



Pediatric Aspects of Inpatient Health Information Technology Systems

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abstract

In the past 3 years, the Health Information Technology for Economic and Clinical Health Act accelerated the adoption of electronic health records (EHRs) with providers and hospitals, who can claim incentive monies related to meaningful use. Despite the increase in adoption of commercial EHRs in pediatric settings, there has been little support for EHR tools and functionalities that promote pediatric quality improvement and patient safety, and children remain at higher risk than adults for medical errors in inpatient environments. Health information technology (HIT) tailored to the needs of pediatric health care providers can improve care by reducing the likelihood of errors through information assurance and minimizing the harm that results from errors. This technical report outlines pediatric-specific concepts, child health needs and their data elements, and required functionalities in inpatient clinical information systems that may be missing in adult-oriented HIT systems with negative consequences for pediatric inpatient care. It is imperative that inpatient (and outpatient) HIT systems be adapted to improve their ability to properly support safe health care delivery for children.

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INTRODUCTION

Children remain at higher risks than adults for medical errors in inpatient environments.^{1,2} The American Academy of Pediatrics (AAP) recognizes the important role of electronic clinical information systems in ensuring and improving the safety³ and quality⁴ of pediatric patient-centered care.⁵ In 2008, the AAP published “Pediatric Aspects of Inpatient Health Information Technology Systems,” which described the goals and mechanisms of clinical information systems in inpatient pediatric work.⁶ In 2010, most pediatric hospitals still lacked basic electronic health record (EHR) functionalities.⁷ Since then, the United States has seen a surge⁸ in adoption of health information technology (HIT), largely because of incentives offered by the American Recovery and Reinvestment Act in 2009 (Pub L No. 111-5)⁹ and, specifically, the Health Information Technology for Economic and Clinical Health (HITECH) Act. HITECH offers \$18 billion in payments to practices and practitioners who meet criteria for “meaningful use”¹⁰ of certified EHR technology¹¹ with the goal of

improving care and facilitating aggregated reporting of quality measures from electronic clinical data. Although pediatric hospitals have made great strides in adopting information technology since the AAP published its first report on inpatient systems, a lag for smaller teaching and nonteaching hospitals¹² as well as regional differences in adoption^{13,14} have been revealed. Even with progress in digitizing US hospitals and physicians' offices,¹⁵ subsequent research into usability, implementation, patient safety, and cost and value of EHRs^{16,17} has demonstrated that much work remains to improve the quality, functionality, usability, and effectiveness of inpatient pediatric HIT systems.^{18,19}

In 2012, children younger than 18 years accounted for 24.1% of the population of the United States.²⁰ Children and infants are a vulnerable population because of age-specific physiologic and developmental variances that may not be adequately addressed by adult-specific data tools.^{16,21} Despite this, no inpatient EHRs developed specifically for the care of children are available commercially. HIT tailored to the needs of children and pediatric health care providers can help to reduce risk by decreasing the likelihood of errors through information assurance (reducing variability in the entry, communication, processing, and recall of patient data)^{22,23} and minimizing the harm that results from errors (pediatric-specific error detection, redundancy, and contextual decision rules).²⁴⁻²⁷

Pediatricians' input on clinical data needs and HIT functionality in ambulatory settings has been outlined.^{28,29} Many of these needs and functions (weight-based drug dosing, anthropometric analysis, immunization tracking, specialized growth charts, and forecasting) are common to pediatric inpatient settings, but there are additional

pediatric needs and functions in inpatient clinical information systems and the interfaces that connect inpatient and ambulatory systems. Adult-oriented HIT systems may lack these pediatric data needs and functionalities, which may have a negative effect on adoption of HIT and user satisfaction in pediatric inpatient care. Furthermore, evaluations of pediatric workflows from a human factors viewpoint identified areas of great complexity (patient identification, medication ordering and administration, alerts, growth charts, vaccinations, laboratory reporting, newborn care, privacy, and radiology reporting) with high stakes for adverse events that may benefit from information technology intervention.³⁰

A base requirement of pediatric HIT functionality is the availability of accurate and appropriate pediatric-specific data. These data and data format requirements for outpatient EHRs have been identified (via HITECH) with articulation of a Model Pediatric EHR format³¹ (based on the HL7 Child Health Functional Profile³²). The Model Pediatric EHR format focuses primarily on pediatric ambulatory HIT. The goal for this technical report is to expand on this model to explore and define inpatient-specific pediatric concepts, data, and functions (Table 1). This technical report uses "must," "should," and "required functionality," similar to the Model Pediatric EHR format, not as a mandate but to indicate that these functionalities are critical for the recognition of a system as with full pediatric functionality.

