**AHRQ Final Report**

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Data Flow and Clinical Outcomes in a Perinatal Continuum of Care System
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**Principal Investigator:**

Donald Levick, M.D., MBA
Chief Medical Information Officer
Lehigh Valley Health Network
124 S. Cedar Crest Blvd. Suite 205
Allentown PA 18104

**Team Members:**

Chad Meyerhoefer, Ph.D
Associate Professor, Department of Economics
Lehigh University
Susan Sherer, Ph.D.
Professor, Department of Management
Lehigh University
Mary Deily, Ph.D
Professor, Department of Economics
Lehigh University
Shin---Yi Chou, Ph.D
Professor, Department of Economics
Lehigh University
Michael Sheinberg, M.D.
Department of Obstetrics/Gynecology
Lehigh Valley Health Network

**Organization:**

Lehigh Valley Hospital
120 S. Cedar Crest Blvd.
Allentown PA 18103

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**Federal Project Officer:**

Ellen V Makar, MSN, RN---BC, CCM, CPHIMS, CENP

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**STRUCTURED ABSTRACT (250 words)**

Purpose: Integration of electronic clinical data across the continuum of care has become a critical success factor for high quality care. We evaluate the impact of interfacing clinical data across the perinatal continuum of care on birth outcomes, physician productivity, and provider and patient satisfaction.
Scope: The study was performed at a tertiary health system and involved several OB Gyn community based practices, a hospital based clinic concentrating o under---insured patients, a high risk pregnancy practice, and a full service labor and delivery service at the hospital.
Methods: We use mixed methods that include both qualitative and quantitative methods. The former involved structured interviews of 75 providers over the study period while the latter involved econometric analysis of data collected by the authors on data transmission, physician productivity, birth outcomes, and provider and patient satisfaction.
Results: Physician productivity and satisfaction decreased during the initial phases of EHR implementation and data integration. This was related to acclimation to the new data sources and the need to develop a familiarity and trust of the data. Over time, and with increased integration of the data, productivity and satisfaction increased; although productivity did not return to pre---implementation levels in all areas.
Quality of care, as measured by a standardized adverse outcome index, improved slightly, related to specific data elements and documents being made available across the continuum of care. We also found that the electronic transmission of some types of clinical information was more important to improving birth outcomes than other information.
Key Words: electronic health records, system integration, data interface, birth outcomes, physician productivity, patient satisfaction

**PURPOSE**

Health information technology (HIT) is now at the forefront of the health care improvement agenda because of its potential to achieve the reductions in medical errors and increases in patient safety necessary to improve clinical outcomes and efficiency. The project studied the impact on maternal/fetal outcomes and provider satisfaction/productivity of the implementation of a perinatal continuum of care information system. This included the implementation of an ambulatory EHR in community based and hospital based OB Gyn Clinics; the implementation of an interface of clinical data between that ambulatory EHR and perinatal information system in place on the Labor & Delivery and Perinatal Triage Units of the Lehigh Valley Hospital. In the process, each of the practice groups migrated from either paper records or a different ambulatory EHR to a vendor supplied commercial EHR. Once implemented, clinical information from each physician office was immediately available when a patient arrived at L&D or Triage, and information from a patient's visits to L&D or Triage was sent back to the office.

The goal was to use both qualitative and quantitative methods to evaluate the impact of this system, and the ability of an integrated EHR to address a recognized failure to deliver accurate, complete, and timely data to physicians and clinical staff at critical clinical points along the perinatal continuum of care.

There were four **specific aims:**
**Aim 1:** Develop grounded theory to describe the process of effective implementation and integration of vendor---supplied ambulatory EHR systems with hospital information systems through qualitative analysis of technology acceptance and use, and complementary organizational and process changes.

**Aim 2:** Examine quantitatively the change in data completeness (complete and accessible data) at the hospital and at the individual practices resulting from the adoption of the integrated EHR system.
**Aim 3:** Examine quantitatively improvements in health outcomes, staff perceptions of patient safety, and patient and medical staff satisfaction, as well as changes in the productivity of primary care and inpatient physicians.
**Aim 4:** Using mixed methods, triangulate the results of the quantitative and qualitative analyses to gain a deeper understanding of how to achieve benefits from an integrated EHR.

**SCOPE**

Improving the health care delivery system in the United States has become a leading policy issue as high costs and poor population---based measures of health care access, quality, and outcomes have been demonstrated relative to other industrialized nations.

Because of its potential to achieve the prescribed reduction in medical errors and increases in patient safety necessary to affect any meaningful progress towards improvements in clinical outcomes and efficiency, health information technology (HIT) is now at the forefront of the health care improvement agenda. One application with great promise is an integrated electronic health record (EHR) that makes a patient's clinical data instantaneously available to all providers throughout a given episode of care, regardless of the location of service provision (hospital, primary care practice) or provider (specialist, primary care physician). Such a system could facilitate coordinated treatment, improve clinical decision making, and reduce the underuse, overuse, and inappropriate use of medications and diagnostic tests.

Many medical errors are attributable to poor communication when a patient transfers from primary care to acute care and back again. Perinatal care in particular requires access to timely information by different providers because the perinatal process is inherently fragmented, with the risk of complication amplified by poor information flow across a given episode of care.[1] Currently, most episodes involve different practices, clinicians, and patient risk profiles, without a single source for data reporting, recording, and monitoring. Timely access to perinatal test and lab results has also been a challenge. Miller reports that prenatal records are either pending or never available 57% of the time at birth, and that it generally takes 1.4 hours to retrieve missing data.[2] LVHN decided to implement, customize and evaluate a specific commercial EHR system at the outpatient OB/GYN practices (where all clinicians are employees of the network), and link it to a companion system in the Labor and Delivery Unit of the network's main hospital, Lehigh Valley Hospital---Cedar Crest (LVH---CC).

