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Research and Applications

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Transition to a new electronic health record and pediatric medication safety: lessons learned in pediatrics within a large academic health system

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ABSTRACT

Objective: While the electronic health record (EHR) has become a standard of care, pediatric patients pose a unique set of risks in adult-oriented systems. We describe medication safety and implementation challenges and solutions in the pediatric population of a large academic center transitioning its EHR to Epic.

Methods: Examination of the roll-out of a new EHR in a mixed neonatal, pediatric and adult tertiary care center with staggered implementation. We followed the voluntarily reported medication error rate for the neonatal and pediatric subsets and specifically monitored the first 3 months after the roll-out of the new EHR. Data was reviewed and compiled by theme.

Results: After implementation, there was a 5-fold increase in the overall number of medication safety reports; by the third month the rate of reported medication errors had returned to baseline. The majority of reports were near misses. Three major safety themes arose: (1) enterprise logic in rounding of doses and dosing volumes; (2) ordering clinician seeing a concentration and product when ordering medications; and (3) the need for standardized dosing units through age contexts created issues with continuous infusions and pump library safeguards.

Conclusions: Future research and work need to be focused on standards and guidelines on implementing an EHR that encompasses all age contexts.

Key words: pediatrics, neonates, patient quality and safety, EHR, informatics

INTRODUCTION

The electronic health record (EHR) and Computer Provider Order Entry systems are the standard of care across healthcare organizations. Benefits include reduced documentation time, improved guideline adherence and decreased medication errors,[1] as well as an overall positive effect on hospital efficiency.[2,3] Pediatric patients, however, are a vulnerable population with a unique set of challenges around medications. Adult-oriented systems may lack functionalities for ranges of body weights, non-standard medication ordering, or other pediatric-specific issues, leading to potential negative effects on adoption and unanticipated errors.[4]

While the benefits of EHR are known and intrinsic risks identified, additional risks are individual to Computer Provider Order Entry implementation. Sittig and Singh[5] have outlined a 3-step approach to the implementation of an EHR to achieve national safety goals: analysis of (1) safety concerns unique to the EHR; (2) safety concerns from failure to use the EHR appropriately; and (3) the use of the EHR to monitor and improve patient safety. Of concern is that one pediatric center reported an increase in mortality in

transferred patients post implementation of a new EHR.[6] Del Beccaro et al.[7] collaborated with this institution to minimize similar errors and showed a nonsignificant trend towards improved mortality when the same EHR was rolled out.

While the data regarding the initial implementation from a paper to new EHR is abundant,[8–12] there is limited information regarding the transition from one EHR to another. A recent multi-center study looking at EHR transitions in an adult population did not show any increase in mortality, adverse safety events, or readmissions in the Medicare population in the immediate roll-out period.[13] Our institution is a mixed adult and pediatric tertiary care center which recently underwent a transition from our internally developed EHR to a commercially available product, Epic (Verona, WI, USA). With this implementation, one common EHR system was developed and implemented across 11 institutions with varying patient populations and levels of care.

The aim of this report is to describe the unique intrinsic safety and implementation issues for pediatrics during transition to a new EHR surrounding medication ordering, dispensing, and administration in the pediatric population of a large academic center treating both adults and children, while standardizing care with 11 other institutions.

METHODS

Setting

Our institution is a 999 bed medical center with 114 pediatric beds. Specific pediatric populations include a newborn nursery, general inpatient beds with general, surgical and pediatric subspecialty care, a pediatric emergency department (ED), 14 pediatric intensive care beds (PICU), 18 neonatal intensive care beds (NICU), and 13 neonatal intermediate care beds. Our institution is 1 of 11 in the network. Another academic institution in the network includes a large tertiary care NICU. Additional community hospital sites contain general community pediatric inpatient care and level 2, intermediate and regular nursery care. Our site is the only site for the majority of pediatric subspecialty inpatient care and is the only site with a pediatric intensive care unit. Additionally, multiple ambulatory practices serve pediatric patients.

Baseline

The original EHR used in our institution was a compilation of internally developed systems developed for specific clinical applications with high usability, but with limited inter-system communication. The Health Information Technology for Economic and Clinical Health Act was signed into law on February 17, 2009, to promote the adoption and meaningful use of health information technology.[14] Following the Health Information Technology for Economic and Clinical Health Act, there was the need to improve network integration of healthcare information. The decision was made to adopt a standardized large commercial EHR with flexibility to customize to individual needs (Epic, Verona, WI, USA).

