# The Impact of Health Information Technology on Work Process and Patient Care in Labor and Delivery

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## Abstract

**Objective:** Implementation of health information technology (HIT) is a national priority to improve patient safety, yet little is known about how electronic charting affects workflow and patient care in busy, fast-paced hospital units. Labor and delivery units are high-risk and high-cost environments in which failures in data transmission or delays in patient care can have tragic consequences. We evaluated the impact of the introduction of an inpatient electronic health record (EHR) on clinical workflow in a high-volume labor and delivery unit in a large university hospital in the United States. **Methods:** A work-sampling study was performed before and after implementation. Objective observers recorded workflow activities for 3.5-hour periods over nine work shifts (day, evening, night) during 2-week study periods before and after EHR implementation. Activities were standardized to counts per shift and compared using Wilcox two-sample tests. **Results:** For all health care workers, after introduction of an EHR, direct patient care activities increased from a mean of 12.0 to 15.4 ($P$ = 0.004); computer activities increased from 1.9 to 8.5 ($P$ <0.0001); and personal/idle time decreased from 3.1 to 1.4 ($P$ = 0.0002). **Conclusion:** The introduction of an EHR into a busy labor and delivery setting did not reduce time spent in direct patient care activities; instead, direct patient care activities increased.

## Introduction

In 1999, the Institute of Medicine (IOM) brought the world's attention to the patient safety vulnerabilities of the U.S. health care system and emphasized the need for widespread adoption of electronic health records (EHRs) as a fundamental component of a new health information technology (HIT) infrastructure designed to improve health care quality.[1] Little research has been done on the impact of HIT, such as EHRs and other interventions, on patient care and safety in obstetrics. Given that childbirth is the leading reason for hospitalization in the United States, comprising over 4 million hospital discharges each year, pregnant women and infants are particularly at risk for safety issues,[2] making evaluation of the impact of EHRs on obstetric care especially timely.

EHRs have yet to be widely implemented in the United States,[3] but data on the impact of these systems on patient safety are conflicting. The use of EHRs with embedded clinical decision support (CDS) can improve adherence to clinical care guidelines,[4] shorten the length of in-hospital stay,[5] and improve overall clinical documentation completeness, legibility, and understandability when compared to traditional paper-based medical records.[6, 7] However, a recent, large study suggested that EHRs are not associated with better quality of care.[8]

Additionally, significant barriers have been identified as limiting ready adoption of these systems. The most commonly cited barriers include high implementation costs, poor integration with legacy systems, fear of technology failure, potential for new kinds of errors, and strong physician resistance due to concerns that practice disruption and loss of clinical productivity are inevitable, regardless of the gains in safety and efficiency the technology might afford.[3, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]

Relatively few studies have evaluated EHRs with respect to their impact on clinical work when compared with the larger body of work on the effects of EHRs on physician and/or patient satisfaction, medication error reduction, clinical guideline compliance, risk reduction, and patient outcomes.[21, 22, 23] Of the studies that have evaluated the impact of EHR implementation on clinical work, the systems under evaluation were found to support both ordering and charting activities, but the studies did not report on time utilization specific to clinical documentation alone.[24, 25, 26, 27, 28] In addition, although there is a growing body of research on how EHRs impact nursing care activities, very few studies have focused on how EHRs affect the amount of time physicians spend in direct patient care activities.[21, 25, 29, 30] Finally, we can find no research on the implementation or use of EHRs in the obstetric setting, an area noted to be lagging behind other specialties in EHR adoption.[31] The aim of the larger patient safety health information technology (HIT) study[a] is to systematically evaluate the value of incremental advancements in HIT integration for patient safety and clinical care. This study focuses on the impact of an inpatient electronic obstetric charting system on clinical workflow in a fast-paced, high-volume labor and delivery (L&D) unit.

# Methods

## Setting

This study was conducted in a large U.S. teaching hospital L&D unit between March 2005 and August 2006 with approval of the hospital Institutional Review Board. The onsite hospital clinics manage over 34,000 prenatal ambulatory clinic patient visits per year. The 450-bed hospital handles over 2,600 deliveries each year from the outpatient clinics, outlying health departments, and transfers. Care on the L&D unit is provided by nurses, obstetrics and family medicine residents, and faculty (including maternal fetal medicine fellows and faculty) and certified nurse midwives.