LVH---CC delivers nearly 3,900 babies each year, almost all of which are handled by the Lehigh Valley Physicians Group. There are three primary obstetrics care practices in the network: The Center for Women's Medicine (CWM), which has one office site at the hospital and 10 physicians, College Heights OB/GYN, with four sites and 13 physicians, and OB/GYN Associates, with three sites and 9 physicians, 3 nurses practitioners and 1 certified nurse midwife. When expectant mothers who are patients of one of the network obstetrics practices think they may be in labor, they go to LVH---CC's L&D Triage Unit, where their condition is evaluated. The physician on duty either formally admits the patient to the L&D Unit or discharges them back home. Exceptions to this general organization involve the treatment of more

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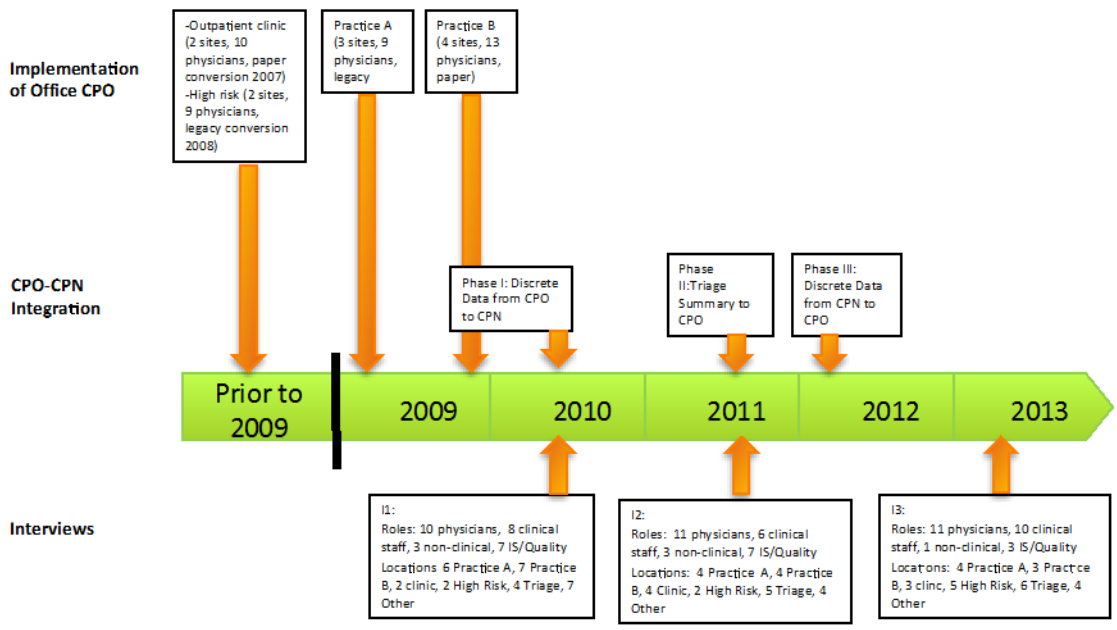
[1] Cherouny P, Federico F, Haraden C, et al. Idealized design of perinatal care. IHI Innovation Series white paper, Institute for Healthcare Improvement, Cambridge MA 2005

[2] Miller DW, Yeast JD, Evans RL. The unavailability of prenatal records at hospital presentation. Obstetrics and Gynecology. 101, 87 (2003)

complex cases, such as multiple births, ectopic pregnancy, or eclampsia. Primary care in these high risk cases is provided at the hospital in the Division of Maternal and Fetal Medicine (MFM), which has nine physicians, either in place of or in collaboration with one of the regular obstetrics practices. However, high risk patients also report to Triage if they think their labor may have started, or for other medical problems such as urinary tract infections, and again are either admitted to the hospital or sent home.

Medical records and information must flow from the OB/GYN practices to the Triage sub---Unit of the L&D Unit, from Triage back to the practices every time a patient is seen but is not admitted, and again from the practices, through Triage, to L&D once a patient is formally admitted. Previously, records were transmitted by courier or fax, methods that have proven inadequate. LVHN then implemented an HIT solution that enabled two---way exchange of patient data between a commercial, certified ambulatory EHR and the inpatient EHR and data systems in order to improve data access and completeness at all points in the perinatal continuum care. The process of installing and linking the systems took place in three phases: In Phase I, the OB/GYN practices implemented the ambulatory EHR (GE's Centricity Physician Office, or CPO) and discrete data elements were interfaced over to the perinatal information system utilized in the inpatient Triage and L&D Units (GE's Centricity Perinatal system, or CPN). In Phase II, visit summary documents (i.e. triage discharge summaries) were interfaced from the perinatal information system to the ambulatory EHR. In Phase III, discrete clinical data elements collected during Triage visits were interfaced from the perinatal information system to specific locations in the ambulatory EHR user interface. See the figure below, which describes the implementation of the ambulatory EHR (CPO) and the timeline for its interface with the perinatal system (CPN). This figure also describes when we interviewed providers for our qualitative analysis:




We used qualitative methods to identify process changes necessary to prevent or mitigate unintended consequences during the EHR implementation. We gathered information during the entire period of implementation, integration, and customization, as problems took time to surface. Through carefully designed surveys and structured interviews, our evaluation included input from clinical staff and providers in all the outpatient and inpatient settings. At the same time, we evaluated the benefits of the integrated EHR quantitatively, using data from the hospital administrative and clinical databases, supplemented by information collected through surveys and interviews. We employed advanced econometric methods to identify the impact of adopting an integrated EHR on the availability and completeness of key clinical information, adverse birth outcomes, patient satisfaction, and staff productivity and satisfaction.