This technical report focuses solely on the distinct needs and functionalities of pediatric inpatient HIT applications and infrastructures to ensure effective and safe pediatric health care delivery beyond those functionalities already supplied in adult-oriented systems. However, this does not imply that standard HIT functionalities omitted from this

report are considered unnecessary for pediatric inpatient systems. Furthermore, adult care may benefit from the pediatric-specific functionalities because there are surprising similarities between pediatric and geriatric care (such as extremes of age, physiology that may differ from younger adult populations, different signs and symptoms of disease, and the need for advocates and guardians).³³ Many issues addressed in this report—for example, adolescent privacy or interoperability with immunization registries—are not inpatient specific but also apply to outpatient systems.

Systems that are included in this analysis include EHRs, anesthesiology documentation systems, provider order entry systems, and stand-alone systems, such as human milk management systems or antimicrobial stewardship management tools.^{34,35} This technical report was narrowed to systems that are used directly by child health care providers in the retrieval of information and the documentation or treatment of children. Although pediatric data are stored and manipulated in other hospital systems as well, such as laboratory management and radiology information systems, this report focuses on systems that are closer to the interface among patients, providers, and information technology systems and the requirement of these systems to support pediatric care.

This technical report can be used as a resource for hospitals and institutions when selecting a new inpatient information system or improving or enhancing existing systems and for developers, designers, or vendors of such systems for guidance on basic pediatric functionality.

Children and their families are central stakeholders in any form of pediatric care as the direct beneficiaries of care (and also as victims of iatrogenic harm resulting from errors). Their

TABLE 1 Pediatric-Specific Functions and Data Needs for Inpatient Electronic Systems Stakeholders

Category	Functionality	Description	Example(s)
Data	Use age-specific time units	Accept, store, and present time data in commonly used and meaningful units.	Ages in months, weeks, days, hours, and minutes for infants.
	Use pediatric-specific units for weight and height	Accept, store, and present anthropomorphic data in different units that can be used interchangeably with those used in older children and adults. Avoid nonmetric measures.	Weights in grams (vs kilograms) and lengths in centimeters (vs meters) for infants).
	Allow pediatric-specific data options	Accept, store, and present child/infant-specific data options.	Apgar scores at multiple time intervals (1, 5, 10, 20 min). Gender as indeterminate if needed (as opposed to unknown); postconceptional age in weeks and days; pediatric-specific end-of-life directives.
Demographics	Specify mother–infant data linkages	Make pertinent maternal data available to users of a child's record.	Maternal blood type and screen, medication list, TORCH screen, GBS screen, syphilis screen, gonorrhea screen, HIV screen linked to the infant record. Other desired data include gestational diabetes, maternal drug use, delivery method, rationale, and complications, etc.
	Standardize family structure documentation	Provide standard electronic format (data entry and presentation) of biological and social linkages of a child to others.	Universal format for pedigree documentation. Extensible notation for varying family structures like adoption or same-sex couples, including guardianship (such as foster care).
Information Access	Ensure adolescent privacy	Allow configuration of information access to adolescent clinical data according to legal status.	Isolation of clinical content and billing data for adolescent care according to local jurisdictional laws. Confidentiality for emancipated minors.
	Maintain continuity and rights to data in foster/custodial care	Allow configuration of access and consent to records for children in foster/custodial care according to law.	Child protective services: bidirectional access to data in emergency placement of children.
	Facilitate safe and accurate care transitions	Facilitate transfer of relevant pediatric-specific data in handoffs.	Age-specific data available during change of shift or perioperatively. Reports usable for children between care teams (inpatient to ambulatory, pediatric to adult care providers).
	Interoperability	Allow seamless electronic data transfer between hospitals and associated pediatric practices including maternal/perinatal medical records.	Electronic summary of hospital course is available to the primary care provider for integration into her EHR.
Documentation	Manage newborn screening data	Facilitate accurate procurement, recording, tracking, and timely communication of infant screening.	Metabolic and hearing screening completion and tracking.
	Manage immunization data	Calculate infant and child vaccination needs based on patient-specific data (age, known immunization lapses). Provide interactive reminders and alerts for providers to reduce “missed opportunities” to vaccinate. Provide support for vaccine procurement and dose management (inpatient pharmacy). Support documentation and reporting of immunization (inpatient, ambulatory, health information exchange).	Identification of immunization lapses in admitted patients. Immunization documentation to the medical home and the local immunization registry. Support for 2-dimensional vaccine barcodes.
	Share health maintenance schedules	Share data on health maintenance issues (screening, immunizations, growth, etc; inpatient, medical home, health information exchange).	Updating and communicating of health maintenance issue list and problem list.
	Document and share growth data appropriately	Share point-of-care measures of height, weight, BMI, and percentiles.	Recording and communicating of height, weight, and trends etc for premature infants or internationally adopted children on special growth charts.

