Information Technology

Redesigning Care Processes Using an Electronic Health Record: A System's Experience

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Many delivery systems currently seek to improve the quality and efficiency of care through introduction of an electronic health record (EHR). Support for EHR adoption has come from government, private health policy organizations, and vendors; research identifies potential EHR benefits.[1–5] Yet, accumulating field reports show that EHR implementations sometimes encounter major obstacles, fall short of expectations, or fail completely.[6–11] Moreover, computerized physician order entry (CPOE) and decision support systems (DSS), functions routinely bundled with EHRs, have not consistently delivered anticipated benefits for safety and quality.[12–17] Many providers are hesitant about investing in an EHR[18–19] until they are more certain of its contributions to quality, efficiency, and their business performance.[20–22]

To attain EHR's full potential, its adoption and implementation should be treated as a means of facilitating redesign of outdated, inefficient, and error-prone care processes and a vehicle for organizational change—rather than just another information technology (IT) innovation.[23] This focus on IT as a means to health care system change fits the Institute of Medicine's call to redesign the way we deliver and pay for care.[24] It is also supported by research documenting how IT innovations interact with existing sociotechnical systems.[6,25–28] Despite recognition of the value in redesigning care processes while using EHRs, few studies document this method within entire hospitals or delivery systems. To meet this need, we describe how Trinity Health, a large multiorganization health care system, addressed EHR–based redesign of care processes in those hospitals preparing to adopt a commercial EHR product, which includes CPOE and DSS. We highlight five principles that guided the EHR–based redesign work and discuss challenges associated with implementing redesign, lessons learned along the way, and the applicability of this experience to other systems.

Implementing a Systemwide EHR

Setting

Trinity Health (TH), the fourth largest U.S. Catholic health care system, resulted from the merger in 2000 of the Holy

Article-at-a-Glance

Background: Implementation of health information technology (HIT) has encountered many difficulties and produced mixed outcomes. Yet Trinity Health, a major integrated delivery system, successfully leveraged implementation of a systemwide electronic health record (EHR) to promote process redesign and continuous quality improvement.

Implementing a Systemwide EHR: After several years of planning, two waves of EHR implementation were launched, in 2001 and 2003. One system HIT team collaborated with each hospital team for 18 months before its 24-hour transition to the EHR. During EHR planning, the system HIT team used five principles of redesign of care processes: (1) identify and address safety problems, (2) promote evidence-based practices, (3) reduce practice variations and standardize terminologies and care processes, (4) improve communication and relationships among clinician roles, and (5) augment multiple uses of data in HIT–supported care processes. Patient-centered work flows were developed to design improved patient care processes for different types of patients, such as medical inpatients and emergency outpatients. These admission-to-discharge work flows addressed gaps in quality, safety, and efficiency and helped ensure that the EHR and decision supports reflected crucial interactions among clinicians and with the patient. By the end of 2008, 13 of Trinity Health's 17 major health care organizations ("ministries") made the transformation to using EHRs.

Discussion: EHR–supported care redesign requires development of substantial system capacities in clinical informatics, customization and standardization of vendor's products, collaboration and coordination between system and hospital implementation teams, quality training for clinicians and change agents, and significant clinician participation in local preparations.

Cross System and Mercy Health Services. TH provides systemwide resources to 44 hospitals, 379 outpatient facilities, and numerous assisted-living, home health, hospice, and senior housing programs through 17 organizations ("ministries") across seven states. So far, 5,500 of more than 8,000 physicians, primarily self-employed private practices, provide patient care using the EHR and CPOE technologies in 13 organizations across 32 facilities (Table 1, right)—and the remaining 4 organizations are slated for implementation by 2011.

Table 1. Phase II Electronic Health Record–Based Redesign and Implementations of the Framework in 17 Organizations

Completed Implementations	Facilities
1. Mercy Hospital–Port Huron, Port Huron, Michigan—May 2003	1
2. Mercy General Health Partners, Muskegon, Michigan—July 2004	2
3. Saint Mary's Health Care, Grand Rapids, Michigan—October 2004; clinics July 2005	3
4. Battle Creek Health System, Battle Creek, Michigan—February 2005	2
5. St. Joseph's Healthcare, Clinton Township, Michigan—April 2005	2
6. Mercy Medical Center – North Iowa, Mason City, Iowa—July 2005;	2
Mercy Clinics (2 of 41 sites) February 2007	2
Mercy-North Iowa Network Hospitals—July and September 2008	7
7. Mercy Medical Center–Sioux City, Iowa—September 2005	1
8. Mercy Medical Center–Dubuque, Dyersville, Iowa—February 2006	2
9. St. Mary Mercy Hospital–Livonia, Michigan—March 2006	1
10. St. Joseph Mercy Oakland–Pontiac, Michigan—March 2007	1
11. Mercy Medical Center–Clinton, Iowa—October 2007	2
12. South Bend, Mishawaka, Plymouth, Indiana—April 2008	3
13. Silver Springs, Maryland—September 2008	1
Planned Implementations	**32**
14. Ann Arbor, Saline, Livingston, Michigan—Spring 2009	3
15. Boise, Idaho—Winter 2010	1
16. Fresno, California—Winter 2011	1
17. Columbus, Westerville, Ohio—Fall 2011	3