Finally, we triangulated the quantitative measures of improved outcomes with process changes made at different provider locations to validate grounded theory regarding how specific redesigns to work flow or operational protocols influence the realization of different benefits made possible by the integrated EHR. In addition, joint analysis of our survey data on the availability and completeness of clinical information at each location in light of qualitative information on process changes and acceptance of the new system by providers allowed us to better understand the role organization change and user attitudes play in insuring complete data. Our evaluation provides basis for estimating the potential costs and benefits from cross continuum HIT systems adopted within a given system of clinicians, systems likely to become increasingly common once standards of interoperability, data exchange, and confidentiality at regional, state and national levels are developed.

## METHODS AND RESULTS

Several studies were undertaken to produce the results for this project. Abstracts of the output from the project provide the detail for the methods and results.

The first abstract provides an overview for the national and local stimuli that have accelerated the implementation of EHR's in the ambulatory and acute care settings. It also provides the first results from the qualitative study of the EHR implementation.

Methods and Results from "The Implementation of a Perinatal Continuum of Care Information System: Lessons Learned" Journal of Healthcare Information Management

**The EHR Imperative**

The U.S. government provided $3 billion for HIT with the passage of the February 2009 American Recovery and Reinvestment Act, much of it intended to modernize, integrate, and link medical record systems. The goal, as stated in the Health Information Technology for Economic and Clinical Health Act (HITECH Act) ---part of 2009 AARA, is to "improve health care quality, safety and efficiency through the promotion of health information technology and electronic health information exchange."

Because of the potential to improve the quality of care, and the stimulus provided by ARRA, electronic medical records (EMRs) are being adopted by healthcare providers across the country at an accelerated rate. While older EMR systems did not facilitate the transfer of information between systems or facilities, policy makers are encouraging the adoption of integrated electronic health records (EHRs) that facilitate coordination across the continuum of care.

Federal initiatives including Meaningful Use have been developed to spur design improvements, standardization, and interoperability, so as to increase the efficiency and effectiveness of EHR's. Breakdowns in communication at the transition of care are a common cause of medical errors. In response, integrated EHRs have emerged as priority among HIT applications.

However, there is little information and limited studies pertaining to the transition of care during pregnancy and childbirth. The "episode of care" for pregnancy occurs over a defined period of time, but often involves multiple sites of care: the primary care office, the OB---Gyn office, the Triage Unit (for acute problems during pregnancy), the Labor and Delivery Unit and the "Mother/Baby" Unit. Maintaining current information about the mother and fetus is a challenge in any system.

**EHR Implementation at Lehigh Valley Health Network**

While operating in a best of breed information system architecture during the grant study period, Lehigh Valley Health Network (LVHN) implemented a perinatal continuum of care information system interfacing several systems in the ambulatory and in---patient environments. Information flowed bi---directionally from the ambulatory EHR in the OB---Gyn community based practices to the Labor & Delivery and Triage Units in the hospital.

The primary aim of the research was to measure the impact of the on maternal and fetal outcomes, clinician productivity and on patient and clinician satisfaction. Information was collected through a formal interview and survey process.

**Lessons learned from the implementation included:**

- An increased appreciation of the difference in culture and process between the ambulatory and L&D environments. Understanding workflow analysis and clinician behavior has been a key learning, and

specific examples are provided.

- The technical challenge of developing and maintaining interfaces in a best of breed environment
- The process for determining which data elements to interface
- Workflow analysis to determine where in the workflow to present the interfaced data.
- It is important to weigh functionality of best---of---breed systems vs. integration of the data in a single source system; against the cost of development and maintenance of interfaces between systems. Clinician needs/demands will vary by department and specialty, and must be weighed against organizational values and goals.
- The simple interfaces (ADT data: registration and insurance information usually found in the billing/scheduling systems) are often not clinically relevant. Once users realize that data can be interfaced, they will request more technically challenging (and more clinically aligned) interfaces.
  - More complex interfaces involving clinical data typically involve extensive mapping of data elements, and may also require normalization of clinical data from the disparate sources.
- Interfacing of data does not guarantee usage of the data. Workflow analysis is necessary to understand how/when clinicians use the data, and processes might require re---design for maximal effectiveness.
  - portion of the data in the electronic health record reveals itself to the clinician and a portion needs to be sought out on a "need to know" basis. In the appropriate balance it is an efficient process. Interfaced data is no different with the exception that it's generally not anticipated or expected, but when available it's usually very valuable. An example would be an interim visit for a pregnant woman to triage between her routine obstetric visits in the office. Simple knowledge that the interaction took place would lead to a valuable "fact---finding" mission for the clinician looking for new medication, diagnosis, etc. Interfacing some of those key data elements then leads to higher quality data, better decision making and can improve efficiency.
  - The decision---making process needs to change as the data integration evolves. Documents that flow into the record, interfaced from another record, need varying levels of processing. A summary document from triage that contains a wealth of information about an important hospital encounter might need authentication, data extraction and reconciliation, including the simple recognition that the encounter took place. Creating standard work process around this and delegation to staff by protocol can create efficient work flow.
- The determination of what data should be interfaced and made available is often specialty specific. A detailed understanding of the clinical workflow is essential prior to developing an interface or integration of data.
  - The story in obstetrics is told over pre---defined, 9 month time---frame that illustrates the importance of knowledge and accuracy of continuum of care data. The perinatal continuum represents an anticipated time of change with progression of data points reflecting that evolution: weight, fundal height, blood pressure, cervical dilation, fetal position, etc.
  - In addition to the obstetric continuum, present or absent data points form the basis of many clinical practice guidelines. Frequently, a patient may start her pregnancy with n high---risk factors, then be diagnosed with one or more during the course of care, and end with a different set. Knowledge of this ever---changing "problem---list" is critical to quality obstetric perinatal management.
- It is critical to determine which data elements are absolutely necessary in the design of encounter templates. Once it is determined which data elements will be captured, it is critical to decide which elements can be entered via free text in which must be entered via structured data entry.
  - The desire for robust analytics and population management pushed many of the decisions towards structured data. However, the clinicians involved in the design process provided front---line experience and feedback that highlighted the need for free text entry.
- When possible, allow for modifications of interfaces based on real---world feedback by users. Finding the

appropriate amount of data to transfer that meets the clinical needs is important.