TABLE 1 Continued

Category	Functionality	Description	Example(s)
Therapy/intervention	Provide pediatric-specific normal values and reference materials	Incorporate and display as appropriate normal pediatric values with links to references.	Age-appropriate norm values provided for weights, blood pressures, laboratory values. Pediatric specific complications.
	Document and share developmental data	Promote documentation of developmental milestones.	Inclusion of developmental screening notation (such as the ASQ).
	Support age-appropriate nutrition	Provide decision support for selecting age-appropriate nutrition.	Default choices for age-appropriate nutrition orders (in conjunction with growth data) such as human milk.
	Provide patient and family-appropriate educational materials	Provide relevant age-specific health education materials tailored to children and their parents, based on their level of health literacy.	Surgery education in Spanish for a Hispanic family with a child who has a congenital heart defect.
	Facilitate weight- and body surface area-based dosing	Facilitate dose calculation of medications, nutrition based on patient data.	Just-in-time drug dosing information for resuscitation.
	Facilitate recording and tracking of exposure	Facilitate cumulative recording of exposure to medications or radiation.	Lifetime dose information for a child receiving chemotherapy or radiation.
	Acquire, use, and maintain pediatric-specific drug dictionaries and formularies	Ensure accurate pediatric drug information through the use of drug dictionaries and formularies that provide weight-based dosing, pediatric-specific decision rules.	Drug dictionaries with pediatric-specific dose ranges and alerts that include single-dose, daily-dose, and cumulative-dose decision support (for cancer chemotherapy).
	Develop and implement pediatric-appropriate orders and order sets	Provide pediatric-specific order menus and order sets including nutrition, laboratory, radiology, and other ancillary service orders. Provide evidence-based disease-specific orders and order sets conforming to national best practice standards and AAP guidelines.	Decision support for inpatient admission promoting an evidence-based asthma-specific order set for a child with status asthmaticus.
	Support prenatal and preadmission orders	Permit anticipatory specification of admission orders and order sets for pediatric inpatients not “in-house.”	Ordering of medications for the expected delivery of a preterm infant (likely to go to the NICU). Registration and ordering for a critically ill child being transported to a PICU from outside the hospital.
	Manage patient-specific tissues and body fluids	Allow storage, tracking, and appropriate management of patient-specific biological samples.	Record, store, track and administer human milk to an infant appropriately. Record, store, track, and use cord blood of an infant for a relative.
Support pediatric-specific sample collection	Provide data and laboratory infrastructure support for collection, processing and storage of variable amounts of samples (lower blood volumes needed for testing) for children.	Pediatric-specific laboratory orders linked to microcontainers for CBC count, chemistries, and blood cultures.	

CBC, complete blood cell; DDST, Denver Developmental Screening Test; GBS, group B *Streptococcus*; TORCH, toxoplasmosis, rubella, cytomegalovirus, herpes simplex, and HIV.

vested interest in the best available tools to manage pediatric care is self-evident.

Pediatricians, pediatric nurses, pharmacists, and other pediatric providers are additional interested stakeholders. Their need for the appropriate tools is driven by the desire to provide the best and safest care possible, in the most efficient manner possible, with the least harm and best outcomes to children and to reduce liability, improve efficiency, and reduce errors and waste.

HIT vendors form a third stakeholder in software and system development as the builders of HIT systems used by providers and hospitals. Their goals are to gain market share, meet production milestones, and ensure and maintain information confidentiality, integrity, and availability. Frequently, they may find conflicts in design and implementation goals that may impede timely development and prioritization of pediatric-specific HIT functions.