Planning

Planning for implementation of a systemwide EHR began at Mercy Health Services in 1998 and expanded when TH was created. The organizations decided to share common core systems, link data with two data centers, establish a systemwide round-the-clock IT support center, and organize a single systemwide health information technology (HIT) team for project management. The EHR is available through a wide area network (WAN) connecting local area networks. A virtual private network allows clinicians remote access to the EHR from their offices and homes. TH's clinical leadership council (CLC), which includes chief nursing officers and vice presidents of medical affairs, proposed this integrated, patient-centered EHR.[29] The CLC appointed interdisciplinary teams of clinicians to design the EHR's content and decide on the initial scope of the HIT functions. Between 2000 and 2002, groups of clinicians (physicians, nurses, pharmacists, and so on) met with IT analysts to specify the EHR's initial configuration with guiding principles for its systemwide operation.[29] These normative principles were then used to guide systemwide change of health care processes using HIT.

Phase I

In 2001, TH implemented the EHR's first phase, which included a clinical data repository (CDR), an EHR viewer for laboratory results, dictated diagnostic and procedure reports, pharmacy system patient medication profiles, and 17 adverse drug event (ADE) alerts for pharmacists. Initial ADE alerts were triggered from pairs of patients' laboratory results and medication data. In 2003, TH launched Phase II with CPOE, clinical documentation, DSS, and new systems for pharmacy, radiology, emergency tracking, finance, and medical records (Table 2, page 84). Adding these functionalities required considerable change in care and communication processes.

Each TH–affiliated hospital and clinic agreed to share data designs for CPOE, DSS, electronic clinical documentation, and work flows. Because emphasis was on changing processes when introducing the EHR, each site engaged its own change agents and deployed members of its quality improvement department to help introduce clinicians to the proposed work flows. TH and hospital leaders identified individuals previously trained in continuous quality improvement (CQI) who had completed redesign projects. These individuals were temporarily assigned 5%–40% of their roles to help with EHR–based redesign and EHR preparation.

The EHR development and care redesign required cooperation between teams representing TH as a whole and teams in each hospital or clinic. At the system (TH) level, the HIT team included two clinical transformation directors and many clinical application analysts working with designs for particular patient populations, such as emergency care or maternal-child care. At the hospital level, executives selected persons for the hospital implementation team because of their training in informatics or knowledge of clinical or business processes, or

Table 2. Implementation Phases for the Health Information Technology*

Phase I: 2001–2005	Phase II: 2003–2009
Clinical data repository	CPOE with order sets
EHR viewer (lab results, diagnostic reports, and dictated physician reports)	Clinical documentation & notes
Pharmacy medication profile	Decision support system tools (alerts, reminders, etc.)
Adverse drug event (drug-lab alerts to pharmacy)	Pharmacy system
	Emergency tracking
	Medical record management/ publishing

* CPOE, computerized physician order entry; EHR, electronic health record.

for their management role. Hospital teams included informatics specialists, pharmacists, directors of nursing practice, physician champions, change agents, future trainers, and information systems staff.

Phase II

In launching in May 2003, the CLC decided on an innovative, single-day transformation at each site. By adopting this "big-bang" approach for Phase II, it hoped to avoid use of duplicate electronic and paper records during transition. This approach avoided typical problems of interfaces between older and newer IT applications. Costs were reduced because each hospital was moving to common core systems and overall designs. The disadvantages were that increased capital and operational resources were needed to prepare for the launch during an 18-month period and a large number of external staff were required to support implementation.

Principles of Redesign

To prepare for Phase II, guidance was needed for the redesign of work flows for all care processes, including those processes that would be supported by the EHR and those for which EHR support would not yet be available. During EHR planning, the system HIT team used five principles for redesign of care processes. In Table 3 (page 85), specific examples are taken from three organizations to illustrate the role of the system and hospital teams in applying these principles of redesign.

1. Identify and Address Safety Problems

TH encouraged disclosure of safety problems and redesign of care to prevent potential harm to patients. Directors of clinical transformation urged clinicians to discuss safety problems within their hospitals and clinics, along with current or possible steps toward improving safety. Moreover, hospitals were encouraged to join the Institute for Healthcare Improvement's 100,000 Lives Campaign,[30] and to avoid sentinel events targeted by The Joint Commission.[31]

2. Promote Evidence-Based Practices

For training in evidence-based practice, physician and nurse champions were sent to an advanced program in health care improvement. Nurses were also educated in the Iowa Model of Evidence-Based Practice.[32] In addition, TH purchased knowledge resources and established a pharmacy council, with responsibility for deciding on best formulary and drug order standards for the entire TH system.