- Transferring too much data between systems would lead to "data overload" and potential loss of efficiency by the clinicians. Others issues associated with data overload include the efficiency that results from having to sort through too much extraneous data. The unintended consequence of this data overload is that the clinician would stop searching for the information altogether. In this case, the clinician reverts back to behavior similar to a paper environment, in which the information is not available at all.
- Transferring too little data could result in the clinician making poor decisions due to inadequate data. Or, could result in inefficiencies due to the clinician having to find a necessary data elsewhere (logging into other systems, delaying care while calling for information, etc.).
- Significant discussions were held among the stakeholders to determine the most appropriate list of data elements to transfer between systems. The decisions were based o available data, ability to transfer the data elements, usability of the data by the clinician, and very frank discussions about which data truly impacted clinical decision---making.
- The IT system implementers anticipated this need for adaptive learning and were prepared for a "phased---in" approach to the interfaces. As the users evolved, they developed the sophistication required to answer more complex questions around discrete data versus summary narratives, embedded versus filed elements and the need for isolated versus trended information.

- Competing priorities (such as Pay for Performance and Meaningful Use) can impact the design of the EHR and the recommended workflow. This must be balanced with the impact on productivity and quality of documentation.
  - Many practices, including those in this project, choose to implement or transition over a short period of time and schedule concurrent decrease in patient volume to accommodate the need for learning and adjustment.
  - Increasingly, the EHR is leveraged for important reasons though in direct competition to the mission of an efficient, quality documented encounter. The ability to capture specific data important to national and local programs for clinical quality is increasingly prioritized. Pay for performance programs and Meaningful Use have all impacted the documentation requirements and workflows in the practices. Often, data requirements specific to these measures could only be captured by the clinician. For reporting purposes, this information had to be captured in the structured data fields, and not as free text in the narrative portions of the encounter note. We found that the numbers of metrics and their increasing frequency of prioritization competed for attention as the clinicians attempted to document meaningful patient encounter.

<u>Methods and Results from "Integrating commercial ambulatory electronic health records with hospital systems: An evolutionary process." Int J Med Inform</u>

This study addressed the research questions: How do users achieve coordinated care goals via information sharing with integrated health records? How do their views evolve and how do they adapt their usage of EHRs to achieve their integration goals? A grounded theory approach was employed, using longitudinal case studies to build theory.

We conducted a qualitative study using an interpretive philosophical perspective, with a longitudinal multiple case embedded design[3]. Each case was an individual practice location and each participant was a

[3] Yin R K. Case Study Research: Design and Methods, 4th edition. Los Angeles, Sage Publications. (2009).

unit of analysis. The study was embedded in a large scale mixed method analysis of the benefits and challenges associated with the introduction and integration of EHRs. In addition to 76 one---hour interviews with both clinical and non---clinical staff participants, we reviewed workflow change documentation and meeting minutes of various committees throughout a five---year implementation and integration process.

We transcribed and coded all qualitative data with NVIVO software, using two coders to ensure reliability and consistency. Interpretations evolved through the iterative analysis of the information within this context. Data collection and analysis occurred iteratively, consistent with grounded theory procedures[4] [5]. Four core conceptual categories emerged: value, reengineering, facilitators, and unexpected consequences, similar to four of the Cs in Glaser's coding family[6] consequences, covariances, causes, and contingencies. In order to ensure that our conclusions are robust, we used multiple sources of data (archival data and interviews) for construct validity, and multiple informants from different hierarchical levels and functional areas to limit bias[7].

**Results**

Analysis of the density of coded comments within the four major conceptual categories revealed an evolution of user focus across three phases, from acceptance to adaptation, and finally coordination. Almost one half of the nodes coded during Phase I of the study were related to (1) facilitating acceptance of an automated clinical documentation tool as a result of performance and usage expectations derived from current work practices, or (2) unexpected consequences that arose when these individual expectations did not match the system and organization goals. While there were a significant proportion of nodes coded to reengineering concepts, our analysis showed that many of these concepts focused on changes required by the system, not on process improvements that could support better integration and use. While the system was introduced within existing work practices, it required providers to make substantial changes to their workflows. Process reengineering to support integration occurred later as users became more familiar with the system and its value.

Physician effort expectancy was particularly high due to (1) new work requirements and (2) navigation difficulties. Physicians now were required to complete billing codes themselves as well as additional documentation that were previously not required entries for them. Performance expectancy was much higher while effort expectancy was lower among other staff, particularly due to two major features of the EHRs: (1) integrated and timely lab reporting and (2) lack of need to search for files.

By Phase II, they focused on what was necessary to adapt the system to meet their needs. Most of the coded nodes were focused on unexpected consequences and reengineering to accommodate these outcomes. Many of the unexpected consequences involved conflicts between system usage and optimal cognitive workflow. In addition to adaptation in data entry, many unexpected consequences resulted from issues involved in finding information. In fact, the users focused more on the information within the system, including what had to change to use this information, and how they had to adapt to better utilize this information. There were several types of adaptive structuration: alternative data entry modes through time and field shifting, and poor information retrieval processes.

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[4] Glaser B, A Strauss. The discovery of grounded theory. Aldine Publishing Company Chicago (1967).