Policy makers at the institutional and governmental levels are another important stakeholder group. As the prevalence of HIT in clinical work grows, issues of governance take on increasing importance, especially as increasing amounts of resources are devoted to the adoption and maintenance of institutional HIT infrastructures. At the national level, policy makers have created incentives for HIT adoption to create such infrastructures to measure the effects of health care innovations (including the adoption of HIT).

It is essential for the interests and needs of children and pediatric care to be represented at the policy-making table. As such, members from all stakeholder groups must have input on the directions that national HIT efforts take. This includes input on the development of infrastructures, standards, and tools to share health information in a secure yet transparent fashion to optimize care.

VULNERABILITIES

Inpatient care environments, increasingly managed through HIT, must be able to meet the needs of children's health. Mismatch of care technologies and patient needs can potentiate harm (or block the benefits of HIT through misuse or nonadoption), resulting in hazards to children. Children and infants are particularly vulnerable populations because of the following:

- the wide range of permissible body weights (less than 1 kg to more than 100 kg) for which medications may be prescribed;
- the need for universal specification of care based on body weight and variances on those specifications (with smaller tolerances for errors, especially at lower weights) based on age/physiology;
- care contexts that are not adequately addressed by adult-specific technology (size of tools), lack of data granularity (grams instead of kilograms), and special measures (such as gestational age or Apgar scores);
- the high frequency of off-label use of medications;
- pediatric specific drug–drug interactions
- the high degree and variation of dependence on guardians or other caregivers for decision making; and
- the fragmentation of the pediatric population into distinct subgroups, each with its own clinical and information needs.³⁶

The vulnerabilities of children in health care settings are not isolated to anatomic and physiologic realms. Psychosocial issues, such as adolescent hidden agendas or difficulties in communication, may impair the discovery of important clinical concerns (such as pain in a nonverbal child). Lack of advanced reasoning may result in the health care system itself being perceived by children as a threat, resulting in further ineffective communication. Avoidance of such problems requires both child advocacy in technical design, implementation, and evaluation and an organizational approach to pediatric patient safety with high reliability.

The design of HIT tailored to the need of pediatric health care providers can and must help reduce errors by adequately meeting these pediatric data needs and by reducing variability in data entry, communication, and display. In addition, HIT can and should provide an active learning infrastructure (of child health care providers) in which such errors (and the harms that may result from them) can be prevented, identified, and corrected.

BARRIERS

Since the previous report, "Pediatric Aspects of Inpatient Health Information Technology Systems,"⁶ some progress has been made in the development of pediatric-specific technology standards. However, lack of standards has remained a significant technical barrier to adoption of pediatric HIT and the exchange of health information.

The development and dissemination of the Model Pediatric EHR format, which was funded by the Agency for Healthcare Research and Quality and supported by the AAP, has advanced standard development on outpatient pediatric EHRs. The Model Pediatric EHR format identified functional requirements for an EHR

to meet the particular needs of children. It identified gaps between existing systems and an optimal EHR for children and created recommendations for functional requirements. Based on the Health Resources and Services Administration's Health IT for Children Toolbox,³⁷ the Health Level Seven International (HL7) EHR-S Functional Model,³⁸ and the HL7 Child Health Work Group's Child Health Functional Profile,³⁹ the resulting format is a set of instructions for EHR vendors that defines functionality and data standard requirements that are essential to pediatrics. It includes more than 700 requirements organized by 21 topic areas. Pediatricians can use the Model Pediatric EHR format to advocate for improved pediatric-specific functionality within their outpatient EHR systems. Similar efforts are missing for inpatient systems.

Most children are cared for during episodes of acute illness in hospitals that also care for adult patients. Pediatric leaders should be aware of clinical stakeholders and their interests regarding HIT adoption. In purely pediatric hospitals, such as tertiary or quaternary university referral centers, obstacles and barriers to the alignment of leadership, staff, resources, and governance may be different from those in nonpediatric hospitals in which smaller groups of child-health focused personnel (ie, child advocates) may have to compete with larger groups of adult-oriented care providers, in both general and specialty care areas.

Pediatric use of EHRs suffers from similar problems as use in adult care, such as increased time to document,³⁹ modification of workflow^{40,41} and communication processes, and a host of new unintended errors.⁴² The specific challenges to use of EHRs in pediatrics and the resulting requirements are listed here.

DATA REQUIREMENTS

Although pediatric medicine has many similarities with adult medicine, substantial differences exist because physiologic, development, anatomic, and psychiatric changes occur at a rapid pace in early life and then slow substantially by the time humans reach adulthood. A function of this velocity of change is the constant variation of norm values based on age in any measurable human variable.

