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Pediatric Private Practice on the National Health Information Network: The PedOne® System

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ABSTRACT
The National Health Information Network (NHIN) is a federal mandate of the US Government. It involves setting the standards for interoperability and effective information technology in health care for hospitals, urgent care, private practices, insurance carriers, and other health care participants. Much attention has been paid to mixed NHIN funding outcomes of Regional Health Information Organizations (RHIOs) but here we take the different perspective of the private practice. This paper examines a Pediatric implementation, PedOne®, that is designed to deliver an intuitive and friendly environment to provide clinical data management and decision support. PedOne® interfaces to public health and internal medical knowledge bases. In an analogy to the Internet Engineering Task Force (IETF) role in building the Internet, we focus on the running code and the physician design involvement to provide lessons learned with respect to Pediatric Electronic Health Records system evolution. The design principles we uncover can be extrapolated to other medical specialties.

Keywords
National Health Information Network, Pediatric Private Practice, Standards, Interoperability, IETF

INTRODUCTION
Small private practices provide up to 80 percent of the U.S. health care but at present it is estimated that less than 20 percent of them are using electronic health records (EHR) (Singer, 2009). In the current Federal economic stimulus legislation, physicians starting in the year 2011 will be eligible for incentive payments ranging from $40,000 to $65,000 with a phase-in spanning several years. Penalties are planned for practices who fail to adopt an EHR system within five years of the start date (Singer, 2009). Naturally, EHR systems are expected to join in the federally mandated National Health Information Network (NHIN) (Anonymous, 2006; Mosquera, 2006) given that billions of dollars have been allocated to health information technology under the American Recovery and Reinvestment Act of 2009 (ARRA) (Halamka, 2009). However, significant obstacles have been identified in the design of EHR systems that will effectively meet physicians needs, operate intuitively, and thus enjoy widespread adoption (Davidson and Heslinga, 2007, Melvin, 2009; Stead and Lin, 2009).

This paper starts by modeling the pediatric private practice patient setting to point out and categorize expected EHR benefits. We then consider an exemplar EHR system, PedOne®, that is designed for pediatrician practices with nurse and physician usability foremost. We will explain its technical architecture, review its major clinical data management modules, and examine how it fits into the putative National Health Information Network (NHIN) (Jepsen, 2006). We also discuss the uncertainties surrounding the state of current health IT systems standards (Noyes, 2009) and the importance of interoperability.

By carefully modeling the patient trajectory in the private pediatric setting, we are able to identify specific benefits (both monetary and societal - improved health care outcomes) that our PedOne® system is expected to deliver.

First let us discuss the types of knowledge we should represent in an EHR system. We should represent the standard medical codes (such as ICD9/10 for diagnosis, CPT for procedure, RxNorm to describe medications, and so on) as well as a set of medical axioms common across specialties. We should also allow for specialty-specific knowledge, such as providing templates for pediatric otitis (earache), pediatric bronchiolitis, and so on where pediatric medicine differs from adult medicine. Furthermore, medical specialties have further subdivisions (areas to emphasize) by region. For example, the U.S. Southwest will see more poisonous snake bites than other regions. The templates that cover common conditions should integrate, as needed, to third party databases that offer useful information such as clinical trial outcomes of a particular medication or mortality rates of a specific condition. This context-sensitive evidence-based medicine informs the diagnoses and procedures outcomes of the patient visit.
Also, we should allow for the individual provider (doctor or nurse) to be able to input his or her own qualitative opinions to aid future sessions. For example, the individual may have opinions about certain courses of treatment or medication options and the system should be able to capture these. The knowledge model can be pictured as a series of general and specific authoritative sources coupled with a qualitative input, as shown in Figure 1. This general approach is similar to that described in (Ginsburg, Kass, Yeh, 2009) in a non-medical enterprise semantic integration setting; the theme is that individual contributions contribute to the group practice going forward.

MODELING THE PEDIATRIC PRIVATE PRACTICE

Now that we have a basic knowledge model in mind, we can now start to bring Electronic Health Records (EHR) to the Pediatrician (and subsequently begin the integration process to the NHIN) via a comprehensive modeling of the interplay between patient, guardian, nurse, doctor, and front-office receptionist. This is accomplished by site visits, observations, and interviews with doctors, nurses, and office managers.