In accordance with the Joint Commission of the Accreditation of the Healthcare Organizations mandate to monitor pediatric medication safety, the hospital monitors and reviews all pediatric-related medication safety events and compiles them for review.[15] In practice, this results in monthly meetings to address pediatric-specific medication needs and concerns. Typical work of this committee includes addressing knowledge gaps identified that may lead to dosing or ordering errors, enhancement requests for the EHR, new medication requests or with expanded indications, and policy/procedure and drug information development. Committee composition includes medication safety pharmacists, pediatric quality experts, front-line clinicians in pediatrics, neonatal and pediatric ICU representatives including attending physician and nurses, certified nurse specialists and EHR specialists. The team follows monthly medication safety events and this served as the primary monitoring of pediatric-specific issues through EHR implementation. As in most centers, safety event reports are completely voluntary and may underestimate actual events. Reporting is done through RL Solutions (Ontario, Canada) which is available for all care staff. End users also had the option of filing help desk tickets to request system fixes and are encouraged to also file a safety report for issues which pose a safety concern. Medication errors are followed by monthly count and are not placed into denominator rates due to inability to determine total orders in the prior EHR system. Process improvements and action plans are developed with the safety concerns monitored over time for recurrence. To maintain consistency, these practices were continued post new EHR implementation.

Pre-implementation

With a 3-year planning horizon led by a national consulting firm, clinical content development was fostered with the vendor, build team, and clinicians to create appropriate clinical content for the EHR across the organization. The goal was to follow best practice with a multidisciplinary team of experts to prepare for implementation.[16] The role of informatics analyst was created as a site-specific liaison between the clinical content/build team and clinicians. The informatics analysts core responsibilities were to understand the workflow of each specialty and department, disseminate information to clinicians, and leadership and foster acceptance of the EHR with peers. A key component of their role was forming relationships and partnerships, and understanding cultures and value systems of particular units. This was key among nursing units and follows key findings by Collins et al.[17] that partnerships across the nursing structure, the medical structure, and the IS structures are integral. Specifically, for pediatrics, a pediatric nurse and neonatal nurse were hired as informatic analysts to work with nursing to understand various pediatric workflows prior to implementation.

For the clinician perspective, specific departments and components of the EHR had specific representatives and content leads. A core physician lead was hired for pediatric content development with site-specific subject matter experts serving as advisory panels to content creation. This leader oversaw both inpatient and ambulatory content development with subject matter experts representing all sites throughout the network. There was an attempt to replicate or optimize existing order sets, workflows, and practices in the new EHR through this content development phase.

Multiple core hires for the network EHR development came from pharmacy backgrounds. Unlike the previous EHR system, the individual drug records, or "medication builds" were built with specific drug concentrations and strengths, creating the need for a detailed review. Specific pediatric pharmacist content leaders led the medication build validation work. Each medication build was reviewed by 2 sites, a large academic institution and a small community hospital, for clinical content, functionality, and dispensing accuracy. Examples of details reviewed included ensuring dosing buttons were within the acceptable range as well as checking default dose, routes, frequencies, order instructions, and available dosing units. Each medication build needed to be validated on test patients in 4

specific contexts: neonatal, infant, pediatric, and adult. Resources were spent on testing higher-risk medications and order sets to ensure congruency with clinical practice, available products, standard concentrations decided on by the enterprise, and to tailor certain medications and practices to specific sites. Examples included aligning pump libraries across adult and pediatric ICUs, standardizing antibiotic concentrations across the enterprise and aligning ICU-based practices of intravenous electrolytes, opioids, sedatives, neuromuscular blockers, vasopressors, emergency medications, insulin, heparin, hypertonic saline, and additional low-frequency/high-risk meds.