The work of a pediatrician is geared toward assessing and evaluating patients and diagnosing and treating illnesses and conditions with a focus on the age-specific norms and diagnoses as well as the velocity of change over time of these parameters. Any HIT must support the age- and development-centric aspect of data interpretation and care—an essential aspect of pediatric health care that is much less important in adult medicine.²¹

Inpatient systems must further support the recording of data in a meaningful fashion to allow immediate interpretation. A good example is the appropriate unit of measure for age: a 0.019-year-old child and a 4440-day-old child do not use units of age that allow immediate interpretation, but a 7-day-old or 12-year-old child include units that allow a provider to immediately switch to age-specific context.

Pediatric data standards must enforce universal consistency of content, format (including data types and standard units of measure), and contexts of use. For example, there is a need for universal neonatal data entry and presentation that uses grams for weight, whereas adult data entry may allow only kilograms or pounds. Birth date and time is necessary knowledge for appropriate infant care because infant weights change daily and birth weights carry special significance, especially in context of gestational/postconceptual

age (small-, appropriate-, or large-for-gestational-age infants). Hour of life information is also used when interpreting neonatal data, such as bilirubin.

For therapeutics, units of measure must be adjusted to reflect pediatric-specific doses, which are usually lower than adult doses. For providers, a dose of 40 mcg is easier to process than 0.04 mg. To avoid dosing errors, unit of measure should be adjusted to allow the dose to be represented with the least complexity.⁴³

Several specific data elements only occur within neonatal care. Examples include gestational age (in weeks and days), birth weight (in grams), Apgar scores (score plus time of administration; at 1, 5, and 10 minutes after birth),⁴⁴ scores for neonatal abstinence, withdrawal⁴⁵ and/or sedation (multiple formats), and infant critical care risk.⁴⁶ In addition, specimens (such as human milk and cord blood) may need to be tracked for future use for specific infants and require auditing data fields (infant identification, mother identification, donor [if not from mother], date of donation, date of use, amount [in milliliters], etc). For fetuses undergoing interventions in utero, prenatal events must be stored and linked to postnatal records.

An informal survey of the AAP Council on Clinical Information Technology mailing list produced the list of pediatric-specific measures in Table 2. Of note, not all measures contain data derived from pediatric patients. One example, based on the recent recommendation by the AAP to screen mothers of newborn infants for postpartum depression, is that pediatric inpatient systems should facilitate scoring for the Edinburgh Postnatal Depression Scale documentation.⁴⁷

Inpatient pediatric systems must allow pediatric-specific data elements to be recorded using the appropriate data type and must allow selection of

patient population based on a search of specific values of these data elements (eg, creation of a list of all newborn infants with Apgar scores less than 5).

The nature of pediatric care further requires variables that do not exist or are not used in adult care.⁴⁸ For example, the ability to record the gender of a newborn child as ambiguous is critical to initiate the appropriate documentation and diagnostic and therapeutic processes.

PEDIATRIC-SPECIFIC FUNCTIONALITY

Demographics

Of particular interest in newborn infants and small infants is the concept of the mother–infant dyad.⁴⁸ This function pertains to the ability to automatically extract and digest maternal data that are pertinent to the health and well-being of the newborn with respect to treatment or prophylaxis. For example, it is important to know that an infant was born to an HIV-positive mother. Knowledge about the maternal infection will allow the pediatrician to treat the infant adequately with antiviral medications to prevent vertical transmission. Data from the mother–infant link ideally should be pulled directly into the infant's clinical documentation and/or problem list. Gestational age at delivery obtained from the delivery record should be used to automatically calculate the infant's postconceptual age to allow for gestational age-appropriate treatment, such as medication dosing. Data not immediately available but of interest to the pediatrician, such as placental abnormalities, should be automatically incorporated into the neonatal record as well.