3. Reduce Practice Variations and Standardize Terminologies and Care Processes

TH promoted CQI and care standardization through quality improvement programs, starting in 1991 with executives, managers, and trainers learning CQI principles and group methods and analyzing data during the first two years. For the next seven years, physician leaders and all staff trained using tools for improvement, data use, and process flow charts. Regular training sessions continued, with introduction of Six Sigma in 2002 and Lean thinking and Value Stream Mapping thereafter. In support of new HIT to document patient symptoms and clinical practices, the system HIT team introduced standardized vocabularies, validated assessment instruments, and standardized work-flow templates.

4. Improve Communication and Relationships Among Clinician Roles

TH promoted participation of clinicians in review of care processes and in development of patient-centered work flows—cross-functional flow charts that describe step-by-step information exchange for all clinicians interacting with a type of patient. The new work flows represent data flow and information used in patient's interactions during registration, admission, daily assessments, care planning, and discharge instructions, along with account management and regulatory reporting.

In addition, the clinical transformation directors met with teams of interdisciplinary clinicians 12–15 months before implementation. Together they developed clinical decision support expert rules for communicating abnormal clinical findings during admission assessments or laboratory results. These rules generate automatic messages to dieticians, social workers, and

Table 3. Examples of Steps Using the Principles for Electronic Health Record (EHR)–Based Redesign of Care*

Principles	System HIT Team	Hospital Implementation and Clinician Teams
1. Identify and address safety problems.	The system team constructed patient-centered work flows, including safety features (e.g., required data fields, DSS reminders, orders and medication alerts). After completing work flows, the clinical transformation director conducted dialogues with hospital clinician teams to expose safety problems and potential risks (e.g., misidentification of patients, medication errors, missed assessments, diagnoses of patient skin and pressure areas, patient risks or failure to rescue from missing information). A series of questions on why current care steps were taken led participants to identify faults in current processes and motivated them to redesign care to respond to the unanswered questions and close gaps in the process. DSS tools and redesigned work flows became part of the work-flow solution with the EHR, which required (forced) documentation and tasks.	The hospital clinician teams were introduced to the new preconstructed patient-centered work-flow steps and reviewed the steps to identify current problems and risks they had. They generated questions (gaps) about care steps in the EHR with the intention of eliminating potential errors and risks in the current process by moving to the new work flows. EHR documentation requirements and clinical decision support rules were introduced to reduce identified safety risks and increase performance. For example, EHR work flows were reconfigured to require nurses to administer only verified medications, to review patient allergies, and to record measured height and weight within one hour of admission rather than just accepting a patient's stated height or weight.
2. Promote evidence-based practices.	The system team trained hospital staff to use a Web-accessible knowledge database. This database provided some of the knowledge resources physicians need to design and build order sets. The system team solicited evidence-based guidelines and standards for every work-flow decision and incorporated the guidelines into the EHR. Citations, guidelines, authorized copyright for instrument use, and other information sources were found to support reference material, design, and work flow within the EHR's forms and decision support tools.	The hospital and clinician teams received training on how evidence is used to redesign work flows and to design EHR components. The teams culled evidence for clinical decision support rules. For example, existing work flows were reconfigured to include nursing assessments for pain level, immunization status, fall risks, tissue integrity, sedation level, and priority needs of patients.
3. Reduce practice variations and standardize terminologies and care processes.	To reduce confusion among clinicians and save them time in collecting, entering, and accessing information, the system team used formal naming conventions and standardized terminologies and definitions. The team provided training on standard designs for service-specific order sets, electronic forms, and DSS clinical rules operating uniformly across sites.† The standard designs and work flows became templates for future users, and were replicated across units and departments in multiple hospitals.	The system and hospital teams asked questions of clinicians to identify inappropriate variations in current processes and to reduce process steps before EHR implementation. For example, clinicians were only to use the primary true source for medications, the EHR's medication profiles for home and inhospital medications. Also, in one hospital's review of cardiology patient services, the staff described how cardiologists' stress test reports were half-dictated and half-handwritten. The implementation team made dictation a standard before implementing EHR functions.
4. Improve communication and relationships among clinician roles.	The system team led discussion about asynchronous electronic data exchange and synchronous (face-to-face or phone) communication. The analyst and director demonstrated asynchronous exchange with clinician expert decision support, CPOE, and messaging an Inbox. Asynchronous communication was used with the DDS rules tool for communication of consults to providers. Synchronous communication was emphasized for any work-flow reporting of critical results and findings from diagnostic tests.	The hospital team improved communication among clinicians and with patients and families by using DDS tools such as CPOE order detail, education forms, and notes within the EHR. In one hospital's work session for medical inpatients, the radiology technicians discussed the current process for communicating preparations for radiology procedures to nurses and subsequent participation of patients in preparations for diagnostic tests. To resolve communication problems, work session participants went through several iterations of procedures for communicating preparations to nurses via CPOE as a DDS tool.
5. Augment multiple uses of data in HIT–supported care processes.	The system team trained hospital team members in use of patient data before arrival, during initial assessment, and during treatment. For example, entries on functional decline or domestic violence facilitated multidisciplinary consultations and provided an early start in dealing with problems that could delay discharge. Clinician decision expert rules were designed to use patterns of information to support notification of diverse specialties and disciplines.	Before and after implementation, the hospital team sought end-user input on best uses for patient information. Examples included steps to ensure early capture of admission assessments, to provide access to patient information by caregivers and staff from multiple disciplines, and to facilitate timely involvement of appropriate disciplines. Availability of EHR data stimulated discovery of additional valuable uses.