Implementation

Implementation was staggered through the network over a 5-year period. The first inpatient rollout (site 1) occurred at the sister tertiary academic health center which contained adult inpatient and intensive care units, obstetric care, and a nursery/NICU but without inpatient pediatric care, PICU, or Pediatric ED care. One year later, our hospital rollout (site 2) consisted of a slightly staggered roll-out with outpatient departments making the initial transition and all inpatient units (both adult and pediatric) as well as the ED rolling out 3 months later. All patient care providers were required to have training on the new EHR and representatives from each department received extra training as "super-users" and "uber-users." During the initial phase of roll-out, informatic analysts, "super-users" and "uber-users" as well as representatives from the EHR company were available to assist care providers both day and night.

Post implementation

With our site 2 roll-out, differences in clinical practice between the sites 1 and 2 institutions created multiple barriers and workarounds that had not been predicted despite multi-year efforts to standardize dosing, drug preparation, and administration. Disparate pharmacy dispensing practices, standard concentrations, dosing units, nursing practices, dosing preferences, and medication delivery devices with site-specific limitations manifested after go live and emerged as themes in safety reports. Neonatal, pediatric, and adult drug library development lacked overarching system integration. Uniform dosing was not standardized, allowing disparate medication dosing practices based on age and weight context (neonate, infant, pediatric, and adult). Order sets and panels were not consistently built with pediatric contexts, leading to standard adult doses being ordered for pediatric patients. Site 1 implementation only included neonatal and adult populations, therefore when our site went live with our pediatric units, the pediatric areas highlighted vast differences, particularly in the PICU which cares for neonates through adults. Formulary changes were made just prior to go live adding to confusion. Variable pump platforms created difficulty, with some hospitals and units using large volume infusion pumps and others using microinfusion pumps with different dose-unit requirements and differing minimum volume rates. New functionalities, such as a medication "orderable" created confusion for physicians, pharmacists and nurses when alternative concentrations were needed. As a result, certain concentrations were available for dispensing but not available in specific pump libraries.

A pediatric project governance was established to address pediatric EHR needs. An institution-based pediatric medication workgroup was formed and met daily to address immediate pediatric medication concerns. Composition was similar to the baseline medication safety site, with additional engagement from informatics and front-line staff. Adult and pediatric specialty taskforces for high risk, complex medications such as chemotherapy and insulin were also formed. Initial meetings were daily, and transitioned to bi-weekly and then monthly meeting. Enterprise medication worksites were established for neonates and pediatrics given effects of mitigations on prior rollout areas to increase standardization efforts and share best practices. A network pediatric committee was established to discuss and prioritize pediatric enhancements for the EHR into larger enterprise workflows and maintain a branch in the long term institutional and enterprise governance.

Analysis

The pediatric medication error count was followed for pediatric-specific errors across all pediatric departments at our institution as the main quantitative measure through this implementation. Safety reports were categorized by type and level of harm to patients. The monthly safety report data are followed prospectively through statistical process control. At time of implementation, the previous 4 years served as baseline and upper and lower control limits are established at 3sigma. Special cause rules were used based on the Institute for Healthcare Improvement with data analyzed with QI Macros for Excel (Denver, CO, USA). Medication issues were further characterized by Medication Error Reporting and Prevention (MERP) criteria by pediatric safety specialist and Category E and above was considered harm.[18] Further qualitative analysis was done through the categorization of themes collected through safety reports, tickets for system fix requests, meeting minutes, and issues tracking tools.

RESULTS

Quantitative Results

The overall number of pediatric medication safety reports was mainly in control over the 5-year period prior to implementation averaging 22 reports a month, with a slight increase to 26 per month in the previous year. With implementation, a 5-fold increase was noted. Despite the increase in volume, there was no increase in reported medication events that led to patient harm. The previous baseline averaged 2 events with possible harm a month and no change was noted through the implementation period. By MERP criteria, the majority of these were category E, with only 2 category F events pre-implementation and no category F events post-implementation. By the third month, medication reports decreased back to baseline reporting levels (Figure 1).

Qualitative Results

Concerns which arose during the preparation and implementation phases were tracked and categorized into themes. Examples of issues highlighted in the validation process (Table 1) included problems with dosing units, only allowing weight-based doses of certain medications, not being able to order half doses of certain medications, lack of pediatric-specific titration in weight-based increments of certain continuous medications, difficulties with dispensing certain medications, missing or conflicting administration instructions, inability to order off-label routes, preparation labels for the dispensing pharmacy staff, dosing guidance, large rounding increments for high-risk medications, and alert warnings/restrictions.