It is not unusual for infants to undergo name changes during their initial admission—for example, from the mother's last name to the father's last name. These patients must be disambiguated in the EHR and in

TABLE 2 Examples of Pediatric-Specific Scores

Pediatric Specific Measure ^a	Description
Pediatric Early Warning (PEW) system score ⁸⁵	Predicts inpatient children with urgent medical needs
PedsQL (Pediatric Quality of Life Inventory) ⁸⁶	Measures health-related quality of life
CARAT (Child Asthma Risk Assessment Tool) ⁸⁷	Assesses child asthma risk
Westley Croup Score ⁸⁸	Measures severity of croup
Wong-Baker FACES Pain Rating Scale ⁸⁹	Measures pediatric pain
Appgar score ⁴⁴	Records newborn health in the first minutes of life
CRIB and CRIB II (Clinical Risk Index for Babies) ⁴⁶	Measures severity of illness in newborn infants
Finnegan Score ⁴⁵	Measures neonatal abstinence
SCARED (Screen for Child Anxiety Related Disorders) ⁹⁰	Screens for child anxiety-related disorders
FLACC (Face, Legs, Activity, Cry, Consolability scale) ⁹¹	Measures pain in nonverbal patients or patients with cognitive impairment
Edinburgh Postnatal Depression Scale ⁴⁷	Measures depression in postpartum mothers
N-PASS (Neonatal Pain, Agitation, Sedation Scale) ⁹²	Measures neonatal pain, agitation, and sedation
Hazelbaker Assessment ⁹³	Evaluates lingual frenulum function
PRISM Score (Pediatric Risk of Mortality) ⁹⁴	Assesses risk of mortality in PICU patients
Pediatric appendicitis score ⁹⁵	Assesses an acute abdomen and diagnoses appendicitis in children
SNAP (Score for Neonatal Acute Physiology) ⁹⁶	Scores neonatal acute physiology and predicts mortality
SNAP-II and SNAPPE-II (Score for Neonatal Acute Physiology II and Score for Neonatal Acute Physiology Perinatal Extension II) ⁹⁷	Scores neonatal acute physiology and predicts mortality
P-MODS (Pediatric Multiple Organ Dysfunction Score) ⁹⁸	Grades multiple organ system dysfunction in critically ill children
PELOD Score (Pediatric Logistic Organ Dysfunction) ⁹⁹	Scores the severity of multiple organ dysfunction syndrome in pediatric intensive care units
PIM (Pediatric Index of Mortality) and PIM-2 ¹⁰⁰	Predicts the risk of death for children <16 y of age in intensive care
PELD (Pediatric End-stage Liver Disease score) ¹⁰¹	Predicts death or death-moved to ICU in children awaiting liver transplantation
PALF (Pediatric Acute Liver Failure) ¹⁰²	Predicts outcome in pediatric acute liver failure
pRIFLE (Pediatric Risk, Injury, Failure, Loss, and End-Stage Renal Disease) ¹⁰³	Characterizes the pattern of acute kidney injury in critically ill children
WAT-1 (Withdrawal Assessment Tool-1) ¹⁰⁴	Assess clinically important withdrawal symptoms in the PICU

^a Sample of available pediatric-specific measures. The list of measures is not exclusive and should not be interpreted as a product endorsement by the AAP.

ancillary systems, such as the blood bank.

Recently, the AAP endorsed marriage for gay parents to promote the well-being of their children.⁴⁹ For inpatient systems, the changes occurring in the family concept mean that systems must be able to record a variety of core family units, such as 2 fathers or 2 mothers.^{50,51} For children in foster care or other custodial arrangements, inpatient health information systems must be able to capture routinely during the admission process (when possible) information on who is permitted to make medical decisions and can consent to care, who is permitted or

not permitted to see the child's health information, and who may or may not visit.⁵²

Access to Information

In pediatrics, providers are faced with patients who develop from total dependence on the care and supervision of others to relative independence and autonomy. Although the reverse is sometimes true in adult medicine (going from autonomy to dependency), the transition is a regular event for pediatricians, with resulting changes of who is permitted to access information and make decisions in the care of a pediatric patient

developing over time. The management of this change must be included in inpatient pediatric systems to avoid privacy, confidentiality, and legal issues. The increasing use of patient portals that provide access to subsets of EHR data has minimized barriers for minor patients to access their own information and make this issue even more pertinent as adoption rates increase.⁵³

Of particular concern is the need to guarantee privacy for adolescent patients to ensure that these patients will seek help for their issues without the fear of parental or societal repercussions.⁵⁴ Requirements for adolescent privacy have been delineated.⁵⁵ Inpatient systems must also support the care of emancipated minors, who in turn may be the parent of another pediatric patient. Emancipated minors must be able to make decisions for their health and their children, which means that systems must be designed to allow obtaining and recording consent by an emancipated minor.⁵⁶

Pediatricians are only too aware of the challenges in caring for children in foster care.^{57,58} Handling consent issues and privacy for these children is more difficult.⁵⁹ Managing information on guardianship and obtaining consent while at the same time supporting the patient's privacy are minimum pediatric requirements for inpatient HIT systems.⁶⁰ Eventually, children will transition their care from their pediatrician to an adult health care provider. In inpatient settings, this means that records created during childhood should be available to adult providers in the future.