* HIT, health information technology; DSS, decision support system; CPOE, computerized physician order entry.

† Brokel J.M., Shaw M.G., Nicholson C.: Expert clinical rules automate steps in delivering evidence-based care in the electronic health record. *Comput Inform Nurs* 24:196–205, Jul.–Aug. 2006.

rehabilitation therapists. The rules are designed to make follow-up faster and more reliable than traditional phone messaging.

5. Augment Multiple Uses of Data in HIT–Supported Care Processes

TH promoted collection of key patient information early in care delivery and designed multiple uses for the information. For example, data on height, weight, allergies, and home medications collected by nurses within an hour of admission are used first to support CPOE and then to support pharmacists' medication-dose verification. Later in the stay, radiology technicians use these data in checking for drug-contrast allergy interactions, and physicians use the data when they write prescriptions at discharge.

Redesign Method Through Patient-Centered Work Flows

Before the start of Phase II, the hospitals and clinics had managed a range of independent CQI activities that focused on process improvement. The process changes targeted by CQI were often isolated; in contrast, the changes to patient care processes introduced during EHR implementation were aligned with one another and targeted systemic improvement.

The first three TH hospitals preparing for EHR concentrated on single-process work flows, which covered one technically defined operation, such as physician's drug and laboratory orders or nurses' documentation. Because TH sought to develop an integrated HIT system throughout its affiliated facilities, a system HIT team prepared prototype patient-centered work flows for guiding the redesign process with the hospital's clinician and implementation teams. These new work flows provided a method to capture all patient care activities, as well as to highlight decisions that clinician groups needed to make regarding information use with the EHR, CPOE, electronic forms, and DSS tools.

Initial Work-Flow Templates

With help from hospital change agents, clinical transformation directors constructed the initial 15 patient-centered work-flow templates for inpatient hospitalizations and ambulatory visits (Table 4, page 87). These work flows reduced variations in processes across units and departments while addressing the patient's care from admission to discharge. The work flows, which were often several pages long, showed interactions between clinicians, patients, and departments (for example, handling lab orders with response to normal, abnormal, and critical results). These patient-centered work flows also linked to distinctive department processes (for example, respiratory therapy documentation) and role-specific work flows (pharmacist drug verification). Other detailed work flows illustrated specific evidence-based steps, such as the clinicians' processing of patient immunizations. One template, an antepartum section of a maternal-child work flow (Figure 1, page 89) that was created using system-standard diagramming software, illustrates how nurses access electronic forms to document assessment interviews using evidence-based design not previously used in paper designed forms.

Hospital Redesign Sessions

Each hospital had at least 18 months to prepare for EHR implementation. Preparations began with system HIT team training hospital implementation teams. The hospital team invited those clinicians, support staff, and managers closest to the work-flow processes to the redesign sessions. The system HIT team introduced the hospital's teams to the EHR, redesign principles, and procedures for reviewing and redesigning care. Hospital teams learned to search, select, and manage CPOE orders, order sets, and DSS messages; to find and use documentation forms and checklists; and to trend and use customized summaries.

Sessions for Clinicians

Fifteen months before EHR activation, the system and hospital teams conducted daylong working sessions and periodic follow-up sessions for clinicians. The first sessions served as a starting point to discuss transformation, identify errors and unjustified-care variations, introduce evidence-based practices, and otherwise improve quality. During sessions, the system team displayed each step in the patient-centered work flows with clinicians and demonstrated how to use the EHR to support the work flow. When physicians could not participate, the informaticians called respective specialists for input to answer questions during the meetings. Members of the physician advisory team also participated in peer-led sessions to review work-flow steps for CPOE and remote access. These physicians also designed and approved order sets, updated medical staff policy/procedures, and arranged training and support for implementation. These sessions provided opportunities for people managing, supporting, or providing a particular type of care to participate in decisions about how work flows would be represented in the EHR (Sidebar 1, page 88).