Prior to this study, all obstetric clinical care documentation was handwritten as free-text progress notes or by using specialized forms for inclusion in the official, paper-based patient record. In June 2005, after this study had begun, all inpatient obstetric charting (including triage, admission, delivery, and discharge) was entered exclusively in a hospital-developed, inpatient electronic, obstetric charting system, referred to as “STORC.” By December 2005, outpatient laboratory data were integrated into STORC, so that this important information would be available when women arrived for delivery. Full outpatient data integration occurred in March

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[a] Funded by the Agency for Healthcare Research and Quality (AHRQ), No. HS015321.

2006. The completion of this outpatient STORC implementation meant that all obstetric data were now collected and displayed in a single, integrated system that was available to clinicians providing care at any point during a woman's pregnancy.

Our study examined inpatient work practices before the initial implementation of STORC in March 2005, when all documentation was paper-based, and in August 2006, 5 months after the full integrated release, when all documentation was completed electronically.

## HIT Intervention

STORC is a comprehensive obstetric charting system designed with the concurrent goals of facilitating clinical care, enabling clinical outcomes data collection, and promoting patient safety. Incremental advances in systems and data integration were released in series to enable evaluation of value enhancements with each release. In its final, fully integrated form, STORC:

- Integrates existing, disparate data sources into a single point-of-care clinical application (e.g., laboratory results reporting and admission, outpatient and inpatient integration, discharge, and transfer data).
- Pulls key clinical (i.e., pregnancy dating; medical, surgical, and obstetric history; allergies), laboratory, and demographic data collected during prior visits or from hospital systems directly into note fields for editing.
- Provides clinical decision support relevant to obstetrics.
- Provides shortcuts and other tools to speed up care activities (e.g., default values, tailored pick lists, calculators to estimate gestational ages).
- Prints documents in standardized formats.
- Prints patient educational materials and discharge instructions in English or Spanish.
- Keeps clinicians apprised of current clinical studies and patient qualifications for enrollment and more.
- Does not provide clinical order entry functionality.

Figure 1 shows an example of the STORC interface, and Figure 2 provides an example of STORC documentation output for the paper medical record.

## Study Design

**Work-sampling.** Work-sampling studies seek to identify the tasks clinicians perform at predetermined, discrete time intervals, so that inferences can be made regarding the overall time a clinician engages in these activities during a given time period. We adapted the work-sampling approach utilized by Fontaine, et al.,[32] because this method allows a single researcher to make multiple observations; it works well in clinical settings where staff work is generally restricted to a single physical location (e.g., an inpatient obstetric unit); and it allows researchers to "blend in" more readily in the practice environment, thus reducing the potential for performance bias.[33] Table 1 describes the formal observations and abstractions we used to identify clinical workflow activities.

**Observations**. Observational sessions took place in 2-week blocks on the L&D Unit. A single researcher conducted three, 3.5-hour observation sessions during each of three standard work