The Patient Trajectory

The model in Figure 2 shows the patient trajectory from left to right as a time-line. The patient arrives at the appointment, checks in, and then visits the clinical section of the office for nurse assessment and doctor interview (either sick- or well-visit). The visit culminates with a full-circle exit stage left as the patient checks out leaves the office. The figure merits careful study as the trajectory features a series of distinct clinical settings involving a set of "actors" (nurse, doctor, patient, guardian, front-office receptionist). The settings have varying degrees of potential benefit of an EHR implementation, both to the patient (healthcare outcome) and to the practice (increased revenue and cash flow). The situations labeled with an arrow have the highest benefit potential and we now discuss in more detail the nature of these benefits.
Figure 2. The Patient Trajectory

Figure 2’s legend shows the color-coded circles representing the various actors. The "Front Office" section on the left is the client-facing receptionists who schedule appointments, answer the telephones, check-in patients, check insurance, and distribute parent handouts (age-appropriate information sheets on diet, exercise, psychological issues, and so on). The EHR system can be extended to include front-office support functions such as a Scheduler, a Telephone Notes system (to document conversations), and a Parent Handout module but in this paper we will limit ourselves to a clinical EHR discussion.

When the patient (accompanied in some cases by the guardian) enters into the "Clinical" region, as the name implies this is where the clinical functions take place as the patient (and guardian) interact with the nurse and doctor. The benefits can be divided into the following general categories:

- Improved doctor and nurse decision making (i.e. diagnosis and procedure selections) leads to improved healthcare outcomes for the patient and decreased exposure to the consequences of medical errors, e.g. damage to reputation and possible legal liabilities
- Decreased data input errors, during, for example, measuring and plotting resulting in improved patient chart quality and, indirectly, improved healthcare outcomes for the patient.
- Body image software affords the doctor and nurse the ability to more accurately depict conditions, e.g. rashes and moles, than traditional shorthand visit notes. The system can store the conditions (image overlays drawn on the standard body image) in a database to regenerate the image on demand.
- Greater patient throughput (number of patients seen per unit time) holding healthcare delivery quality constant, ceteris paribus, results in increased revenue for the practice.
- Decreased levels of diagnosis and procedure coding errors resulting in less payer delay and therefore increased cash flow to the practice.
The above categories meet the current administration's American Reinvestment and Recovery Act of 2009 challenge (Anonymous, 2009) of using technology to engineer improved healthcare at a lower cost (increased revenues, ceteris paribus, lower the investment cost).

As Figure 2 shows, the first step in the timeline that occurs in the Clinical region is the Assessment activity where vitals are measured by a nurse or physician assistant and simple qualitative facts about the patient are recorded. Notice that the Assessment box is shaded and highlighted with an arrow. As the legend indicates, this is one of the key clinical functions where a well-designed EHR system will reap tangible benefits.

We discuss the details of these benefits below as we consider the specific clinical activities.

We now depart from Figure 2 for the time being to discuss the (Nurse) Assessment clinical function in detail. We will return to Figure 2 to discuss the doctor sick- and well-visit functions.

**The Nurse Assessment**

Figure 3 shows the Nurse Assessment Activity Diagram modeled in UML2 (see Russell et al. (2006) for a discussion of the power of UML2 to model business processes). In this clinical function, basic qualitative patient information such as allergies, current medications, person(s) accompanying the patient (if any), is recorded as well as quantitative data such as blood pressure, height, weight, and head circumference (for infants).

In early PedOne® design meetings, office managers and physicians identified this stage as error-prone: since the numeric readings are plotted manually in metric system units on a standard graph paper that shows Center for Disease Control standard percentile curves, faulty data entry on the plot paper and thus faulty plots were commonly seen in practice. An EHR system can assist with automated unit conversion and automated plotting functions. Equally importantly, the EHR system can offer a historical entry of prior visits' measurements (as recorded in paper charts) and offer electronic edit of those historical entries.

Figure 3 includes some age-dependent branch activities, such as a hearing and vision test for 4 to 5 year olds.