The working sessions provided the clinicians and hospital implementation teams opportunities to assess proposed work flows and to resolve technical and content gaps. During the ses-

Table 4. Types of Patient-Centered Work Flows from Point of New Design Until Implementation at Hospitals

Patient-Centered Work Flow	Jul.–Dec. 2004	Jan.–Jun. 2005	Jul.–Dec. 2005	Jan.–Jun. 2006 (# hospitals)	Jul.–Dec. 2006	Jan.–Jun. 2007	Jul.–Dec. 2007
Emergency Walk-in and Ambulance Arrival	New design	Implemented	Implemented	Implemented (2 hospitals)		Implemented	Implemented
Cardiovascular Medical Inpatient		New design		Implemented (2 hospitals)	Includes the surgical inpatient	Implemented	Implemented
Joint Orthopedic Surgical Inpatient		New design		Implemented (1 hospital)	Included in ambulatory surgery	Implemented	Implemented
Ambulatory Diagnostic Radiology		New design		Implemented (2 hospitals)		Implemented	Implemented
Skilled Nursing and Acute Rehab		New design		Implemented (2 hospitals)		Implemented	Implemented
Maternal-Child and Neonatal ICU		New design		Implemented (2 hospitals)		Implemented	Implemented
Ambulatory Surgery and Procedures		New design		Implemented (2 hospitals)		Implemented	Implemented
Behavioral Medicine		New design		Implemented (2 hospitals)		Implemented	Implemented
Pediatrics Care			New design			Implemented	Implemented
Oncology–Research–Non-research			New design			Implemented	Implemented
Critical Care			New design			Implemented	Implemented
Medication Management and Reconciliation			New design			Implemented	Implemented
Clinic Visit Types (Pregnancy, Well Child, Health Maintenance, Chronic Care Management)				New design		Implemented (2 clinics)	Implemented
Critical Access Hospitals				Modifications in designs	Modifications in designs	New design	Implemented
Surgery/Anesthesia Services							Implemented

sions, clinician teams added evidence-based steps in providing care, adapted patient-centered work flows for their hospital services, and identified gaps in care processes needing improvement. To help align the EHR to local conditions, session participants recorded content gaps between current and future care processes as questions about "who, where, what and when" steps in patient-centered work flows. The questions elicited ways to reduce variation and eliminate waste in local practices. Comparisons across units about who would document and use EHR information brought to light unjustifiable local variations. Through these comparisons, clinicians raised safety concerns or questioned the quality of current care processes. Every question about content or technical steps was framed in terms of a gap between current and desired practices, which required further examination and resolution. Admission work-flow steps were locally altered 20%–30% of the time, whereas only 0%–5% of clinical processes changed. Clinical work flows included evidence-supported practices to meet safety and accreditation standards. Through this process, clinicians accepted many aspects of the future work flow to further evidence-based, standardize care that could enhance safety and efficiency.

Addressing Content Gaps

After these sessions, hospital implementation teams met with local managers and clinicians to address content gaps. The managers were responsible for follow-through in their respective areas. Through this iterative process, the redesigned patient-centered work flows matured and took on design details

Sidebar 1. Clinician Work Session Example

In the clinical work sessions, nurses, therapists, nurse managers, pharmacists, and registration staff met to review a patient-centered work flow for a total of eight hours with the system information technology (IT) analyst, the hospital's implementation team, and the clinical transformation director. The director displayed portions of the proposed, step-by-step, patient-centered work flow template on an overhead screen. Then the system IT analyst demonstrated how to use the electronic health record (EHR)'s electronic forms, order sets, and so on.

For example, in a session on maternal-child patient-centered work flow (Figure 1, page 89), the director posed a series of redesign questions for participants, such as "What do nurses do when a laboring mother reports she is taking a yellow pill?" This question was followed by "What steps will happen to allow us to evaluate interactions during hospitalization if we have documented a yellow pill?" These questions helped participants identify variations in how nurses handle the unknown home medication in current care processes and ways that this gap could be addressed with the help of HIT.

For the maternal-child work flow, two neonatal nurse practitioners (NNPs) reported the need to adjust ventilator settings frequently during the first few hours after birth. In the current (paper) process, each modification required a separate order. In response to this input, the work flow was reconfigured to allow NNPs to enter a single ventilator order and modify the order after any adjustments rather than entering a new order each time. The EHR then displayed an easy-to-follow history of order modifications for the newborn.

that addressed gaps found in each hospital and clinic. Clinicians and physician champions improved proposed care processes and standardized many practices that had previously varied unnecessarily. Once agreement was reached, the revised work flows were presented to all clinicians on the intranet.

Completed patient-centered work flows provided trainers with scenarios for training all clinicians in EHR usage. Clinicians were given opportunities to role-play using intranet-posted work flows.

Course of Implementation

In 2005, Phase I of implementation was completed at all TH hospitals, resulting in increased data use and in averting of potential ADEs through pharmacist-initiated contacts with physicians. In May 2003, the first hospital to launch into Phase II EHR with CPOE and single work-flow process designs identified missing processes for patient cost-accounting of care, care planning, decision support, quality reporting, physician discharge summary, and prescribed home medications. Because financial gains would be nonexistent without financial work flows, implementation at the next two hospitals was delayed until 2004, when these additional work flows could be added. The resulting implementation at these two hospitals did improve cost recovery, as anticipated.