Pediatric systems must facilitate transfer of relevant pediatric-specific data in handoffs. Handoffs occur between hospital units, hospital services, different shifts, and outpatient and inpatient providers. Handoffs are known to be high-risk procedures introducing discontinuity

of care and are a prime source of medical errors. Methods such as ISBAR (identification, situation, background, assessment, and recommendation), adjusted to permit pediatric data elements (see previous discussion), may improve the safety of handoffs.

A major goal of widespread HIT adoption is the establishment of interoperability between health care systems and primary care providers within a region (and nationally). However, nonalignment between systems because of competition may create barriers to the interoperability and integration of electronic child health information.⁶¹ Pediatric leaders within health systems (hospitals, group practices) should be aware of regional efforts to promote health information exchange standards for such systems as registries for childhood immunizations as well as metabolic/genetic and hearing screening tests. The goal should be to harmonize institutional standards with business affiliate groups under the Health Insurance Portability and Accountability Act (Pub L No. 104-191 [1996]).

Documentation

Inpatient stays are usually associated with episodes of acute illness requiring evaluation and treatment followed by subsequent discharge to either home or another institution. Children may have extended lengths of stay in the hospital for days, weeks, or months. Although the main focus of providers will be on the episode of acute illness, health maintenance efforts for this captive pediatric population are important. Inpatient systems must support ordering and documentation of well-child care and health maintenance tasks such as those recommended in *Bright Futures* for children hospitalized for long period of times.⁶² The ability to document developmental milestones is necessary for pediatric inpatients. Disease may present with delayed or

failed attainment of developmental goals.⁶³ Thus, in an inpatient setting, guided documentation for capturing age-appropriate milestones can provide vital diagnostic clues.

Inpatient systems must support documentation, tracking, and notification associated with newborn screening and genetic testing. Furthermore, because requirements for newborn screening vary from state to state, systems must support documentation according to local laws. Reporting of newborn screening results may not improve follow-up of abnormal findings. Thus, clinical decision support to aid providers in the management of results, including testing of relatives, is needed to address this issue.⁶⁴

It is vitally important that inpatient systems not only allow for the ordering but also the documentation of immunizations.⁶⁵ Two-dimensional barcode technology should be supported. An exchange of immunization data with a health information exchange or an immunization repository must be available. The ability to connect to immunization forecasting tools with reminders will improve the number of patients who receive immunizations while hospitalized.

Growth charts that allow a provider to compare the patient's height, weight, and BMI to norm values and allow the determination of a growth velocity are vital to the work of pediatricians and must be included in inpatient systems. Growth charts should allow for automatic plotting of values and percentile determination. In addition to normal charts, the system should provide specialty growth charts for specific diseases, such as Down syndrome.⁶⁶

Children frequently have different norm and critical values than adults. These different norms can be found in vital signs, physical examination features, laboratory values, or findings on imaging studies. Inpatient

systems that store and display pediatric values should accommodate these different norm values and should not only display the age-appropriate reference ranges but also display results in adjusted graphs.⁶⁷ For example, the blood pressure of a preterm neonate should not be displayed on an adult graph with y-axis values ranging from 0 to 200 mm Hg but on a neonatal graph with y-axis values from 0 to 80 mm Hg. Laboratory values should display norm values for the age of the patient, and any clinical decision support designed to alert providers of abnormal values should be designed with age-specific norm values in mind to prevent meaningless alerts and resulting alert fatigue.⁶⁸⁻⁷¹

Nutritional choices for very young children are different from those for adults. Inpatient HIT systems must support the ordering, dispensing, and feeding of age-specific nutrition, including the appropriate modality (eg, formula or breastfeeding). An inventory of human milk and age-specific formulas for neonates or infants, as well as special diets for older children with developmental or nutritional problems, must be available. Because support of adequate growth and, recently, the prevention of obesity are important in pediatrics, caloric densities to allow for easy calculation of intake should be available.⁷² Weight velocity calculations should have age-appropriate calculations (eg, g/kg/day or g/day).