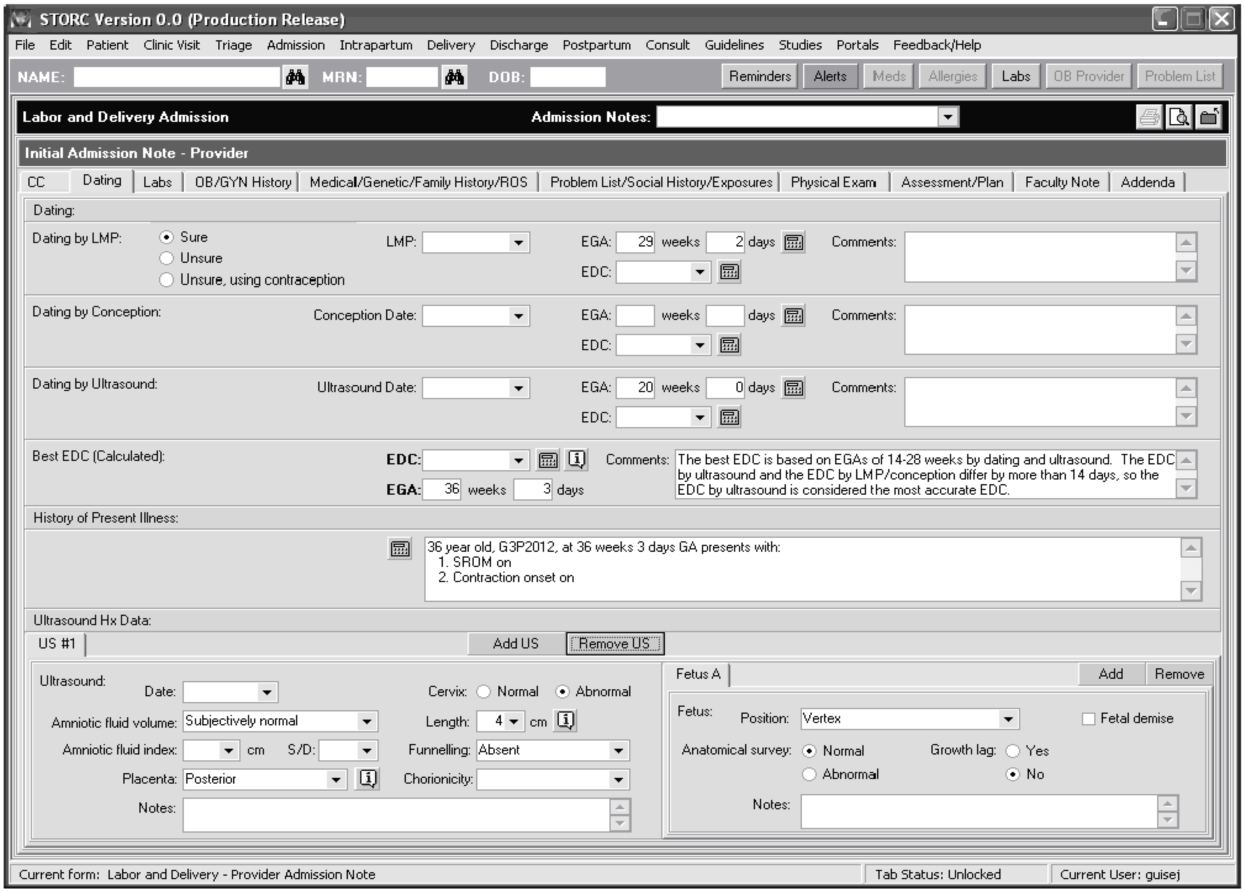



**Figure 1.** Example of STORC interface.

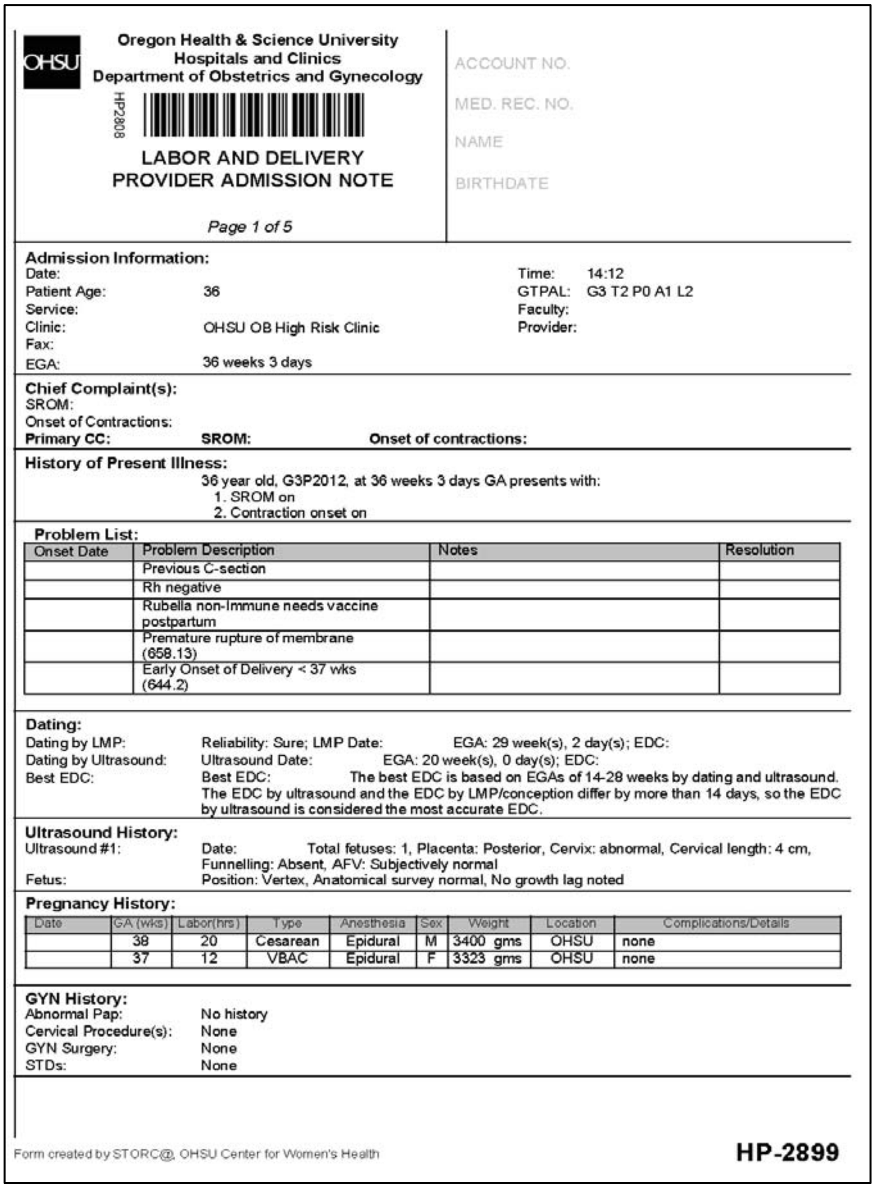
shifts (i.e., 7 am-3 pm, 3 pm-11 pm, and 11 pm-7 am) for a total of nine observation sessions during each 2-week block. Use of a single researcher eliminated interobserver bias; the observational periods were spread across the three daily shifts to assure collection of a comprehensive and representational set of work tasks.

At the start of each sampling session, the researcher obtained a list of the health care providers (i.e., nurses, medical residents, medical faculty) scheduled to work during that period. Nurse midwives were excluded from this study because they have a lower volume of patient care and would not be expected to be on L&D many times, if at all, during the observation period. All providers on duty were randomly assigned observation times throughout a 3.5-hour observation period.

The researcher cycled through the list, observing the work activities of each provider every 10 minutes, using an obstetric workflow abstraction form to record the observations. When the next provider could not be located in any L&D room, the activity was listed as “off floor,” and the next provider on the list was located for observation. Providers had the option to decline observation; in these cases the observation for that provider for the specific time interval became “declined participation.” When providers were in patient rooms, the provider was assumed to be involved in direct patient care activities and recorded accordingly. When a provider was involved in simultaneous activities, one of which involved direct patient care (e.g., talking with a patient’s family member while on hold on the telephone), the researcher recorded the direct patient care activity as the primary activity.