[5] Strong D, O Volkoff. Understanding organization---enterprise system fit: a path to theorizing the information technology artifact. MIS Quarterly 34(4): 731---756. (2010)

[6] Glaser B.. Theoretical Sensitiivity. Mill Valley, CA, Sociology Press. (1978)

[7] Eisenhardt K M, Graebner M. Theory building from cases: opportunities and challenges. Academy of Management Journal 50(1): 25---32. (2007)

Data entry processes were adapted via time shifting, for example entering patient information at the end of the day rather than during a patient visit, or field shifting, for example, entering free text rather than (or in addition to) requested entry formats. Dysfunctional data retrieval practices involved system underutilization or avoidance or inordinate amount of time allocated to information retrieval. Whereas previously, when the information was unavailable, the providers just "did the best they could" with the information that they had. Once they knew that more information was available, they felt compelled (medically and legally) to find and review this information. However, this often resulted in inefficient data retrieval processes accompanied by frustration and sometimes a learned helplessness.

One year after completion of phase III, the density of coding continued to focus on unexpected consequences and reengineering, as the system continued to be adapted. During this phase, we saw system design changes required to make the system more useable, particularly for care coordination. While the density of coding to value concepts remained fairly constant, within the sub---node classifications move occurred toward greater focus on the value of the information in order to achieve coordinated care, rather than on productivity and efficiency improvements. However, there were limits to the acceptance and use of the data itself, as many comments centered on issues with trust of data submitted by others. In fact, even when data such as lab test results were available directly within discrete system fields, data verification was still typically done against source lab results, which were now scanned as complete documents within the record.

Since standardization is a critical concept in integration, we analyzed relationships between standardization as a facilitator and value concepts over time. We found that there was a significant change in how users perceived standardization. In the beginning, as the EHR was introduced into the offices, there were concerns about whether and how clinical documentation could be standardized. Providers were accustomed to documenting in their own way, personalizing their notes, in ways that provided visual memory cues. By the end of Phase II, as providers began to use the system and adapt it to their needs, they focused on the unexpected consequences of lack of standardization for information retrieval. If providers documented differently or the scanned documents were entered with non---standard labels, information was not easily located.

By the time that information was flowing in both directions after Phase III concluded, there began to be much more active acceptance of standardization and its value for coordinated care, as users came to appreciate its importance.

By analyzing the relationships between facilitation and reengineering concepts with coordination value, we found changes in the impetus for process reengineering to achieve coordination. In Phase I, most of the complementary changes in roles, work processes, and relationships that typically accompany new systems[8] [9] [10] were driven directly by the system itself. As the system was rolled out, ensuring completion of standard fields for quality reporting and the availability of records across multiple locations required organizationally imposed work processes, including specific policies for completion and sign---off, organizational follow---up via the quality department, and additional training. By the completion of Phase

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[8] Powell T C, Dent---Micallef A. Information technology as competitive advantage: the role of human, business, and technology resources. Strategic Management Journal 18(5): 375---405. (1997).

[9] Davern M, Kauffman R.. Discovering potential and realizing value from information technology investments.
Journal of Management Information Systems 16(4): 121---143. (2000)

[10] Barua A, Konana P, Whinston A. An empirical investigation of net---enabled business value. MIS Quarterly 28(4): 585---620. (2004)

II, there were many individual workarounds to accommodate integrated system problems. One year after completion of Phase II and the system changes, individual adaptation was more aligned with organizational goals for coordination. As users began to value the information that flowed back and forth, they adapted their behaviors to match coordination goals.

Analyzing patterns of discussion related to interoperability, trust, and work process concepts, we found that individuals did not rely on computer integration when data were available through more familiar sources. It was originally expected that direct computer---to---computer exchange of data from the office into the hospital system would be a source of efficiency, since it could enable providers to find information within the same system in which they documented their hospital visits. However, the transfer of data from the office system (CPO) directly to the triage system CPN never became a useful feature for the providers because (1) dataflow were unreliable; (2) access was not within standard workflow; and (3) CPO office records provided alternative access to the same information and became directly accessible from the hospital when CPO terminals were installed on inpatient L&D unit. On the other hand, the direct computer---to---computer data transfer from the triage CPN system to the CPO system was much more valued because the triage summary provided information that was previously unavailable in the ambulatory practices and the discrete data were directly within the workflow of the providers.

**Discussion**

Results show that implementing and integrating EHRs is an evolutionary process. The users' vision evolves from viewing EHRs as an automated clinical document tool (Phase I) to a clinical information retrieval and management tool (Phase II) to a system for care coordination (Phase III). This is a multi---step process, requiring system use and complementary process change, first requiring acceptance, then adaptation to individual needs, especially regarding information retrieval, and finally, learning what data to trust.

Results also show that software interoperability is not the only way to coordinate. In fact, because users trust familiar sources, electronic exchange may not be the most useful mechanism for information sharing, particularly if the information exchange is not trusted. Even if information is provided in more efficient ways, it is trust in the information source, not software interoperability that is critical for information sharing. Simple introduction of system does not enable complete integration and coordination. While the goal of health care integration is reciprocal interdependence, we found that it required time and organizational effort with progression first through several stages of coordination.

Pooled coordination through standardization, the first coordination mechanism accompanying the implementation of the EHRs, was initially threatened by user response to the system. To generate standard metrics, LVHN instituted a single patient ambulatory EHR used by all specialties. These included specific fields that the providers were to use in order to capture and report on quality statistics. However, as LVHN rolled out the system, they found that some providers preferred free text input, which threatened pooled coordination.

As the system was integrated, sequential coordination mechanisms were required. Final completion of the documentation of the office visit or encounter by the physician, referred to as a "sign---off," was required to make the system available to other users. Also the triage provider had to select an ambulatory practice in order for that practice to receive the triage information. If she failed to do so, the information would not flow to any of the outpatient providers. The organization initially had to develop policies to enforce sequential coordination.