TH completed four implementations in 2005, two in 2006, two in 2007, and two in 2008. None of the implementations were aborted or delayed beyond 24 hours. By the end of 2008, five years after the launch of Phase II, 13 organizations had completed the Phase II implementation. Implementation for the remaining 4 organizations is slated for 2011.

Monitoring Implementation

To monitor implementations, the health system tracks on a round-the-clock basis all phone calls from each hospital, with issues (for example, devices, interfaces, software defects, file errors, upgrades, enhancements, access requests) logged by application and by organization. Each issue is prioritized on a scale of one to seven (one, any life-threatening or patient care critical issue; seven, system access requests). No high-priority issues were reported.

In addition, each hospital monitors a wide range of indicators on a monthly basis, including Centers for Medicare & Medicaid (CMS) clinical indicators, financial performance margins, lengths of stay, errors, and any issues reported. More specifically, the EHR–based redesign reinforced TH's capacity to implement evidence-based practice, quality, and patient safety across many sites using work flow. Dependence on the EHR and its availability directly affects the flow of patient care. Therefore, the system HIT staff reported on the time (in seconds; 0.7–3 seconds) required for clinicians to access patient information. Overall, the EHR operational availability within a year is cumulatively at 99.96%, down times are rare, and unscheduled events or scheduled upgrades are both supported by the backup-data center.

In May 2003, one of the system indicators, physicians' CPOE rate, resulted in monitoring of other work-flow steps, such as clinician order management. (The CPOE rate was defined as all physician entered orders, physician protocol orders, and allied health provider entered orders divided by total orders.) As of June 2007, nurses, pharmacists, and therapists were managing more than 300,000 orders per day that were placed or updated by physicians. In hospitals with an EHR, physicians entered more than 85% of the emergency room orders using CPOE.[33]

An average CPOE rate of 70% has been sustained since 2005 in hospitals with an EHR.[33,34] By 2007, clinician work flows had (1) increased nursing time at the patient's bedside by