## Statistical Analysis

The main outcome of interest for this study was the counts of clustered clinical activities prior to the implementation of STORC in the inpatient setting and 1 year after STORC was fully operational. All analyses were performed using SAS®/STATS software release 9.2 (SAS Institute, Cary, NC). Provider type and the ratio of nurses to patients (used to assess unit workload) in the two observational periods were compared using Chi-square and Wilcox two-sample tests.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HP2808
LABOR AND DELIVERY
PROVIDER ADMISSION NOTE
Page 1 of 5

ACCOUNT NO.
MED. REC. NO.
NAME
BIRTHDATE

**Admission Information:**
Date:
Patient Age: 36
Service:
Clinic: OHSU OB High Risk Clinic
Fax:
EGA: 36 weeks 3 days
Time: 14:12
GTPAL: G3 T2 P0 A1 L2
Faculty:
Provider:

**Chief Complaint(s):**
SROM:
Onset of Contractions:
**Primary CC:** **SROM:** **Onset of contractions:**

**History of Present Illness:**
36 year old, G3P2012, at 36 weeks 3 days GA presents with:
1. SROM on
2. Contraction onset on

**Problem List:**

| Onset Date | Problem Description | Notes | Resolution |
|---|---|---|---|
| | Previous C-section | | |
| | Rh negative | | |
| | Rubella non-Immune needs vaccine postpartum | | |
| | Premature rupture of membrane (658.13) | | |
| | Early Onset of Delivery < 37 wks (644.2) | | |

**Dating:**
Dating by LMP: Reliability: Sure; LMP Date: EGA: 29 week(s), 2 day(s); EDC:
Dating by Ultrasound: Ultrasound Date: EGA: 20 week(s), 0 day(s); EDC:
Best EDC: Best EDC: The best EDC is based on EGAs of 14-28 weeks by dating and ultrasound. The EDC by ultrasound and the EDC by LMP/conception differ by more than 14 days, so the EDC by ultrasound is considered the most accurate EDC.