Challenges which emerged post-implementation were similarly tracked and categorized as displayed in Table 2. Post-implementation, there was an increase in medication barcode scanning and configuration issues in the new system leading to the need

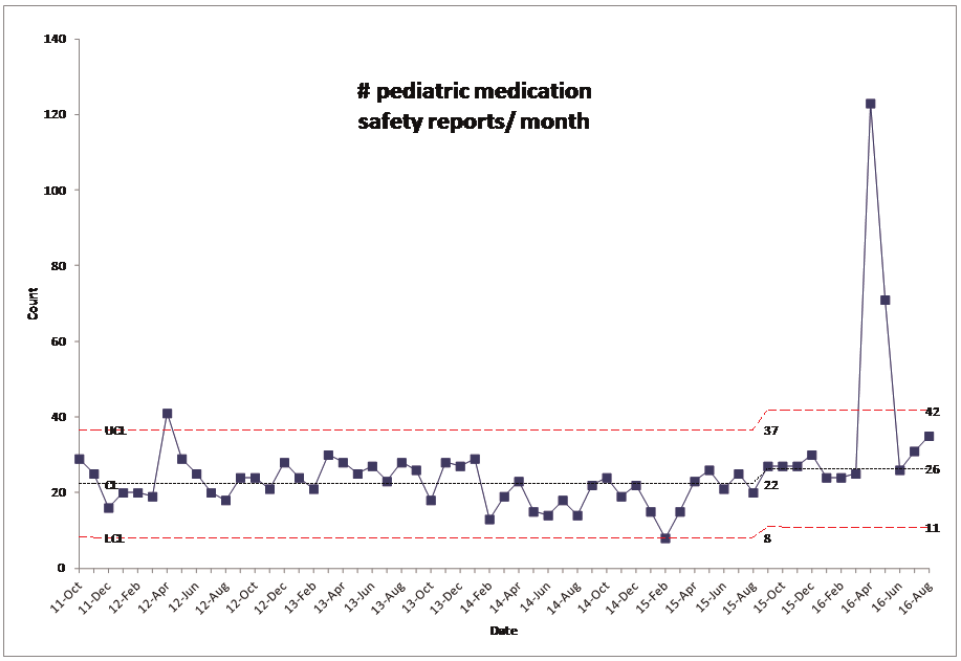

Figure 1. Statistical process control chart of medication related safety reports by month before and after implementation (April 2016). Dotted lines reflect upper and lower control limits.

for troubleshooting and re-processing by the pharmacists, resulting in late medications. Medication ordering issues also increased after go-live due to a needed learning curve of the new capabilities of the EHR.

Both tables depict certain issues related to the overall EHR logic which created pediatric specific challenges. For example, the enterprise decision on the computerized rounding algorithm did not account for enough sensitivity for the pediatric population, and affected high risk medications or those with narrow therapeutic indices (such as enoxaparin, potassium chloride, and amikacin) or rounding dosing volumes to the nearest 0.1 mL/h, which created dosing issues in sedative and vasopressor infusions for premature neonates. Second, the use of a patient weight and dosing weight caused risk and confusion as they could vary significantly over the course of a long hospitalization. Third, the EHR logic in preference lists dictated which medications were available to be ordered. As our pediatric program was within an adult hospital and the facility list was composed of "adult" medications, a neonatal preference list was used in the nurseries and NICU; a neonatal/pediatric preference list was used in areas where there could be neonates, infants, or pediatric patients (PICU and general inpatient floors); and a pediatric hematology/oncology list was used to differentiate pediatric-specific chemotherapy mixtures. Pediatric-specific orders and products had to be added to the emergency preference list since clinicians could see patients in the pediatric area of the ED or in the adult areas. Thus, providers could unknowingly pick the incorrect formulations or not have access to pediatric-specific orders, putting pediatric patients at greater risk for medication error and causing significant delays. Additionally, the risk of omitted medications could also lead to confusion because a prescriber might not realize there is a different concentration of a drug or an extended release formulation.

