Laboratory Order Errors Before and After Implementation of Electronic Health Record

RANA WALLEY, ANN H. PEDEN, WARREN MAY

ABSTRACT

An analysis of laboratory order entry errors on randomly selected inpatient records was conducted comparing errors 12 months before and after implementation of an electronic health record (EHR) at a 571-bed community health system.

Methods: A total of 720 medical records were reviewed with 10,176 orders before EHR implementation and 11,455 orders after. Errors evaluated included unsigned, duplicate, illegible, and omitted orders, results with no order, and transcription errors. Data analysis included the independent-samples t-test and Pearson Chi-square test.

Results: There was a significant difference in laboratory order entry errors before and after EHR implementation ($p<0.05$). The percentages of unsigned orders decreased from 8.6% to 7.6%. Orders with missing results decreased from 16.5% to 11.3%, and duplicate orders decreased from 9.1% to 5.8%. Added, illegible, missing, and incorrectly transcribed orders with previous rates of 3.72%, 0.8%, 2.8%, and 0.9% were eliminated.

Conclusion: Implementation of an EHR appears to improve clinical laboratory order entry.

ABBREVIATIONS: CMS- Centers for Medicare & Medicaid Services, CPOE- computerized physician order entry, CQM- clinical quality measures, EHR- electronic health record, LOS- length of stay, LIS- laboratory information system, HIS- hospital information system, HIM- health information management, HPF- horizon patient folder, QI- quality indicator, IQR- Interquartile Range.

INDEX TERMS: Electronic health records, medical order entry systems, hospital information systems, centers for Medicare and Medicaid services (U.S.), medical errors, patient care, patient safety

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INTRODUCTION

Medical errors are a serious issue.[1] Medical errors can occur in any area of the hospital including the clinical laboratory. Laboratory testing can be separated into 3 phases: pre-analytical, analytical, and post-analytical. Errors may occur in any phase of testing, but most errors occur in the pre-analytical phase.[2] The pre-analytical phase is the time from when the test order is placed until the testing process begins. The analytical phase includes all phases of the testing itself, and the post-analytical phase begins after testing and consists of result reporting and interpretation. Error rates from 6-18 % have been previously reported for clinical laboratory order entry, which is a pre-analytical event.[2]

In 2011, the Center for Medicaid and Medicare Services (CMS) initiated an electronic health record (EHR) incentive program. CMS states that EHR will decrease medical errors, duplicate tests, and improve the quality of patient care. The EHR incentive program allows hospitals that implement EHR and demonstrate "meaningful use" to receive incentive payments between $2,000,000-$6,370,400 per year.[3] There are 9 objectives listed by CMS that constitute "meaningful use". One of those objectives states that

computerized physician order entry (CPOE) must be used to enter medication, laboratory, and radiology orders.[4] CPOE allows physicians to enter all orders directly into the EHR eliminating the need for re-entry into a laboratory or hospital information system. In order to receive incentive payments and avoid penalties, hospitals have been required to monitor and report specific clinical quality measures (CQMs) established by CMS. EHR systems are being implemented at hospitals with the expectation that patient safety will improve.

Previous studies have compared medication errors before and after CPOE implementation.[5-8] Comparisons of verbal, unsigned, and duplicate orders for laboratory tests, pharmacy, and radiology before and after EHR have also been made.[9-11] The percentage of missed tests (orders with no result), added tests (results with no orders), illegible requests, and transcription errors (erroneous test name) have been identified as quality indicators (QI) in laboratory medicine.[12] No studies were identified that compared the proportions of the preceding QIs, unsigned orders, and duplicate orders before and after EHR implementation in a community hospital system.

EHR systems are expensive. The study site spent $32 million on the EHR system. There is more pressure for hospitals to improve patient safety and provide physicians up-to-date information on each patient. EHR implementation is a step many hospitals are taking to fulfill these requirements. This study seeks to investigate whether EHR implementation will improve laboratory quality and patient safety and care by decreasing the incidence of laboratory order entry errors.

METHODS

Data was collected for the 12 months preceding and following EHR implementation by retrospective chart review (July 2011-June 2013). The study site is a community hospital system including 2 hospitals with 571 beds, and over 18,000 inpatient admissions per year. More than three hundred physicians serve on staff. The study site chose Epic (Epic Systems Corp., Madison, Wisconsin) as their EHR, which has a CPOE component. EHR was introduced via "big bang" in July 2012. A review of 30 charts per month was done for a total of n=360 charts pre EHR and n=360 post EHR. Inpatients with a length of stay (LOS) from 3 to 30 days with a minimum of 5 clinical laboratory orders were included in this study. Inpatients with any diagnosis, admitted to any floor or unit were eligible for inclusion in the study. After EHR implementation, all orders were entered through the EHR system by physicians, nurses, physician assistants, pharmacists, and other allied health professionals. The study site Institutional Review Board (IRB) approved this study and waived informed consent. Patient privacy and confidentiality were maintained.