Portion of Maternal-Child Patient-Centered Work Flow

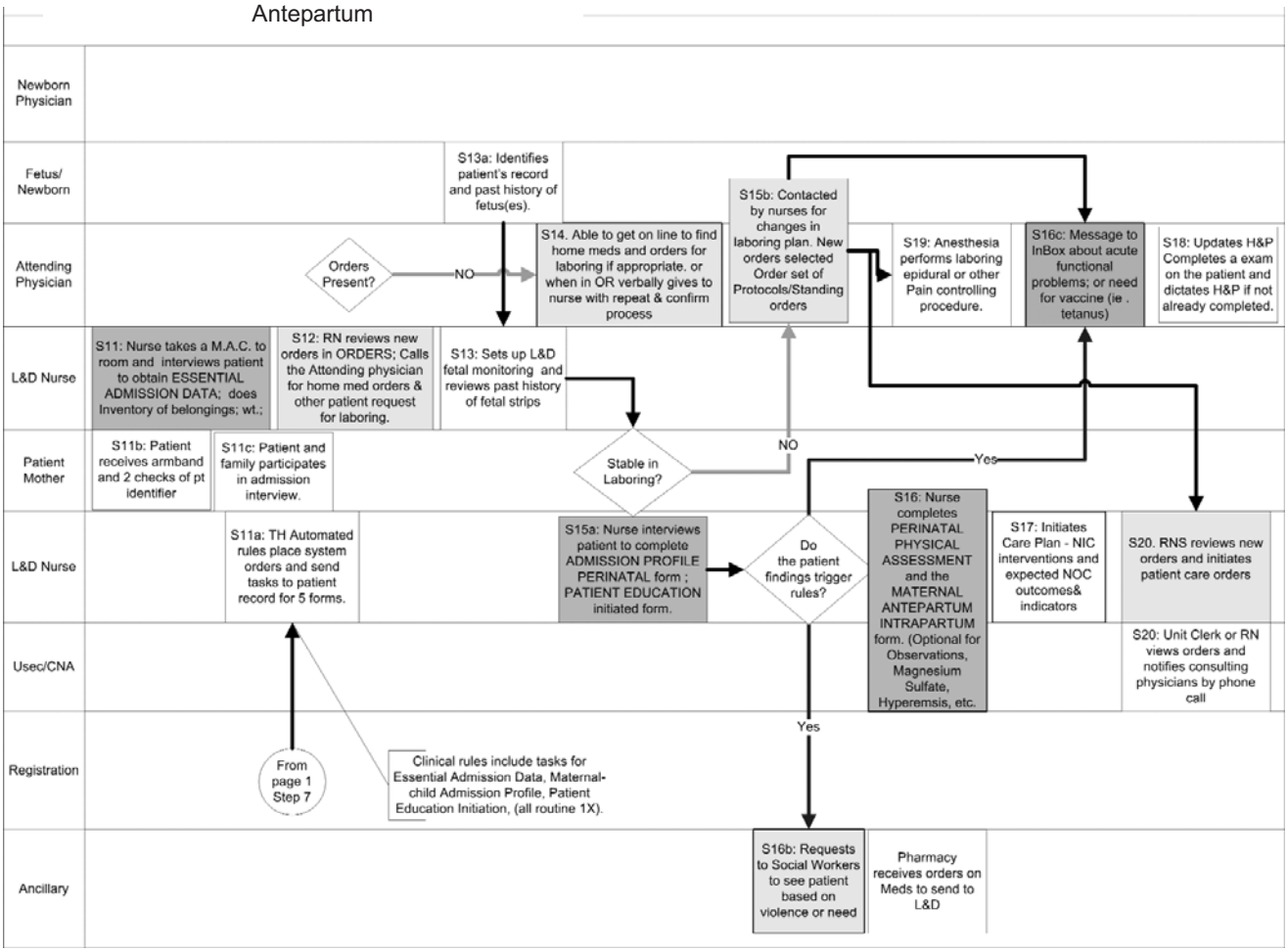

Figure 1. *The example illustrates the activity steps of the patient interactions with clinicians and EHR systems within the antepartum portion of a maternal-child patient-centered work flow. OR, operating room; H&P, history and physical; M.A.C., mobile access computer; wt., weight; RN, registered nurse; L&D, labor and delivery; QS, fetal monitor; TH, Trinity Health; NIC, nursing intervention classification; NOC, nursing outcome classification; RNS, registered nurses; Usec, unit secretary; CNA, certified nursing assistant; UC, unit clerk.*

8%, (2) resulted in 40% faster delivery of urgent medications, (3) increased assessments for patients at risk of falls and pressure ulcers, and (4) increased immunization reminders and drug alerts.[35] Overall, after implementation the system reported decreasing average length of stay (0.25 days) and increasing financial margins (Table 5, page 90). The hospital clinicians increased compliance with Joint Commission standards (for example, surgical site checking,* high-risk drug administrations,† and National Patient Safety Goals for reading back verbal orders and medication reconciliation between home and hospital orders‡.

TH's HIT team visited departments/units and held meetings with clinicians, nurse managers, and informatics specialists in each hospital a month after EHR activation. Preliminary evaluations document practitioners' widespread acceptance of the EHR and of patient-centered work flows.[33–35] These early evaluations confirmed growing user comfort with the work flows/EHR and declining requests for technical support. EHR usage has become routine and has replaced 80% of paper

* Standard UP.01.02.01. Mark the procedure site. In The Joint Commission: *2009 Comprehensive Accreditation Manual for Hospitals: The Official Handbook*. Oakbrook Terrace, IL: Joint Commission Resources, 2009, pp. NPSG-21–NPSG-22.

† Standard MM.01.01.03, pp. MM-4–MM-5.

‡ Goal 2. Improve the effectiveness of communication among caregivers, pp. NPSG-5; Goal 8. Accurately and completely reconcile medications across the continuum of care, pp. NPSG-14–NPSG-17.

Table 5. Overall Health System Indicators During Years of Electronic Health Record Implementation

Indicators	2004	2005	2006	2007	2008
Average Length of Stay	4.89	4.64	4.46	4.43	4.46
Operating Margin	2.65%	2.75%	5.87%	5.3%	5.7%

records. With respect to the maternal-child antepartum work flow (Figure 1), the nurses collected more standard admission data with the EHR, and DSS tools evoked automated messages to social workers and dietitians for rapid follow-up on potential problems. Yet, HIT still cannot integrate data from the fetal monitoring devices into the EHR; as a result, nurses have to produce duplicate documentation.

Discussion

Implementing an EHR led to cost savings and gains in productivity within the medical record and information management departments because very few items were left on paper documents.[33] Yet, one cannot attribute the cost savings and other improvements solely to technology. System and hospital clinician involvement in development and implementation of patient-centered work flows fostered acceptance of change and helped align EHR documentation with best clinical practices and with accounting procedures. The clinicians understood how the order sets and documented patient data were used by other disciplines. The contributions of user involvement toward acceptance of technical and administrative innovations have been documented in other industries, as well as in health care.[36,37]

The patient-centered work flows helped EHR designers avoid oversimplification of care processes and omission of crucial interactions among clinicians. These are well-documented risks with EHR and CPOE,[38] which sometimes produce unintended consequences.[6,25,26] Steps in the patient-centered work flows represent opportunities for clinicians, quality experts, and local change agents to reduce care variations (for example, patient discharge instructions), apply evidence-based practices (for example, in the pneumonia order set), and seek solutions to quality problems (for example, documenting intravenous catheter site and status), as well as to improve their performance (for example, heart failure discharge education).