As physicians began to use data in the record as a source of information, particularly as the office---based physicians saw the value of the data flowing back from the hospital, there were additional adaptations to standardize where and when data were recorded. Individuals were more apt to work together to develop standards that enabled improved information retrieval. As providers saw the value of the data, they adapted their behaviors.

**Conclusions**

Commercial off---the---shelf EHR, which is expected to be the most common form of implementation as health networks scramble to comply with federal regulations, is challenging to integrate within existing applications and health care processes. Simply implementing clinical documentation tool without explicit attention to work practice change can result in adaptations that may not match organizational aspirations. Traditional technology acceptance factors, especially performance and usage expectancy, are critical to understanding the initial acceptance and use of EHRs. Enabling individuals to customize the application can make the initial implementation more palatable to users concerned about standardization, but over time they begin to recognize the role of standardization for information retrieval, and subsequently, for care coordination. Structural adaptations will occur, with some unexpected consequences, especially for coordination. System and process changes are required to foster reciprocal coordination, some of which will require organizational imposition and system change. Over time, as more information is integrated, trust in the information becomes a critical factor. Time is needed in order to achieve the goal of reciprocal coordination, and continued training is critical.

When multiple systems are used within a health network, integration of data from one system to another presents specific challenges. Information that is "pushed" from one system to another can be unreliable, in part because cultural differences may not be fully understood. Trust in information can be more useful than interoperability. People will use systems with which they are most familiar, where it is easiest to find the information, and when they can trust the veracity of the information.

<u>Methods and Results from, "A Mixed Method Study of Information Availability on Pregnancy Outcomes" Annual Workshop o Health IT and Economics</u>

We fill a gap in the literature by directly estimating the effect on patient outcomes of the availability of specific types of clinical information necessary for the proper management of pregnancy. In our study changes in information availability over time result from the installation of an EHR system at outpatient OB/GYN offices and its subsequent interface with the hospital's EHR system on a subunit of the Labor and Delivery Unit called Triage. We consider the independent effect of several different pieces of clinical data o outcomes that are sensitive to information availability at the OB/GYN offices as well as outcomes sensitive to information availability on the inpatient Triage Unit, and determine which specific data elements are most important.

We surveyed providers directly at the point of care about their access to patients' historical clinical information, and control for the actual availability of this information in the electronic record, in order to isolate the impact of information perceived by providers. The surveys asked providers to indicate whether each of seven pieces of clinical information from patient's prenatal record was available for review on Triage. Specifically, we asked providers about information on blood pressure, cervical examinations, the antenatal problem list, non---stress tests, group B strep tests, the prior uterine incision type(s), and tubal sterilization requests (for Medicaid patients only). These pieces of clinical information were determined by

LVHN physicians as being most important to the proper management of pregnancy cases on the inpatient Labor and Delivery Unit.

We administered our outpatient surveys at the OB/GYN offices between June 201 and April 201 over three rounds; each lasting between three and four months. In this case, we asked providers whether they were aware the patient had recently visited the inpatient Labor and Delivery Triage Unit, and how they knew this information. We then asked whether information on cervical examinations, non---stress test results, new diagnoses, and laboratory work from the patient's most recent visit to Triage was available for review during the office visit.

The timing of both surveys was contemporaneous with the deployment of an integrated system designed to increase the flow of clinical information between the outpatient and inpatient settings. The various stages of implementation coincided with the timing of the survey collection.

Concurrent to our quantitative data collection, we qualitatively investigated how providers accessed clinical information and what process changes affected information availability during and after EHR implementation. We reviewed archival data, such as hospital staff meetings and workflow change documentation, and conducted approximately 75 interviews of personnel (providers and staff) both in the offices and the hospital, at three points in time throughout the implementation process. Interviews focused on implementation facilitation, workflow changes, process reengineering within the offices and the triage unit, and attitudes towards the system and the implementation process.

We used multiple regression to determine whether greater clinical information availability, as measured by the indicator variables constructed from responses to our Triage and office surveys, was associated with improvements in pregnancy outcomes and changes in care processes.

All our specifications include variables to control for variation in individual patient characteristics and the baseline risk of adverse birth outcomes. These include the mother's age, race, insurance status; the mother's admission type; whether she had one of several pre---existing conditions; whether she had one of several non---preventable birth complications; whether she had a previous C---section; whether her delivery was a multiple birth; and indicator variables for her quartile in the patient risk distribution based on DCG/HCC patient risk scores. In models of pregnancy and birth outcomes (but not care processes, we also control for the delivery type.

**Results**

For nearly all measures, with the exception of tubal sterilization requests for Medicaid patients, perceived data availability in Triage increases over time. We expect that the trend is explained by the deployment and improved functionality of the EHR system over the same time period.

We find that the availability in Triage of both non---stress results from the patient's prenatal record, and tubal sterilization requests for Medicaid patients are significantly associated with reductions in the likelihood of obstetric trauma. Both pieces of clinical information are associated with a 7 percentage point reduction in obstetric trauma, which is 100 percent of the mean level of obstetric trauma in our estimation sample. We find that information on cervical exam results, the antenatal problem list, non---stress test results, and the group B stress test result were all associated with a higher probability of labor induction. The availability of several data elements in Triage (cervical exam results, blood pressure, the antenatal problem list, and the group B strep test) were associated with lower likelihood of performing a C---section delivery.

While none of the information availability indicators are precisely estimated for preterm birth, the availability of the results from lab tests performed on Triage at the OB/GYN offices was associated with a reduction in the probability of preterm birth of 5 percentage points. The availability of lab test results, cervical exam results, and new diagnoses found at Triage were all associated with a reduction in the probability that the baby had low birth weight.