Figure 4 shows an excerpt of the PedOne® Nurse Assessment Function. The major input sections are organized as tabs in the Adobe Flex front-end, basic patient information is shown on the upper right, and a plot of the patient's height (cm., Y-axis) is shown versus the patient's age (X-axis) is shown as the red line amongst the CDC percentile curves in black (ranging from the 5th percentile to the 95th percentile). Data inputs are converted to metric and stored in a database table.
Usability Note

A comment on medical data input: it is extremely undesirable to have data input interfere with the clinical setting. Not only should the caregiver’s efficiency not be harmed (Clayton, 2005; Poissant et al., 2005, Pizziferri et al., 2005) but we should also preserve the quality of communication between the nurse, guardian, and patient. Excess attention paid to the technology will detract from questions that might arise, thus having a potentially deleterious effect on the overall health outcome. Thus input areas should be large, well-labeled, and easy to find with a mouse. Small tablets and PDA devices result in time wasting hunting for the input areas. This is not to say they have no place in the clinical setting; rather, it is a tradeoff - the time spent finding small input areas versus time that one could spend otherwise making direct communication with the patient and guardian. In any case, it is quite counterproductive to force vertical scrolling on a user; thus we avoid vertical scrolling in PedOne. In Flex, it is easy to divide up the input functions into discrete full screens without scrolling using tabbed dividers. The result is a user-friendly computing experience that does not detract from the communication avenues. The tab the user is currently positioned on should be highlighted. A corollary useful technique, since the inputs are divided by tabs, is the notion of a completion bar that can be intuitively displayed as a thermometer icon. These interface considerations are good candidates to validate via for clinical trials.

In the particular example of Figure 4, the patient’s weight started low (below the 10th percentile) and improved over time, ending up above the 50th percentile. Electronic plot views are handy tools to visualize longitudinal data sets and can quickly reveal problems with the patient’s medical picture or indeed with the underlying data itself (if the red line was far above or below the CDC curves). This corresponds with the recent National Academy of Sciences report (Stead and Lin, 2009) that stresses the need to easily visualize trends over time in healthcare IT.

The Sick Visit

Referring back to Figure 2, the next step after a Nurse Assessment is often an interview with the physician: a sick- or a well-visit. We consider the case of the sick-visit first. An example screenshot is shown in Figure 5 of a Sick Visit with the patient exhibiting signs of Acute Otitis Media.
As Figure 5 shows, at the top we have basic patient information and tabs dividing up the major user input sections (analogous to the Nurse Assessment). On the left, we see that the patient is showing otitis symptoms and this is reflected in the comments. On the right, we see various anatomical diagrams are displayed with the most specific one (the ear canals) left-most. As a design note, it is important to provide customization here – an administrative user should be able to choose new anatomical diagrams or edit suggested ones. The possible diagnoses in this context are presented as a set of standardized ICD9 codes that can be checked. Similarly, a set of contextual procedures (CPT codes) are also presented and can be checked. The lower right pane shows an integration effort between PedOne® and the American College of Physicians PIER database. PIER is an electronic knowledge base (in XML format) of internal medicine that includes some pediatrics-specific modules. In Figure 4, we are showing PIER “rationale” and “evidence” sections – there are many more, including clinical trial information, literature citations, and so on. PIER has been integrated in other clinical environments using the “InfoButton” HL7-compliant standard (Del Fiol et al., 2007) but here we simply show some sample pediatric PIER content without the use of “InfoButton” context triggers. We expect a tight integration with the ICD9 diagnosis database table and the CPT database table, as well as context-sensitive PIER XML display, to improve healthcare outcomes and provide a more accurate code passing to the billing department for improved revenue generation. The tradeoff in “evidence based medicine” data displays is that an interface that is too busy defeats the fundamental expected benefit of improved patient throughput.

The sick visit module is starred in Figure 2 to indicate it is an important integration point to public health. As the NHIN takes shape, epidemiological tracking will improve and the individual practice “spokes” will roll up to the public health “hubs” for better epidemic (and other public health menace) control.

The Well Visit

The majority of patient visits fall into the other category, a Well Visit. An example of the Well Visit screen is shown in Figure 6.
Figure 6. Excerpt from the Doctor Well Visit form using a female six year old patient as an example.