In addition, the work flows provided stronger support for multiple uses of EHR data than traditional single-process work flows. TH used the EHR to improve care provision, rather than just model existing, problematic care processes, as some HIT projects have done.[28]

EHR implementation posed several challenges that may also arise in other systems. First, the vendor's off-the-shelf EHR lacked standardized evidence-based content. TH had to provide the content configuration before it could construct patient-centered work flows and align the EHR design to its own priorities. To build its own content and clinical work flows, TH had to hire professionals trained in clinical informatics and transformation techniques. Although this standardization process was costly, the principles introduced through standardization were valuable in redesign work sessions. Application of these principles also helped TH improve its financial margins and address accreditation and regulatory requirements.

A second challenge involved synchronizing development of DSS tools with patient-centered work flows before training clinicians on new care processes. Critical functionalities were not always purchased at the start of the preparatory period. For example, in one hospital emergency room (ER), the hospital implementation team had to adopt the system's ER patient-centered work flow just days before starting staff training. Fortunately, the ER physician champion and staff successfully adopted the template and improved the work flow.

A third challenge involved freeing clinicians from clinical duties so they could participate in care redesign and HIT training. At the urging of TH's top management, all hospitals ensured sufficient staff involvement in EHR preparation by releasing full-time staff from some clinical duties and assigning extra hours to part-time or temporary staff. When clinicians participated to make work-flow decisions, preparations moved forward.

What lessons can be drawn from TH's experience in EHR–based process redesign? First, advanced work on patient-centered work flows, as opposed to more common single-process work flows (for example, blood order), can significantly reduce the need for EHR modifications after activation. The hospital implementation teams discovered that the single-process work flows did not adequately reflect the complex flows of everyday patient care. Single-process work flows overlooked important interactions among staff and omitted communications to and from patients. As a result, after activation, many changes were needed to represent communication and care

steps that had been oversimplified or overlooked completely. When subsequent hospitals and clinics shared patient-centered work flows across sites, clinical staff quickly recognized how other clinicians were delivering services with information technology, using evidence-based order sets and electronic forms, and were introducing new ways of managing care.

Second, a clinician learns HIT use through role-play of care practices. To facilitate role-play, patient-centered work flows were used in training about care transformation, not just EHR use. After training, clinicians were able to practice steps to deliver patient care with the EHR, as reflected in patient-centered work flows. In the early days of implementation, interactions with the EHR technology were reinforced through repetition. A related challenge was how to encourage physicians to engage in role-play. This was accomplished through just-in-time training and support that demonstrated EHR safety features and evidence-based content and that showed how to communicate information to those who must decide, perform, or evaluate care. The principles for patient care embodied in the EHR were unarguable. Physician advisory teams used these safety and quality messages frequently in their meetings with clinicians on work-flow redesign.

Third, the organizations that were most successful in finding clinician change agents experienced fewer problems with EHR implementation and sustained high usage of CPOE within a few days of implementation. Overall, the history of CQI training provided a culture for change management and encouraged involvement of people closest to the processes to participate in redesign and adoption of change.

Overall, the evolution of HIT implementation has significantly changed from the initial start-up in 2001. Preparations for the big-bang approach involved seven essential milestones. The first two milestones were to assess the physician and hospital's awareness of the new HIT and to identify resources to support its implementation. The third milestone was to analyze faults within current processes and to redesign better processes in preparation for the EHR. After redesigning care, the remaining milestones were to complete the content build, test acceptance, train, and establish cutover and activation of the new processes and the new HIT. Clinicians were thus engaged early in the preparatory steps well over a year before big-bang implementation. One clinic, for example, took up to 1,500 hours to prepare its standardized designs and work-flow templates.

Although worthy of examination, TH's IT initiative is unlikely to be fully replicated. Unlike executives in less well-integrated systems, TH's leaders could mandate comparable IT changes across an entire integrated delivery system and could generously support local implementation with system resources. In addition, many of the TH facilities employed hospitalists, who, unlike many attendings and residents, only had to learn to use a single IT system. These employed physicians may also have been less able to resist management-driven HIT initiatives than are physicians with multiple referral options. There may also have been distinctive or even unique technical features of some of the original commercial IT products or the TH customizations. TH's carefully coordinated program, with its simultaneous, systemwide EHR activation, departs from the more popular incremental approach to HIT implementation.

Moreover, TH's capacity for customizing content in vendor products distinguished it from organizations seeking to install off-the-shelf products. Like TH, other systems that have successfully installed sophisticated HIT products typically report that they customized and refined the IT through close and long-term work with users, vendors, consultants, and internal designers.[5,17,39] Additional case studies of HIT implementation will help us further understand the distinctive contributions of these and other features of the TH approach and will produce more robust guidelines for successful implementation.

Conclusion

The TH experience suggests that redesign of clinical care can provide a solid foundation for introducing advanced HIT within a large health care delivery system. This approach requires development of substantial internal capacities in clinical informatics, customization and standardization of content within vendors' products, and careful coordination between system and hospital implementation teams. The initiative also requires significant participation in planning by clinicians and local change agents. J

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