While our results indicate that perceived information availability increased over time, our interviews suggest that providers did not always obtain information from the automated user interface. With the exception of blood pressure information, which was frequently in the inpatient EHR and reported as available, providers most often reported that data elements were available for review on Triage even though they were not present in the inpatient EHR. This is consistent with the finding from our provider interviews that they often accessed the patient's information directly from outpatient EHR terminals installed on Triage rather than from the interfaced data that was theoretically available through the inpatient EHR. Moreover, these results indicate the need for providers to find alternative methods of accessing the patient's prenatal record given the apparent gaps in the completeness of data in the inpatient EHR.

In the period during which data was flowing electronically from the inpatient to outpatient EHR, data elements were most commonly found in the EHR, but reported by providers as not available, indicating that providers had difficulty accessing the data through the outpatient EHR user interface.

**Discussion and Conclusion**

Our results suggest that the availability to providers of certain types of clinical information from a patient's prenatal record was associated with significant reductions in adverse pregnancy outcomes and birth events. In particular, the availability o Triage of non---stress test results from the prenatal record was associated with significant reductions in the likelihood of obstetric trauma, while blood pressure and problem list data were associated with large reductions in the weighted adverse outcomes score (WAOS). Each of these clinical data elements is important in the prevention of adverse birth outcomes.

The fact that we find that greater data availability on Triage is associated with higher rates of medical induction of labor suggests that often the additional information allows providers to place patients in a higher risk category which in some cases helps providers to more closely monitor patient health and in other cases reduces the need for C---sections.

We also find that more information from Triage visits in the OB/GYN offices is associated with improved pregnancy outcomes, and a reduction in the likelihood in low birth weight, in particular. Triage visits often occur towards the end of pregnancy when pregnant women are close to full term. One possible explanation for our results is that more readily available information affords physicians the opportunity to safely monitor patients with complications in the outpatient setting and help bring those patients to full term before they deliver their babies, thereby reducing the prevalence of preterm births and low birth weight babies.

Although we find that increased information availability over the period of EHR implementation improved birth outcomes, we also find that that the mechanism for increasing information availability was not always directly through the inpatient EHR via the automatic flow of clinical information across the two care settings. Instead, providers on Triage often accessed the prenatal record through outpatient EHR terminals installed on the Triage unit rather than through the inpatient---outpatient EHR interface, as

expected. This was due to several factors. Initially, dataflow from the outpatient to inpatient system was unreliable because data were often missing. Moreover, the outpatient prenatal data required access through a separate tab within the inpatient system that was not part of the standard review of patient history. Thus users did not regularly utilize this feature and many did not even realize that it existed. This suggests that implementation of an integrated EHR system should insure that information access is incorporated directly within standard workflow. In some cases, this will require modifications to existing work roles and processes. Furthermore, we found that users depend upon the information that is perceived to be most reliable, complete, and consistent, even if it requires accessing two separate systems rather than a single one. Users need to trust the information source. Despite the fact that providers on the triage unit often relied on two separate user interfaces to access clinical information, and sometimes did not easily retrieve the information, they felt that information availability improved relative to the period prior to installation of the new EHR system. Moreover, the physicians confirmed that this improved quality of care.

Methods and Results from "The Consequences of Electronic Health Record Adoption for Physician Productivity and Birth Outcomes." Industrial and Labor Relations Review

**Background**

Studies of information technology investments in business suggest that they improve productivity, but that those improvements take time to fully develop, requiring intensive process reengineering to adapt work practices to the new technology. Studies of the productivity impact of EHRs on physicians suggest at most small positive gains, and that the learning period may be lengthy.

However, there has been little or no work examining the impact of EHRs that share data across care settings on physician productivity and the quality of their medical services. A physician's services may be more effective when combined with better information, and the quality of health outcomes for patients may improve. Improvements in quality could also result in the substitution of physician time across tasks if, for example, the time needed to treat complications of pregnancy caused by poor coordination of care is reduced, allowing for more time spent counseling patients during visits.

**Data / Methods**

We use mixed methods to investigate how integration of electronic health records between ambulatory and hospital practices affected physician productivity and birth outcomes at large health network. We collected and analyzed both qualitative and quantitative data generated during the staged implementation of the integrated EHR. The qualitative data came from multiple rounds of physician and staff interviews. Analysis of these interviews allows us to identify common themes associated with the implementation and perceived usefulness of the new technology as experienced by these providers, and provides insight into our quantitative results.

In our quantitative analysis, we estimate the effect of the integrated EHR system on measures of physician productivity, quality of birth outcomes, and clinical decision making using the following linear fixed effects specification:

$$Y_{kit} \quad \beta_0 \quad \beta_1 \quad EHR_{it} \beta_2 \quad LEARN_{it} \qquad \beta_3 \bullet C_{it} \quad \beta_4 \bullet ST_{it} \quad \beta_5 \bullet STS_{it} \quad \rho_k \qquad \pi_i, \quad \eta_t \varepsilon_{ikt},$$

where *k* is the individual physician, *i* is the primary care practice site, *t* is month, and $Y_{kit}$ is a measure of the productivity, birth quality, or clinical decision making of physician *k* of practice site *i* in month t. $EHR_{it}$

is a vector of three dummy variables indicating the current phase of EHR integration and $LEARN_{it}$ is a vector of two variables measuring physician learning at practice site *i* in month *t*. We also include a vector of control variables, $C_{it}$ a a practice site---specific linear trend, $ST_{it}$ its square, $STS_{it}$ and fixed effects for physician, $\rho_k$, practice site, $\pi_i$, and season, $\eta_t$ and $\varepsilon_{ik}$ is a white noise error term.

