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Interoperability in Hospital Information Systems: a Return-On-Investment Study Comparing CPOE with and without Laboratory Integration

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Abstract: Despite its many advantages, using a computerized patient record is still considered as a time consuming activity for care providers. In numerous situations, time is wasted because of the lack of interoperability between systems. In this study, we aim to assess the time gains that nursing teams could achieve with a tightly integrated computerized order entry system. Using a time-motion method, we compared expected versus effective time spent managing laboratory orders for two different computerized systems: one integrated, the other not integrated. Our results tend to show that nurses will complete their task an average of five times faster than their expected performance ($p < 0.001$). We also showed that a tightly integrated system provides a threefold speed gain for nurses compared to a non-integrated CPOE with the laboratory information system ($p < 0.001$). We evaluated the economic benefit of this gain, therefore arguing for a strong interoperability of systems, in addition to patient safety benefits.

Keywords: Computerized physician order entry, electronic prescribing, nurse, time consumption.

1. Introduction

Computerized physician order entry (CPOE) and e-prescribing systems constitute a major component of electronic health records (EHR) and are identified as a strategic goal for most modern hospitals [1]. Many studies showed strong evidences of reduction of medication errors and adverse drug events following CPOE implementation [2]. However, adoption of EHRs and CPOEs in hospitals has been slow due to many factors including: the high purchase-implementation-maintenance cost of such systems, the immaturity of software products, the lack of integration between different components of a hospital information system (HIS), medical staff resistance and the emergence of new mortality and morbidity causes [1][3-4]. EHRs' actual return on investments has been debated since their inception and represents another implementation barrier. Recent studies have shown that these systems may be worth every dollar invested if implemented correctly with a high level of integration [5,6]. Such conclusions are now

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acknowledged by the US administration with the ARRA HITECH stimulus act of 2009. Regarding CPOE, studies are showing a gap between medical teams' perceived value on the topic and their intent to adopt it. Most of the teams are reluctant to cross the gap on the premises that CPOE is a time-inefficient or time-consuming task [1]. Different methods have been tried to objectively evaluate the impact of CPOE systems on physicians and nurses' workflow in terms of time gains or losses [7-9]. Studies focused on CPOE concluded that, if carefully implemented, it will not greatly disrupt nursing staff workflow [10-11].

2. Research Question and Methods

Issues around perceived time consumption generated by e-prescribing systems represent an important barrier to rapid adoption of CPOE by nursing teams. In this paper we aim to measure the difference between perceived time spent on e-prescribing and real time measurements. We also computed time gains for nurses derived from the implementation of a second generation CPOE with a higher integration level with the Hospital Information System (HIS). The setting for the study was the Geneva university hospitals in the department of geriatrics and rehabilitation. A computerized patient record (CPR), mostly developed in-house, is used in all facilities and runs on more than 7'500 desktops and more than 1'000 laptops. The CPR uses a Java component-based architecture with a message oriented middleware. It includes an in-house CPOE system, called "Presco", a widely deployed multi-purpose order entry platform for drugs, radiology, laboratory, nursing care, to name a few. Presco has built-in decision support, such as information on drugs, specific rules according to specialty, (for example pediatrics orders); it supports orders sets, various kinds of alerts and reminders up to complex clinical pathways. It is tightly integrated with the CPR, thus rules can be based on laboratory or other clinical information. The study takes benefit from the fact that we still use a specific user interface for laboratory requests (Request, used by nurses to rewrite orders given by physicians in the CPOE). The direct link between the CPOE and the laboratory system is available, but the study was performed during the rollout of the direct link, thus allowing measuring the time that was spared by building the direct link. We used time-motion methods to evaluate time nurses would have spent on computers by either transcribing order entries from Presco to "Request" or directly validating order entries in Presco, using the direct link. In addition, and for each ways, nurses were first asked to subjectively evaluate the time they would spent doing the job. Time-motion methods are considered the gold standard as they capture the nurses' tasks continuously during a set time interval (here the computer activity related to e-prescribing) [11]. The time motion measures were performed by the same person during fall 2008 in a geriatric ward on 101 prescribing tasks in 33 units involving 66 nurses. Statistical analysis was performed using PASW® Statistics17. We didn't apply normal law since our number of observation (100) doesn't respect Gaussian distribution for all the parameters and used Wilcoxon signed ranks tests to compare means.