Inpatient settings must have systems in place that manage the storage, expiration dates, and proper administration of human milk⁷³ and, to prevent inadvertent exposure, should reduce the risk of the feeding of human milk from the wrong mother. With donor human milk being used in NICUs, this nutritional alternative should be managed as well.

Educational materials and handouts tailored to both the pediatric-specific

conditions (such as congenital heart disease) as well as the appropriate cognitive and reading level for both children and their parents are important to keeping families informed and teaching them to manage chronic diseases. In pediatric settings, multiple versions of the same material may be required to serve the needs of both child and guardian.

EHRs must further promote the creation and documentation of pediatric quality measures to ensure that services provided to children can be measured in a meaningful way to capture the impact of services and interventions on the health and well-being of children.

Therapy and Intervention

One of the most important functions of pediatric inpatient systems is the requirement that systems must be able to support pediatric weight-based dosing and dosing based on body surface.^{23,74,75} These calculations must extend into dose range alerts as well, in which systems should be capable of creating alerts based on the dose per weight, total daily dose per weight, dose per surface area, total daily dose per surface area, and total dose and total daily dose. Providing weight-based dosing has been shown to reduce errors and potential patient harm in continuous infusions²⁶ and nutrition (parenteral and enteral) orders³ as well as regular medications.²⁵ In the ordering of chemotherapy medication with narrow therapeutic windows,²¹ the use of both weight-based dosing and weight-based dosing alerts has been found valuable.⁷⁷ For pediatric patients who are at the beginning of their exposure to medications and radiation, the implementation of lifelong cumulative dose range checks are more important than in adults. When building pediatric dose range alerts, institutions should be cautious to prevent overalerting, which can result in fatigue. Underdosing alerts provide less value to providers than overdosing alerts.⁷⁸ The highest value

for dose range alerts may be found in pediatric oncology patients.⁷⁸

Building medication orders with prepopulated dosing recommendations provides incentives to providers to select preferred doses by making ordering less time-consuming for providers. These selections result in standardization, reduced prescribing errors, and increased safety to pediatric patients.⁷⁹

Order sets for children should be available that allow providers to select the correct evidence-based laboratory tests and radiology studies, which may minimize the amount of blood required and the radiation exposure. HIT systems should also support radiology protocols, which may allow standard radiation doses to be adapted as suitable for children. Preferred imaging studies may vary depending on age and development and can minimize radiation exposure.⁸⁰

Past experiences have illustrated the importance of allowing health care providers to “do the right thing” and not to stop them from performing appropriate actions. The implementation of computerized physician order entry described by Han et al demonstrated the importance of permitting order placement on preadmitted patients.⁸¹ A pediatric-specific need in the age of advanced prenatal diagnostics is the ability to place orders for patients who have not yet been born and thus are not legally considered “persons.” For example, a delivery of an infant with complex heart disease is anticipated, and a prostaglandin drip is desired to be started immediately after delivery. In this case, the ability to order, dispense, and deliver the medication before the physical arrival of a patient is crucial.

THE FUTURE FOR INPATIENT PEDIATRIC HIT SYSTEMS

As a result of the American Recovery and Reinvestment Act, many hospitals have implemented HIT systems to

achieve eligibility and collect meaningful use incentive payments. Children’s hospitals report an increase in EHR adoption from 21% in 2008 to 59% in 2011.¹² Although the HITECH Act has many requirements aimed at improving the effective use of HIT, only stage 2 contained valid pediatric measures for the use of HIT in children. Although these measures are helpful, they do not address one of the core problems of HIT in inpatient settings: —many systems were designed with adult care in mind and lack basic safety features as outlined in this paper article to prevent injury or harm as a result of the use of these systems in children.

A recent analysis of costs demonstrated that the use of advanced EHRs in pediatric inpatient settings increased costs by 7%.⁸² Of note, this study did not inquire whether the hospitals were using EHR technology that was customized for use in children. Effort must next be directed in addressing the specific needs pediatric patients and their providers have in the inpatient setting, with the goal of increasing safety and effectiveness but also to realize the savings experienced in adult settings.^{83,84}

As stakeholders, parents and pediatricians must continue to lobby for improvement of inpatient (and outpatient) HIT systems to enhance their ability to properly support safe and efficient health care delivery for children. The design, development, and adoption of pediatric-specific functionality in inpatient HIT systems is the only clear path toward achieving this important goal.

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