Our measures of the quality of obstetric services are based on a cardinal index of 10 pre---identified adverse birth events that typically occur during or immediately after delivery. After identifying the adverse events through chart review, we weighted them in accordance with their severity, and summed the weighted values across mother and her baby(ies) for each delivery. We then averaged the weighted index values across all of the physician's deliveries in a given month. Because the distribution of a physician's index values is right skewed with a mass point at zero, we analyze the index using two measures. The first of these is an indicator for whether the weighted index is positive, which reflects the monthly incidence of adverse birth events. The second indicator, which reflects the severity of adverse birth outcomes, is the log of index value, calculated over observations where the index is non---zero.

**Results**

Four major themes related to physician productivity and outcomes were derived from the qualitative analysis. First, significant learning is required, not just for data entry but also for information retrieval. Second, coordination mechanisms take time to evolve, and require the organizational imposition of new policies. Third, information from EHRs should be available within standard workflow or from familiar sources, which often requires significant process reengineering. And finally, as workflow changes and coordination improves over time, increased information availability is valued by the physicians.

Our quantitative analysis indicated that the installation of the ambulatory EHR was associated with an 11% decrease in total wRVUs relative to the overall mean, with a significant decline after initial installation of the ambulatory EHR at the primary care sites, representing one---way integration as ambulatory data became available in the hospital. This is the result of significant learning and work practice adjustments necessary to integrate and coordinate. However, the subsequent interface of the ambulatory EHR with the perinatal EHR in triage in the second stage of implementation was associated with productivity gains. In particular, total wRVUs increased by 8.4 percent after the triage discharge summary was transmitted to the outpatient practices. The impact of stage 3 on total wRVUs was negative but not significant. While none of the marginal effects measuring the impact of the EHR implementation o wRVUs/visit are precisely estimated, the estimates suggest an increase in treatment intensity. The coefficients o the learning variables in the total wRVUs models are not precisely estimated, but suggest a concave learning curve. In contrast, there is a statistically significant convex learning curve for wRVUs/visit.

Treatment intensity increased and birth outcomes improved, particularly after two---way integration was enabled. In particular, we estimate 37% reduction in the severity of adverse birth events, such as harm to the mother or baby during delivery, following all stages of EHR integration.

**Discussion and Conclusions**

The qualitative results suggest that physician productivity after implementation of the integrated EHR was impacted by the need to accommodate learning of new documentation and retrieval practices, adoption of coordination mechanisms, and subsequent workflow adaptations. These results are supported by our quantitative analysis, where we found a persistent 11% reduction in total RVUs, with a significant decline after initial installation of the ambulatory EHR at the primary care sites, which enabled only one way data integration. Total wRVUs increased as a result of the two---way integration enabled through the

transmission of the triage discharge summary, though the total impact of the EHR was never positive, and decreased again during the final stage of EHR integration.

On the other hand, users perceive that having more information available can lead to improved outcomes over time, and our quantitative results show intensity of care increased as wRVUs/visit rose towards the end of the sample period, particularly after the introduction of the triage summary. Further, there was a statistically significant decline in inductions and in the severity of adverse birth events, and, although not significant, downward trends in C---sections and in the incidence of adverse birth outcomes toward the end of the study period.

While the integration of discrete data elements from the perinatal EHR directly into the ambulatory EHR did not significantly impact productivity or treatment intensity, physicians' new ability to view a more complete picture of the patient's pregnancy supports the improvements in quality of care, and downward trends in inductions and C---sections.

While we cannot be certain whether physician induced demand or changes in patient scheduling contributed to higher treatment intensity, our interviews do suggest that increased information availability enabled providers to identify problems and respond with more intensive care.

Methods and Results from "Provider and patient satisfaction with electronic health record capabilities" In draft.

Current research suggests the effectiveness of electronic health record systems (EHR) in reducing costs, raising provider productivity, and improving health outcomes is mixed. Most studies rely on secondary datasets that contain limited or n information on work process changes surrounding EHR implementations, and as a result, can only identify the reduced form impact of EHRs on outcomes. We used mixed methods to determine how different categories of providers, such as physicians, clinical staff, and non---clinical staff as well as patients view the effectiveness of various EHR attributes in improving the flow of clinical information across care setting; reducing the potential for medical errors; and improving the efficiency of health care delivery. Our data on provider satisfaction are drawn from surveys we implemented in 2009, 2010, 2102, and 2013 at OB/GYN practices at a large healthcare network in Pennsylvania. The first set of surveys were conducted either prior to the implementation of the EHR, and the subsequent surveys were conducted over the period during which more advanced EHR capabilities were enabled. We merged these survey data to administrative records containing information on job categories, demographics, and years of experience. We also conducted 75 interviews with physician, clinical staff and non---clinical staff over the same time period, and coded the transcribed interviews using NVivo software to determine common themes in responses. Our data on patient satisfaction were collected from OB/GYN patient surveys on satisfaction with their medical care over the same pre and post--- EHR implementation period. We merged these data to administrative records containing information on patient demographics and illness diagnoses necessary to compute DCG/HHC risk scores.

Univariate and multivariate analyses using the provider survey data indicate that physicians were the least satisfied with clinical information availability prior to EHR installation, but experienced the largest gain in satisfaction with progressively increasing level of EHR---enabled information availability. Nonetheless, physicians and other clinical staff were less satisfied with the ease of EHR use, and other measures of how

the EHR improved their workflow than non---clinical staff. Findings from our qualitative analysis suggest this may be due to additional data entry requirements imposed on clinicians through the EHR. Multivariate analyses of patient satisfaction surveys reflect both the dissatisfaction of clinicians with additional work requirements imposed by EHRs, and their enthusiasm for greater information availability resulting from the systems. Patient satisfaction dropped uniformly after the initial installation of the EHR, but increased following the introduction of advanced information sharing capabilities.

## LIST OF PUBLICATIONS AND PRODUCTS

Meyerhoefer C, Sherer S, et al. Provider and patient satisfaction with electronic health record capabilities. In draft.

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