The Well Visit is simply a database-driven set of questions and answers appropriate to the patient’s age group and gender. The tabbed interface should be familiar by now as well as the patient’s basic information at the top of the screen. Clumsy vertical scrolling is never an option. Inputs are validated by business logic rules. It is important to recognize that many questions and possible answers are a matter of taste and will vary from practice to practice and from region to region. Thus it is essential to provide an administrative interface where a privileged user can modify the questions and possible answers. Well visits also generate diagnoses and procedures (ICD9 and CPT codes) for use by the billing department – as with the Sick Visit, this is the link between clinical activities and revenue generation. Thus it is very important to make sure the correct codes are passed. As a side-note, the penalties for miscoding are severe. Insurance carriers may place miscoded claims into a “Fraud” bucket and delay payment by up to six to nine months, thus severely impacting cash flow (Office Manager Interview, priv. comm.).

Other Clinical Functions

Another important clinical function to support in an EHR system are the administrations of additional procedures and equipment (CPT codes), such as immunization, a splint, a bandage, and so on. These usually take place after the Nurse Assessment and may take the place of the Well Visit. Immunizations are particularly interesting from a health care quality perspective. A well-designed EHR system will allow immunization lot details to be recorded and this may come in very handy when, for example, a certain lot is determined to be faulty. In addition, the system should communicate without undue user effort the weekly or monthly immunization activities to the state immunization board for regulatory purposes. Thus this module is starred in Figure 2 – to indicate that it, too (as well as the Sick Visit) is an important integration point to public health. In the future, as the NHIN takes shape, the various state immunization boards will interoperate and serve as “hubs” – thus the “spokes”, the private practices, will be able to track children as they enter one practice and exit another even if it is across state lines. As with other clinical modules, the system should be able to match CPTs well to the context and offer the best-suited ones in a selection list, thus minimizing miscoding.

PEDONE® TECHNICAL ARCHITECTURE

The PedOne® system takes advantage of recent advances in rich client web development frameworks. Specifically, we use ADOBE Flex on the front-end (Flex offers a wide range of front-end user interface tools and techniques, such as AJAX (Garrett, 2005) to communicate asynchronously with the back-end database - thus obviating the need for a clumsy "Submit" button). Flex is a rich client that offers extensive animation techniques - we have only, as of this writing, made use of a small percentage of Flex’s potential power. As a side note, developers familiar with the open source Eclipse visual code-building environment enjoy using the Flex Eclipse plug-in. Those not familiar with Eclipse can use Adobe’s visual Flex Builder application. On the back-end, we use the MySQL relational database (http://www.mysql.com) - a product that is well supported and can scale quite easily to thousands of practices. To connect the front-end and the back-end, we use a middleware that is included in Google Apps cloud computing architecture (Foley, 2008) - namely, the open source Django web application framework. Django (http://www.djangoproject.com) is a Python middleware that offers the convenient
feature of Object Relational Mapping (ORM). In this way, object oriented programmers can code database access routines without being mired in native or vendor-extended SQL. To put it another way, the solution becomes agnostic to the database vendor.

In the medical field, it is often necessary to produce precise printed forms for, e.g., billing claims, vaccination reports, and patient invoices. We make use of a Flex PDF generator in these situations and the PDF generator code is a small piece of PHP running on the server.

As a philosophical note, as the NHIN interoperability messaging protocol standards and business logic components take shape, technical choices made by a given practice should not constrain them from participating. The “Google Apps” stack we describe is not constraining and should prove to be flexible going forward.

**CONCLUDING REMARKS**

**Total Cost of Ownership Comments**

We must consider the Total Cost of Ownership (TCO) as discussed in the Congressional Budget Office report (Hagen and Richmond, 2008).