A second theme identified was gaps related to a need for standardization of medication concentrations and clinical processes across the enterprise. There were several issues with the alignment of medication administration steps starting from the ordering process and ending with delivery to the patient. This led to lack of congruence between the EHR order, the age and weight context of the patient, the pump library, and the medication stock availability. The orders and order sets designed for the site 1 roll-out did not always match the concentrations available at our institution or those available in the automated dispensing cabinets in particular units. Additional misalignment between the EHR ordering options and the dosing dictionaries in the IV medication pumps or dictionaries in the automated dispensing cabinets led to delays in medication administration, or unsafe workarounds resulting in manual overrides with loss of protective guardrails in administration and inability to scan a medication, putting patients, and nurses at greater risk for medical errors.

A third theme was a need for standardization in dosing units among age contexts. The only PICU in the system faced the largest challenges due to context dependent changing since all populations could occur in this location, while this problem would rarely be encountered in neonatal or adult specific environments. Of particular concern was the lack of standardization of dosing units for continuous infusions, including muscle relaxant and vasoactive drips in the adult and pediatric ICUs. Based on a patient's weight, the dosing unit and drug library context would shift. For example, an 8-year-old patient may be running an infusion of epinephrine in microgram/kilogram/minute (mcg/kg/min) and next door a 9-year-old patient may be running an infusion in mcg/min based on the adult context of a weight over 40 kg. This risk was noted in adult units as well, as a frail underweight 80 year old adult would require the practitioners to dose in pediatric context once under 40 kg. The work around again required the bedside nurse leaving safety rail guards of the infusion pumps, limiting their use as safety mechanism.

DISCUSSION

Despite a 3-year multidisciplinary preparation, there were significant and urgent safety concerns which emerged at Go Live.

Table 1. Pre-implementation Preparation and Challenges: New Features to our EHR

Topic	Challenges To Plan For:
Ordering with Concentration-specific Medication Builds	Varying pump platforms per site and need to build syringe and large volume pump (LVP) records Need for all sites to agree on concentrations Central line wording absent in medication name description
Dose Units	Multiple dose units per medication can be error-prone with differing preferences among pediatric sites Examples: mL/kg vs mL/kg/h, mg/kg vs mg/kg/day
Rounding Increments	Differing practices per site to 10th or a 100th decimal point Examples: Insulin half-unit rounding increment needed in pediatric patients, enema half-doses
Rounding: Syringe vs Bag Dispensing	Syringe rounding increments of 0.01 mL/h, vs bag rounding increments of 0.1 mL/h. Bag records could result in over-rounding by >10%–20%, a safety concern in smaller patients Need to select concentrations and syringe records to avoid bag-associated rounding by 0.1 mL/h
Titration Questions for Continuous Infusions	Adult titration questions set up, but not reviewed by pediatric/neonatal experts; conservative initial dosing and dose titration-increments needed Dosing buttons were in weight based units but titration questions in adult nonweight based units
Preference Medication Lists:Neonatal, Neonatal/Pediatric	Medications missing. Examples: creating neonatal records to appear for neonate-only preference lists with need to appear on pediatric lists as neonates could be on the general care floors or in the PICU and aligning pump wt profiles Ancillary areas that also see pediatric patients: OR, PACU, ED Specialty Preference lists: Adult heme/onc vs pediatric heme/onc who needed pediatric-specific medication records
New Fourth Dictionary: Infant dictionary	Infant dictionary assigned by age/weight—need to provide dosing options or else pediatric guidance is not available
Med Record Build Validation by Both Clinical and Compounding Pharmacists	Extra time must be allotted for review by both specialized pharmacist roles in order for neonatal and pediatric nuances to be addressed and for accuracy that reflects practice Examples: 1. Clinical Pharmacist: can select appropriate rounding increments to avoid under or over-rounding for pediatric/neonatal mixes 2. Compounding Pharmacist can validate the medication is built with the appropriate concentration for doses to be accurately prepared, including setting up the system with aliquot dilutions that can be scanned as the ingredient for preparing the final dose
Electronic Warning Alerts:Max Dose AlertsNo Hard stops	Too many alerts instead of only clinically significant or above certain thresholds e.g., 10%–20% Important for detecting factor of ten errors with meds like Heparin, Clonidine, Levothyroxine, used in pediatrics
Medication Instructions	Previous system only listed one set of instructions for all practitioners. New system has the ability to list instructions for each practitioner site, but not visible to each site. Example: dosing visible to prescribers and pharmacists, but not nursing Agreement across sites is a requirement, therefore these instructions seem underutilized
Dispensing Logic Based on Weight and Age	Shared across all sites Time should be allotted for testing. To ensure neonatal concentrations are configured properly to avoid dose volumes that are too high or too low for preparation Useful for designating syringe for NICU vs Minibag for adults
Dispensing multiple doses with one label	New dispensing format, that caused confusion; examples with one label with one dose, as well as multiple doses with one label Education and practice alerts were shared institutionally

OR, operating room; PACU, post anesthesia care unit; ED, emergency department.