**Ultrasound History:**
Ultrasound #1: Date: Total fetuses: 1, Placenta: Posterior, Cervix: abnormal, Cervical length: 4 cm, Funnelling: Absent, AFV: Subjectively normal
Fetus: Position: Vertex, Anatomical survey normal, No growth lag noted

**Pregnancy History:**

| Date | GA (wks) | Labor(hrs) | Type | Anesthesia | Sex | Weight | Location | Complications/Details |
|---|---|---|---|---|---|---|---|---|
| | 38 | 20 | Cesarean | Epidural | M | 3400 gms | OHSU | none |
| | 37 | 12 | VBAC | Epidural | F | 3323 gms | OHSU | none |

**GYN History:**
Abnormal Pap: No history
Cervical Procedure(s): None
GYN Surgery: None
STDs: None

Form created by STORC@, OHSU Center for Women's Health
**HP-2899**

**Figure 2.** Example of formatted output from STORC.

Recorded activities for each provider were treated as independent observations and standardized to activity counts per 8-hour shift. Activity differences between the before- and after-implementation study periods were compared using the Wilcox two-sample test. Workload-adjusted activity on direct patient care was analyzed using analysis of covariance (ANCOVA) with a generalized linear model.

## Table 1. Work activity categories and their operational definitions

| Work activity | Operational definition |
|---|---|
| Off floor | Provider to be observed cannot be located during observation period |
| Declined participation | Provider declines to participate in the scheduled observation |
| Talk/phone (internal) | For telephone calls internal to OHSU. Includes the time from picking up the phone to hanging up the phone for voice calls. Does not include the time spent on the phone on-hold or during faxing |
| Wait/phone (internal) | For telephone calls internal to OHSU. Includes the time from when the clinician is put on-hold to when the other party reconnects or the clinician hangs up. The clinician may be engaged in another task at the same time |
| Talk/phone (external) | For telephone calls external to OHSU. Includes the time from picking up the phone to hanging up the phone for voice calls |
| Wait/phone (external) | For telephone calls external to OHSU. Includes the time from when the clinician is put on-hold to when the other party reconnects or the clinician hangs up. The clinician may be engaged in another task at the same time |
| Fax | Initiated when the clinician first engages fax forms and ends when the clinician completes use of the fax machine. During fax transmission of longer documents, the clinician may be engaged in another activity while the fax is completing |
| Direct patient care | Includes any face-to-face interaction with the patient, in our out of the exam room. This may include interactions with the patient's family |
| Talk/person | Involves talking to anyone other than the patient or the patient's family |
| Read/paper | Includes reading or viewing anything on paper, including, but not limited to, the paper medical record, printouts, reference materials, etc. |
| Write/paper | Includes writing information onto any paper and/or writing on the L&D unit patient management "white board" |
| Personal | Includes any non-work-related activity, such as scheduled and unscheduled breaks, personal phone calls, interactions with nonemployees, non-work-related interactions with co-workers, etc. |
| Read/computer | Includes any form of viewing or reading data on a computer screen, or making printouts |
| Write/computer | Includes any form of entering data into the computer, whether by keyboard or mouse |
| Gather/check | Includes time spent gathering and checking information, supplies, or medications needed for the delivery of care. This includes work with the medication-dispensing machines, evaluation of fetal and/or maternal monitoring strips or displays, checking the L&D "white board," etc. |
| Listening/recording | Listening to information recorded on a cassette recorder or Dictaphone |
| Talk/recording | Dictation for transcription |
| Environmental maintenance (nonclinical) | Organizing nonclinical work areas: arranging documents, replacing printer toner, maintaining other office equipment, etc. |
| Environmental maintenance (clinical) | Cleaning or setting up patient encounter areas |
| Travel | Time spent in transit from one work area to another |
| Other | Any activity that cannot be classified in one of the above categories |

# Results

## Basic Study Characteristics

Table 2 describes the basic characteristics of the study, including the number of observations for each type of provider and the unit workload (estimated by the ratio of nurses to patients). A total of 195 observations were obtained over the two study periods: 61.5 percent of observations involved nurses; 31.8 percent involved residents; the remaining 6.7 percent involved medical faculty.