Naturally, implementing a health IT system involves significant expenditures. The CBO report mentions estimates between $25,000 and $45,000 per physician for EHR adoption. The hope, of course, is that overall health outcomes increase (Castro, 2007) without an onerous burden on the adopting practices. One way to keep costs down is by placing the majority of technical assistance online and keeping the interface intuitive. Another way is to utilize economies of scale and in a subscription model, offer low price points per month to a widely distributed audience (read this as significantly lower than the low end of the CBO estimate range given above). To mitigate the risk that we will have “productive time lost in learning to use the system and in adjusting patterns of work” (Hagen and Richmond, 2008) it is important to model the work practices thoroughly as we have done in this paper and identify key processes that we will target as improvement areas in a successful implementation. Other factors, such as appropriate security standards and HIPAA compliance, are in fact relatively straightforward to implement with off-the-shelf communication encryption standards and data archival standards.

**NHIN Communication**

Another important factor is information interchange with other NHIN partners. For example, a pediatric system should be able to send and receive data to state immunization boards. A more futuristic goal would be the secure communication of pediatric records to urgent care if the patient is en route due to some emergency. Or, conversely, the communication of newborn data from the hospital or birthing center to the private practice before the pediatrician has even seen the newborn. The Office of the National Coordinator of Health Information Technology (ONCHIT) in conjunction with the Healthcare Information Technology Standards Panel (HITSP; http://www.hitsp.org) will set standards in this area; usually comprised of business logic layered on top of simple XML messaging.

**National Academy of Sciences Healthcare I.T. Principles**

In a recent National Academy of Sciences report on Healthcare Information Technology that attempts to engage the computer science community in the program of healthcare informatics, a set of key principles are enunciated (Stead and Lin, 2009). Many of these are of interest to repeat because they dovetail nicely with the PedOne design experiences touched upon in this paper as will become evident by the brief comments we suffix.

- **Focus on Improvements in Care—Technology Is Secondary.** Comment: yes, the technology solution should be in the background – an always-on “dial tone” that does not detract from the clinical setting.
- **Record Available Data So They Can Be Used For Care, Process Improvement, and Research.** Comment: yes, the data can be viewed longitudinally for a single patient, aggregated for epidemiological purposes, and shared with appropriate security mechanisms with public health bodies such as state immunization boards.
- **Design for Human and Organization Factors.** Comment: yes, the system design should present no counter-intuitive surprises.
- **Support the Cognitive Functions of All Caregivers, Including Health Professionals, Patients, and Their Families.** Comment: once again, the system should not be surprising and model existing thought patterns carefully before implementation.
• Archive Data for Subsequent Re-Interpretation. Comment: yes, the raw data should be carefully preserved in database tables. For example, a mis-diagnosis may still contain relevant supplemental diagrams and the system should be able to re-create those diagrams.

• Seek and Develop Technologies that Clarify the Context of Data. Comment: one such approach is the timely integration of data in context as we saw in the PIER integration of the Otitis sick-visit example in Figure 5. If data is withheld until it is likely needed, this will ameliorate the problem of lack of context.

Moving the Solution to other Specialties: General Comments

Figure 1 provides a first-step knowledge model blueprint to transform this solution to another specialty, for example oncology or podiatry. Another important consideration in a "specialty port" is considering specific data needs. In some ways, pediatric private practice is simpler than other specialties because its set of inputs and outputs is limited. For example, cardiology will deal with EKG's and need to store and access those complex data objects. Oncology will need X-Rays, MRI's, and other diagnostic imagery. Pediatric private practice refers emergencies to urgent care hence it has very little need for images such as X-Ray. It will not have equipment to make an X-Ray and can get by with a fax machine or a scanner in the rare event it needs to interpret an X-Ray. To sum up, some specialties are easier than others. EHR for Pediatrics is one of the less complicated in terms of the range of inputs and outputs. Still, certain stock images (such as a generic human body and zoomed in images of body parts) are useful across all specialties to depict external conditions (rashes, scrapes, cuts, fractures, moles, and so on).

Next Steps

As the PedOne® system continues to be beta-tested at small pediatric practices, the next step is to quantify insofar as this is possible specific benefits accruing to system adopters in the clinical functions we identified in Figure 1. The “before” scenario might be paper-based or it might be as a result from a switch from another electronic vendor. We also expect tangible benefits to accrue from certain front-office helper applications, such as Scheduler, and we plan to measure efficiency gains in such tasks as appointment creation, change, and cancellation.

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