Our strong safety reporting culture and go live structure of informatic analysts and super-user communication with centralized committees enabled us to respond quickly. Since no EHR can be perfect on day one, detecting issues, and having the ability to react quickly are critical. Vigilance on the part of physicians, pediatric unit based pharmacists, and nurses prevented transition risks from reaching the patients. The average number of medication safety reports filed per month returned to baseline within 3 months and in fact we have seen a decline in the months that followed. And things were fixed quickly—for example, 15 new neonatal medication records were built in a week once issues were discovered. As our experience has shown, standardization of practices across the network is essential in the build, maintenance, upgrade, and future rollouts of the EHR. We eventually established a network pediatric committee to discuss and prioritize pediatric enhancements for the EHR into larger enterprise workflows and maintain a branch in the long-term institutional and enterprise governance. This committee allowed agreement on standard dosing guidance and build enhancements, and now addresses more complicated issues such as standardized dosing, standardized concentrations, common pump platform, and shared policies and procedures.

On our review, several major themes emerged that highlighted issues with the preparation for implementation. These themes could be categorized into issues related to the specific EHR logic including medication rounding, multiple patient weights, and preference lists; a need for standardized process alignment especially with regards to medication concentrations; and a need for standardization among adult medicine and pediatrics, particularly for dosing units of high risk medications. One major barrier and learning point for multi-network rollouts is early consideration of the needs of the institution

Table 2. Post-implementation Challenges

Themes	Specific challenges and examples
Differences with EHR Logic	Multiple weights per patient Example: New process of recording actual weight and dosing weight caused significant confusion when weights differed Functionality of "orderables" in both adult and pediatric contexts As well as a way to order and dispense pediatric-specific medication practices (e.g., administering IV dexamethasone orally) Dose unit setting in shared systems created unexpected display of dose units on medication preparation labels. Examples: insulin setting in automatic dispensing machine resulted in dose unit problems on the preparation label
Need for Standardized Process Alignment Across Multiple Health Systems	Attempting to standardize concentrations across multiple sites without full process alignment Example: Neonatal concentrations of many intermittent meds were much higher than previously due to a different practice in the Site 1 NICU Lack of congruence between the EHR order, the age context of the patient, pump library, and medication stock availability Example: orders/order sets for the Site 1 roll-out did not always match concentrations available at our institution or in particular units Misalignment between the EHR ordering options and dosing dictionaries in IV medication pumps or automated dispensing cabinets led to delays and/or manual overrides
Need for standardization for the dosing units of high risk meds	Discrepancies between infusion and bolus dosing units Example: The order for certain infusions were mcg/kg/min and bolus was mg/kg. The microinfusion pumps could not be programmed in two different units. The nurse would need to figure out dose in mcg, go outside drug library or draw up medication from vial Discrepancies between adults and pediatrics: need for standardization of units for muscle relaxant and vasoactive drips in the adult and pediatric ICU's led to weight based standardization. Based on a patient's weight, the drug library context would shift from mcg/kg/min to mcg/min based on a weight over 40 kg. This was particularly hazardous in the PICU where patient weights ranged from neonatal to adult
Change request process—System Improvement via Tickets	Steep learning curve initially with new system resulting in communication issues via emailed requests. All sites must understand implications of change to their site Maximizing webex demonstrations and premeeting between sites prior to voting on changes is recommended

which cares for the most complex pediatric patient in an EHR roll-out.

