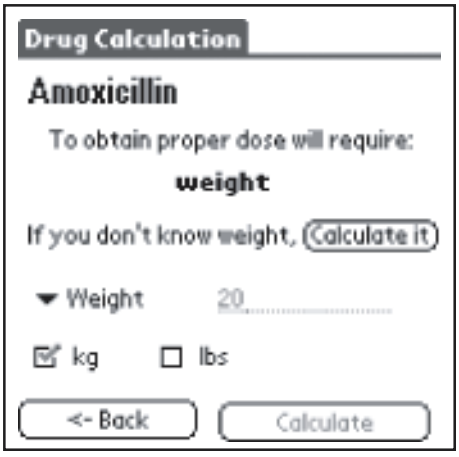

Fig 2 - A weight of 20 kg is entered.

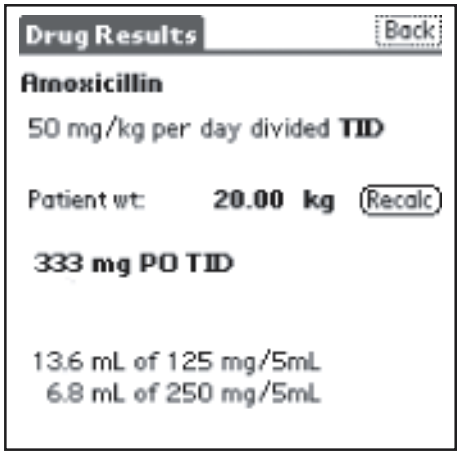

Fig 3 - Results are displayed.

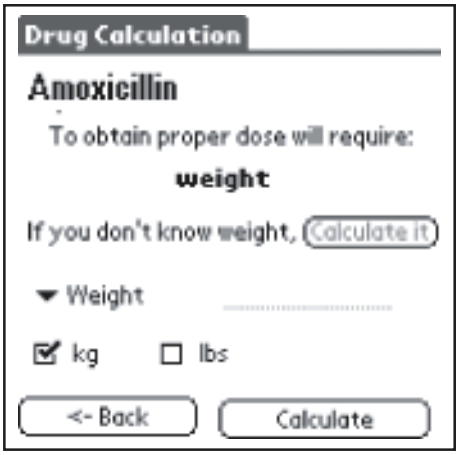

Fig 4 - Or, if you do not know the weight, the dosing calculator can estimate it for you.

Fig 5 - Choose length or age. Here, an age of 6 months and gender of female are entered; and since the child seems about "average" for her age, the 50th weight percentile is selected.

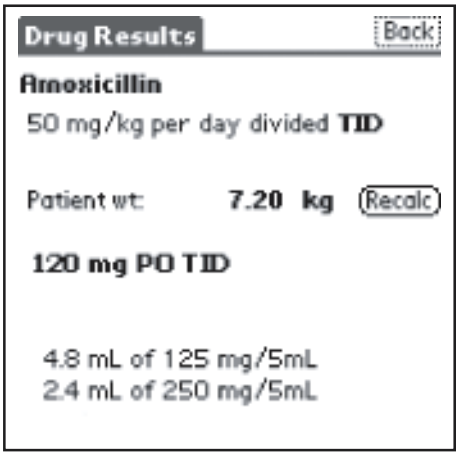

Fig 6 - Results are displayed.

- Access to all information through one shared index

- Seamless interconnections between all resources through hyperlinks (instantly connect to relevant drug and dosing information with the appropriate medical reference source link)

Among the many PDA medical and drug reference programs available, only PEPID has pioneered this concept. They have developed a suite of applications, each one geared to different health care professionals that may work with children on a regular basis. The different publications can be seen at www.pepid.com. Certainly, other all-in-one products will follow in the near future as the integration of information and decision-support tools will be more and more recognized as a means to provide faster, more efficient and more effective care – and reduce medical and drug-related errors.

Meanwhile, doctors are continually striving to be efficient patient care coordinators. In group practices or during hospital ward rounds, PDAs of each team member can be synchronized and patient information shared in an efficient, wireless "electronic handover". Several excellent patient management applications have already been programmed, such as Patient Keeper (www.patientkeeper.com) and NueMD (www.nuemd.com). Across the country, PDAs accompany interns and practicing physicians on their rounds, and have become an integral aspect of medical school and professional clinical healthcare experience.[22]

PDAs and Medicine: Logistics

Should a medical student or practitioner decide to take advantage of this ongoing "PDA revolution," several important factors must first be considered. After all, efficient point-of-care computing demands:

- Portability: A practical PDA should fit in a pants pocket or lab coat

- Practicality: Battery life must be least as long as a typical medical workday. Most PDAs have battery lives of 1 to 4 weeks (depending on usage, and whether the device is rechargeable or uses disposable alkaline batteries); note, however, that color displays generally deplete batteries about twice as fast as monochrome screens

- Screen clarity: Although current PDAs offer very high-resolution screens, clarity within particular software applications can vary. Color can generally improve screen clarity, but is currently used by few medical applications

- Adequate memory: A minimum of 16 MB is recommended for medical applications and e-texts, which tend to be relatively large (1 to 5 MB). However, 8 MB would be sufficient if the device is expandable through compact flash, secure digital or memory stick cards

- PC synchronization: Choose a PDA that can easily synchronize with your PC. USB (universal serial bus) synchronization is faster than the older serial type of synchronization.

Once the proper PDA and resident software have been chosen, any healthcare practitioner will have the necessary point-of-care information required to help minimize the risk of medical error. As PDA use becomes readily more common throughout the medical community, the time will soon arrive when their absence in a medical setting will prove as surprising as their presence is now.

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