The hospital system Health Information Management (HIM) department provided discharge lists for dates of interest in Excel spreadsheets. The random number generator tool in Excel was used to assign each medical record a random number. The medical records were then sorted based on the Excel generated random number and the first 30 randomly sorted medical records meeting the inclusion criteria (3-30 day LOS and ≥ 5 laboratory orders) were included in the study. For permanent storage, all medical records before EHR implementation were scanned and stored as PDF files that were then available through McKesson's Horizon Patient Folder™ (HPF) (McKesson Information Solutions, Alpharetta, GA). HIM added the requested randomly selected charts to a HPF viewer queue. Through the HPF queue "paper" charts could be reviewed and data collected. Patient demographic information was found on the "face sheet" and physician orders were found in either the "ER Orders" or "Physician Orders" tabs. Results for orders were found in the "Lab Finals" tab. Results were not collected, only recorded as present or absent. Any result present that did not have an order was recorded as "result with no order".

Record review after EHR was less cumbersome. In the EHR, patient demographics were found under the "patient information" tab and all laboratory orders and results were found under the "Laboratory" tab. After selecting the admission of interest, all laboratory orders were displayed with details. Laboratory order details included the test ordered, entering user, ordering provider, electronically signed by, date, time, result or

canceled.

Laboratory orders were reviewed for order entry abnormalities and errors identified as issues in the literature. Order errors of interest for this study included: unsigned orders, duplicate orders, orders with no results, results with no orders, illegible orders, missed/omitted orders, and transcription errors.[10-15]

Data collected for each laboratory order included the test or panel and the presence or absence of a provider signature, result, duplicate order, illegible order, or transcription error. An order was identified as unsigned if there was no provider signature present at the time of chart review. All chart reviews were collected ≥ 6 months after patient discharge. A result with no order was classified as an added order, and an order with no result was classified as missing. For this study a duplicate order was defined as any order that was made after an initial order for the same test within in a time frame not typically required for patient evaluation.[16] Duplicate orders were most often entered by a second physician before the original order had been resulted. A transcription error was defined as any order entered into the HIS that did not match the original written order. Each order could contain more than 1 error.

Data were analyzed with the Mann-Whitney U and Pearson Chi-square (χ^2) tests using SPSS (IBM SPSS Statistics v22). The medians of each dependent variable were compared using the Mann-Whitney U test to compare differences between the two independent variables before and after EHR. If a difference was indicated by $p<0.05$, the relationship was analyzed further with the Chi-square crosstabulation function in SPSS. For the analysis of unsigned orders, duplicates, or missing results the percentage difference was found for each year to account for the different number of orders.

RESULTS

Three hundred sixty patient charts were analyzed before and after implementation of the EHR. Table 1 lists the results for patient demographics, payor group, and length of stay for before and after EHR implementation. There was no significant difference in race, gender, age, or payor group as all p-values were greater than 0.05.

The LOS for study inclusion ranged from 3 to 30 days which could have led to outliers and extreme values. In order to discard these outliers or extreme values, the median LOS and interquartile range (IQR) for the LOS were used to compare the length of stay before and after EHR. For this study the median was the middle LOS after all LOS were ordered as a group. The IQR was defined as the middle 50% or 25th to 75th percentiles for all LOS observations. The median LOS for the year before EHR was 4.0 days, while the median length of stay for the year after EHR was 5.0 days, a difference that was statistically significant (p=0.018). Thus, it appears that after EHR implementation, the median patient LOS was longer by about 1.0 day which is also reflected in the shift in the IQR by approximately the same 1.0 day.

Table 1: Demographic distributions before and after implementation of EHR.

	Before EHR	After EHR	p-value
Total n	360	360	
Race			
White	76.4 %	74.4 %	0.740
Black	22.2 %	23.7 %	
Other	1.4 %	1.9 %	
Gender			
Female	52.8 %	55.8 %	0.411
Male	47.2 %	44.2 %	
Age			
0 – 28 days	3.6 %	1.9 %	0.315
29 days – 15years	3.9 %	1.9 %	
15 – 44 years	18.1 %	17.2 %	
45 – 64 years	28.9 %	29.7 %	
65 years or older	45.6 %	49.2 %	
Payor	(n=360)	(n=358)	
Medicaid	12.5 %	15.9 %	0.609
Medicare	56.7 %	56.1 %	
Tricare	1.4 %	0.8 %	
Private	19.7 %	17.0 %	
Self-Pay	9.7 %	10.1 %	
LOS			
Median	4.0	5.0	0.018
IQR	3.0 – 7.0	3.7 – 8.0	

The results were calculated using the Pearson's Chi-square test for independence.