**Table 2. Characteristics of observational period**

| Factors | STORC EHR | | Comparison *P-value* |
|---|---|---|---|
| | Before | After | |
| **Observation times** | | | |
| Duration (weeks) | 2 | 2 | |
| Hours/shift | 3.5 | 3.5 | |
| **Shifts** | | | |
| Total | 9 | 9 | |
| Day/evening/night | 3 / 3 / 3 | 3 / 3 / 3 | |
| **Observations** | **N (%)** | **N (%)** | |
| Nurse | 61 (61.0) | 59 (62.1) | NS |
| Resident | 32 (32.0) | 30 (31.6) | NS |
| Attending physician | 7 (7.0) | 6 (6.3) | NS |
| Total | 100 | 95 | |
| **Workload** | | | |
| Nurses/patients (mean ± SD) | 0.98 ± 0.31 | 1.00 ± 0.37 | NS |

As shown in Table 3, both the counts of computer-related activities (1.9 vs. 8.5, *P* <0.0001) and direct patient care (12.0 vs. 15.4, *P* = 0.004) increased significantly following STORC implementation. Similar patterns were observed for nurses and residents.

It is also notable that counts of nurses' activities related to gathering and checking medical records (1.5 vs. 3.0, *P* = 0.002) increased after STORC EHR implementation. Although comparisons for faculty were not statistically significant due to small sample size, activity counts for computer work (0.3 vs. 4.2), direct patient care (7.8 vs. 8.8), and talking to nurses or residents (8.2 vs. 11.4) all increased after the implementation of STORC. Because talking to other workers is a vital component of direct patient care, we grouped direct patient care activities and talking with other workers together under the header "patient-related work" to more fully assess the impact of STORC on these activities. Patient-related work activities increased significantly (20.1 vs. 23.9, *P* = 0.001) overall, with residents having the greatest activity count increase (21.3 vs. 25.8, *P* = 0.005), followed by nurses (13.0 vs. 16.1, *P* = 0.02).

Although the amount of paperwork did not seem to decrease (4.3 vs. 4.5 counts per shift), personal/idle waiting time decreased from 4.1 to 1.8 counts per shift. Activity counts for other recorded activities—such as telephone/fax use, recording, environmental maintenance, and traveling—were very low before STORC implementation, and no significant difference was detected (data not shown).

**Table 3. Working pattern by provider type**

| Provider/activity | STORC Before Mean[a] | STORC Before ±SD | STORC After Mean[a] | STORC After ±SD | Comparison $P$-value[b] |
|---|---|---|---|---|---|
| **Overall** | | | | | |
| Total observations | 100 | | 95 | | |
| Computer work | 1.9 | 3.8 | 8.5 | 5.6 | <0.0001 |
| Direct patient care | 12.0 | 8.3 | 15.4 | 8.8 | 0.004 |
| Talk to other workers | 8.1 | 5.6 | 8.5 | 5.8 | NS |
| Paper work | 3.9 | 3.3 | 4.2 | 3.8 | NS |
| Personal/idle waiting | 3.1 | 3.9 | 1.4 | 2.3 | 0.0002 |
| **Nurse** | | | | | |
| Total observations | 61 | | 59 | | |
| Computer work | 1.5 | 2.9 | 9.7 | 5.7 | <0.0001 |
| Direct patient care | 13.0 | 8.5 | 16.1 | 8.8 | 0.06 |
| Talk to other workers | 6.9 | 5.0 | 7.3 | 4.7 | NS |
| Paper work | 4.3 | 3.5 | 4.5 | 3.9 | NS |
| Personal/idle waiting | 4.1 | 4.5 | 1.8 | 2.7 | 0.0007 |
| Gather and check medical records | 1.5 | 2.0 | 3.0 | 3.0 | 0.002 |
| **Resident** | | | | | |
| Total observations | 32 | | 30 | | |
| Computer work | 3.1 | 5.3 | 6.9 | 4.7 | <0.0001 |
| Direct patient care | 10.9 | 6.8 | 15.4 | 9.2 | 0.05 |
| Talk to other workers | 10.4 | 5.1 | 10.4 | 6.8 | NS |
| Paper work | 3.2 | 3.2 | 4.1 | 3.7 | NS |
| Personal/idle waiting | 1.3 | 1.7 | 0.7 | 1.2 | 0.07 |
| **MD attending** | | | | | |
| Total observations | 7 | | 6 | | |
| Computer work | 0.3 | 0.9 | 4.2 | 5.3 | 0.06 |
| Direct patient care | 7.8 | 11.6 | 8.8 | 3.7 | NS |
| Talk to other workers | 8.2 | 9.5 | 11.4 | 7.4 | NS |
| Paper work | 3.3 | 2.2 | 1.9 | 2.3 | NS |
| Personal/idle waiting | 0.7 | 1.1 | 0.4 | 0.9 | NS |