Many of the initial decisions made in the preimplementation process had dramatic impact for pediatrics and had already been in use for a year before the consequences could be understood and realized, creating barriers to correction. Earlier recognition of critical logic issues may have occurred and less intensive reversals may have resulted if the most comprehensive center led the roll-out effort. One of the problems is that there is no specific application in this commercial vendor that focuses on pediatrics. Instead, pediatric functions are all parts of applications and creation of build is siloed into adult processes, creating a lack of central awareness of pediatric impacts. Thus, pediatrics must be represented at all enterprise meetings, as it touches every specialty and processes. Due to the size of pediatrics within the enterprise there are fewer representatives available than in the adult population and thus less voice into decision making, creating additional risk in a vulnerable population. This has been voiced by Lehmann,[4] who noted conflicts in design and implementation goals may impede timely development and prioritization of pediatric-specific health information technology (HIT) function. Prior to implementation, sites should conduct comprehensive simulations using the live environment versus the test environment and test functionality through the complete process including ordering, pharmacy verification, preparation and dispensing, administration, scanning and documentation. During implementation and post implementation there needs to be a structured path on how to escalate pediatric safety concerns and prioritizations that may appropriately compete with the larger adult population. In retrospect, greater pediatric representation at all neonatal-pediatric-adult meetings pre-implementation, implementation, and post implementation to ensure that pediatric concerns are addressed is a key component in this type of roll-out.

Many studies have shown that an EHR can be implemented safely in an individual institution, and the recent multi-center study showed that EHR transitions can be safely made in the adult population.[13] Pediatrics, however, presents unique challenges with potential danger in acute patients.[6] We saw an increase in pediatric medication safety reports with the majority of our events reported from the neonatal and pediatric ICUs, highlighting acute children as a particular area susceptible to the dangers of a new EHR. Although we had no major harm done to any patient, many were avoided through provider vigilance, and we know for every near miss there is potential for catastrophic harm. We credit the culture of safety with a high degree of vigilance at our institution from preventing any serious harm events. Procedures were put in place for escalation of issues as soon as they were detected and enhanced multidisciplinary communication allowed.

While we focused on medication-related reports, there are several other safety and quality metrics that may have been significantly impacted by the EHR roll-out that we are unable to address. Examples of this could include delays in patient care, increases in provider documentation time, delayed discharges, changes in patient satisfaction, and changes in billing and reimbursement. There are multiple gaps in the literature regarding guidelines and a roadmap for inpatient pediatrics within a multidisciplinary hospital transitioning to an EHR use and what to expect which only institutions describing their experience can fill.

There are several additional limitations to our study. While medication error safety reports are a measure of potential harm or "near misses" our patient population may be too small to detect any clinical harm during the EHR roll-out. There were also many high-level issues that were recognized in the weeks leading up to the roll-out due to a concerted effort by the validating pharmacists working with the medication builders to understand the system and the implications of current functionality on pediatrics. Furthermore, this work only followed voluntary reports of medication errors. Voluntary reporting does not uncover all issues and people may have been reluctant to report harm or not have time to fill out near miss issues. However, there is a multi-year core structure and existing framework which remained unchanged during the EHR-roll which we hope mitigated this concern. There may have been a bias towards reporting safety events in the setting of a new EHR roll-out and the accompanying frustrations of staff. We were limited in our ability to categorize reports and generate themes by the level of details provided in the report which can vary greatly, and we were unable to quantify the data supporting each theme, although the authors were all involved in its categorization and mitigation in real time.

CONCLUSION

Despite extensive preparation, multiple issues were encountered and unanticipated with the EHR transition in pediatrics. Pediatric representation is needed in any EHR build in the earliest stages with multi-institution roll outs within a network, the most comprehensive hospital with all age contexts should lead the efforts. Standardization across institutions cannot be stressed enough and should be made prior to the roll-out of a new EHR to limit the number of changes being implemented at once. No matter how extensive the planning, medication errors should be anticipated with any EHR transition and mitigation strategies and governance structures designed for rapid resolution of problems should be put in place to minimize the effects on patient safety. As more institutions transition their EHRs, further research into medication errors as well as other quality metrics are needed in the pediatric population, especially in the context of a mixed pediatric and adult institution. Larger multi-institutional studies are needed to assess changes in clinical outcomes such as morbidity or mortality in pediatrics.

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COMPETING INTERESTS

None.

CONTRIBUTORS

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication.

This project was undertaken as a quality improvement initiative and as such was not supervised by the institutional review board per their policies.

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