The annual number of orders placed and the average orders placed per patient are shown in Table 2. The Mann-Whitney Nonparametric independent samples test for distributions across 2 groups was used to determine if there was a significant difference in the total number or orders placed for the 2 groups, before and after EHR. There was no significant difference in the number of orders placed before (10,176 orders) or after (11,455 orders) EHR (p=0.157). The number of orders was further analyzed by considering the median number of orders placed per patient for each year. The median number of orders per patient for the year before EHR was 21, while after EHR the median number of orders per patient was 23. There was no significant difference in the median number of orders placed before and after EHR (p=0.175).

Results for the analysis of duplicate orders and unsigned orders can also be seen in Table 2. In the year before EHR the total number of duplicate orders was 921 (9.05%) and unsigned orders totaled 877 (8.61%). In the year after EHR, duplicate orders totaled 664 (5.8%) and unsigned orders totaled 865 (7.55%). The Chi-Square Test for Independence was performed using the categorical divisions described above as well as the Nonparametric Mann-Whitney U test for differences between 2 groups. Both tests show a significant difference in orders without a provider signature (p=.020 Mann-Whitney, p=0.042 Chi-Square) and duplicate orders (p=0.016 Mann-Whitney, p<0.01 Chi-square).

DISCUSSION

The literature shows potential benefits of EHR with CPOE including improvement in physician ordering patterns, increased compliance with guidelines, more efficient use of time, and improved communication.[17] Most studies investigating the impact of CPOE have been related to medication errors.[18] Studies evaluating the effects of CPOE on laboratory services have shown CPOE implementation significantly reduced laboratory turnaround time (TAT).[19] Since there is no evidence of a relationship between patient demographic categories before and after EHR implementation these factors can be excluded as the cause for the difference in order errors before and after EHR. Although this study found a correlation between the length of stay and implementation of EHR that is indicated by the 1 day increase in LOS after EHR, another study of hip fracture patients found that EHR implementation had no effect on LOS.[20]

The introduction of the EHR brought about big changes for hospital staff work flow. This study shows there is evidence that the decrease in unsigned orders, duplicates, orders without results, and other entry errors is related to the implementation of EHR. Fewer duplicate orders will mean less time spent by healthcare professionals canceling duplicates or discerning which orders are duplicates. Less time spent canceling duplicates results in more time for patient care. Fewer duplicate orders will result in fewer duplicate tests and less lost revenue. Although a statistical relationship cannot be studied for errors eliminated by EHR, data indicate an additional 8.2% reduction in errors due to those categories (results with no corresponding order, illegible handwriting, omitted orders, and transcription errors) that were eliminated by EHR. The data obtained in this study offer important information on the effectiveness of EHR with CPOE as it relates to clinical laboratory workflow.

Table 2: Totals and percentages before and after EHR.

Total n	Before EHR 360	After EHR 360	p-value
Total Number of Orders	10,176	11,455	0.157*
Median Number of Orders placed per patient			
Median	21.0	23.0	0.175*
IQR	13.0 – 32.0	14.0 – 38.0	
Unsigned Orders	877 (8.6%)	865 (7.6%)	0.020* (0.042)**
Duplicate Orders	921 (9.1%)	664 (5.8%)	0.016* (<0.001)**
Results with no Order	379 (3.72%)	0	---
Illegible Orders	82 (0.8%)	0	---
Missed/Omitted Tests	288 (2.8%)	0	---
Transcription Errors	86 (0.9%)	0	---
Total Orders with Errors	1748 (17.2%)	733 (6.4%)	<0.001* (<0.001)**

*Denotes p-values determined using the Mann-Whitney U Test and
** Denotes p-values determined using the Chi-Square Test for Independence.

This study suggests that implementation of EHR significantly reduced laboratory order entry errors. Additional studies are needed to determine if the variables selected are meaningful and useful for long term monitoring of quality laboratory services. Since the completion of this study, EHR updates at the study site include pop-up windows that are activated when a possible duplicate order is placed. It may be beneficial to study duplicate orders after this update. A learning curve is associated with new technology and may have played a part in the rise and fall of order errors as demonstrated in the error rates. The laboratory is a vital part of healthcare providing diagnostic results that must be delivered promptly and accurately for high quality patient care. As Medicare reimbursement transitions from fee-for-service to value based payments, quality healthcare service is crucial. Performance improvement studies that show a reduction in errors can demonstrate dedication to quality patient care. Quality improvement studies should be conducted continuously over time to monitor and improve processes of patient care.

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