a Mean count/8-hour shift.

b Adjusted for unit workload (ratio of nurses to patients).

## Direct Patient Care Activities

Comparisons of direct patient care activity counts before and after STORC implementation are summarized in Figure 3. Even after adjusting for workload, direct patient care activity counts showed a statistically significant increase for nurses (13.0 vs. 16.1, $P = 0.04$) and residents (10.9 vs. 15.4, $P = 0.02$). Although activity counts for attending staff increased, these differences were not significant. Overall, direct patient care activity increased significantly ($P = 0.03$) following implementation of STORC.

# Discussion

Our results suggest that an EHR can be successfully implemented in busy, fast-paced, procedure-oriented hospital units without negatively affecting activities directly involving patients. We believe this finding is very important to patients, providers, hospitals, and policymakers, particularly during childbirth, when fetal status can change in minutes, but the experience leaves a permanent memory for families.

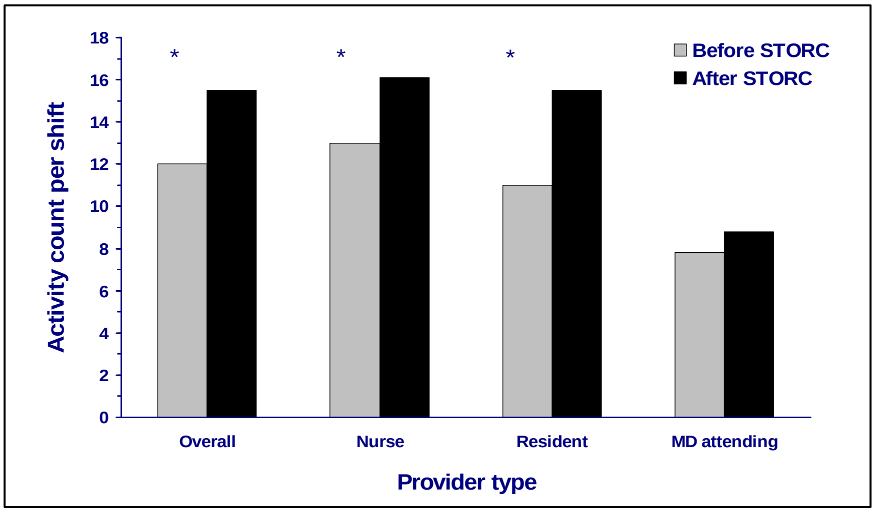


**Figure 3.** Direct patient care before and after STORC implementation. (* $P < 0.05$)

We expected computer work to increase with the introduction of an EHR because the system marked the formal shift from pen-and-paper documentation to the computer. However, we were pleased to discover that this increase did not appear to come at the expense of direct patient care work. In fact, direct patient care activity counts significantly increased for nurses and medical residents, suggesting that EHRs, like STORC, might improve practice efficiency in other areas, despite the greater time spent at the computer. For example, direct importing of laboratory, prenatal visit, and scheduling data into the electronic patient record might have reduced the amount of time clinicians spent locating and collating this information from disparate sources in order to compile and synthesize sufficient data to provide care. Additionally, embedded calculators for determining due dates (estimated dates of conception), Bishop's scores, and preconfigured selections (e.g., pick lists, menus) may have led to time savings for clinicians.

Finally, the amount of time spent repeatedly transcribing these data points from one form to another may have been significantly reduced. This is because STORC is designed to pull data forward as collected, so that once the information is recorded, it populates all forms where this information is required (while allowing editing).

The increase in activity counts for gathering and checking medical records might have resulted from STORC's lack of order-entry functionality. This means that clinical orders were still written into the paper medical record, requiring providers to locate the paper record. In addition, this EHR had not implemented the unit "white board" electronically. The white board was updated frequently to reflect the most up-to-date, at-a-glance information for all patients in the unit, and thus required constant management.

The EHR implementation also coincided with the introduction of a new maternal/fetal monitoring system on the L&D unit. The new work associated with this system (e.g., reading monitoring strips, documenting interventions) is most likely reflected in the increased time spent processing these new data and interacting with the monitors.

The reduction in idle waiting activity counts likely resulted from the improved availability of patient information in a single electronic source. For example, prior to STORC implementation, when a woman arrived for an unscheduled delivery, the L&D staff spent significant time locating the paper prenatal record or contacting the ambulatory clinics to have copies of the record faxed to the unit. Because this information is now collected electronically, it is available immediately when the woman arrives for delivery, eliminating this often frustrating search for important historical clinical data.

Overall, the shifts in types and amounts of work activities were reasonable with the introduction of the computerization of clinical documentation. The time-saving improvements with the technology (e.g., single source of information, prenatal visit information available at the time of delivery) did not entirely offset the increased time required to document patient care. However, these changes did not appear to negatively affect total direct patient care activities, despite concerns to the contrary.

We believe this study provides an important view of the positive value that HIT interventions can have on clinical care for high-reliability units if they facilitate integration of data across systems, saving clinicians time and ultimately improving patient care and safety.

## Study Limitations

This study has some limitations. The brief observational periods used for evaluations and small sample size (particularly in observations of medical faculty) might have affected statistical significance. It is difficult to determine if longer observation periods would have affected these results.

As previously mentioned, STORC is a clinical documentation system that does not provide order-entry functionality. It is possible that some changes in workflow might not have been as dramatically affected had order entry functionality and this documentation system been combined. Because order-entry systems are known to slow down the ordering process, it is possible that additional order-entry functionality might increase computer activity.

Most importantly, the results reflect an EHR designed to accommodate workflow on a busy L&D unit. It is possible that a study of a more general EHR (e.g., one not specifically tailored to the work practices of the specific unit or clinical specialty) might not yield similar results.

We believe that by taking this unique opportunity to assess the work activities of clinical staff during incremental data integration into an EHR, the significant benefits of data integration in general and its potentially positive impacts on patient safety are demonstrated. Furthermore, measurement in a high-volume, fast-paced L&D environment offers substantial reassurance to other high-acuity units for the potential benefits of adopting EHR systems.

### Future Work

Regardless of time savings or loss, it is important to consider whether we are actually improving the quality and completeness of the information collected and recorded for perinatal care. Clinical information systems can promote standardization in data collection, prompt providers to document information they might otherwise forget or ignore, and crosscheck information for consistency across documentation. In addition, if the system is carefully designed with research needs in mind, the data can be collected and stored in discrete, retrievable fields, such that clinical research is more readily supported, obviating the need for traditional chart reviews. The shift to an EHR certainly provides a ripe opportunity to determine if clinical care documentation actually improves quality and comprehensiveness, and if in turn, this can be related to improved patient outcomes through data availability for research.

## Conclusion

The introduction of a clinical information system into a busy L&D setting did not reduce the total count of direct patient care activities. This study may assuage physician fears about the potential for loss of direct patient care time due to documentation time spent on electronic systems. Although overall computer work increased, this was not to the detriment of patient care. The increase in computer work is an unavoidable by-product of the technology age. This is not to say that the shift from paper to computer is seamless, effortless, or easy. The shift does require that clinicians rework their routines, which alone can cause strong emotional reactions and resistance to change. Happily, we see an overall increase in patient-related work, which we believe translates directly to higher quality care in the obstetric setting.

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