3. Results

3.1. Order Entry Values

Nbpr represents the number of prescribed exams entered in Presco for one patient. *Chkb* represents the number of checkboxes needed to validate the exams using the direct link. The difference between *Chkb* and *Nbpr* is explained by the use of order sets that regroups orders in one entry. *Labs* represents the number of different laboratories that will perform the lab analysis. This number reflects the quantity of stickers printed to identify samples that will be carried to the various laboratories. *Nonc* represents the number of lab exams that cannot be prescribed using CPOE. This number reflects the quantity of exams that cannot be e-prescribed and need paper work to be sent. 68% of the patients in our sample were not concerned; 19 patients had one *Nonc* exam; 8 patients had two and 5 patients had three or four *Nonc* exams.

3.2. Time Observed and Measured

Test represents the estimated time that nurses expect to process the job. This estimation is purely subjective depending on the expected complexity of the order entry task. *Treq* represents the observed time spent by nurses to complete their order entry in the Request environment. This measure is objective. *Tpre* represents the observed time spent by nurses to complete the job using the direct link, thus only validating the order. This measure is objective.

3.3. Potential Gain

Means comparison of *Test* versus *Treq* to complete an order entry in the Request environment shows a gain of 104 seconds on what was expected by nurses (3 minutes instead of 4 minutes 44). Means comparison of the *Test* versus *Tpre* to complete an order entry in the Presco environment shows a gain of 233 seconds on what was expected by nurses (less than one minute instead of 4 minutes 44). Means comparison of the *Treq* versus *Tpre* to complete an order entry using the direct link shows a gain of 129 seconds compared to retranscription of orders in Request (less than one minute instead of 3 minutes) ($p < 0.001$).

3.4. Time Observed and Measured Related to Number or Exams

Test/N represents the estimated time that nurses expect to spend to keyboard their order entry (*Test*) divided by the number of exams to enter (*N*). This estimation is purely subjective depending on the expected complexity of the order entry task and experience doing so. For our sample we have an average 55 seconds of estimated time consumption by each patient's order entry with a Median of 30 seconds per order entry. The maximum estimation is 6 minutes (360 sec.) and the minimum estimation is 9 seconds average time per order entry. *Treq/N* represents the measured time that nurses spent to keyboard their order entry (*Treq*) in the Request environment divided by the number of exams to enter (*Nbpr*). This estimation is objective. In our sample, we have an average 37 seconds of time consumption by each patient's order entry with a Median of 21 seconds per order entry. The maximum measure is 4 minutes and 10

seconds (250 sec.) but concerns only two nurses. The minimum measure is 7 seconds average time per order entry. $Tpre/N$ represents the measured time that nurses spent to validate the order that has been sent automatically using the direct link ($Tpre$) divided by the number of exams to enter ($Nbpr$). This estimation is objective. In our sample, we have an average of 11 seconds of time consumption by each patient's order entry with a Median of 5.6 seconds per order entry. The maximum measure is 52 seconds per order entry but concerns only two nurses. Ten nurses have an average time of entry per order of more than 45 seconds. The minimum measure is around 2 second average time per order entry.

3.5. Potential Gain Related to Numbers of Exams

Means comparison of $Test/N$ versus $Treq/N$ to complete an order entry in the Request environment considering the number of exams, shows an average gain of 18 seconds per order entry on what was expected by nurses. Means comparison of the $Test/N$ versus $Tpre/N$ to complete an order entry, shows an average gain of 44 seconds on what was expected by nurses per factor (almost five times faster than expected). Means comparison of the measured time in the Request environment ($Treq/N$) versus measured time ($Tpre/N$) to complete an order entry in the Presco environment, shows a gain of almost 26 seconds on what was realized by nurses in the old system (more than three times faster than in the former system) ($p < 0.001$).

3.6. Influence of the Number of Exams in the Time Estimated and Observed

Plotting $Test$ and $Treq$ with the $Nbpr$ confirms a positive correlation between these variable. This relationship diminishes when plotting $Tpre$ with $Nbpr$. The number of order entry to keyboard in the system does not influence the time consumption in the same amount than in the older system or the nurses' estimation. 100% of the time needed in Presco to complete order sets range between 45 to 60 seconds. Time gain from the Presco system plotted to the number of exam show a high time gain level when the number of exams increases in volume.

4. Discussion and Conclusion

There are several limitations to this study. The level of nurses' technophilia has not been evaluated, but certainly accounts in the observed results. Even if we can assume a fairly distributed level (only one or two extra ranged time) in the dataset, this will certainly be a variable to measure and integrate in future work. Several other parameters associated with technophilia would be interesting to collect (age, country of origin, level of academic formation, training courses followed, seniority in the hospital, etc.). Another limit of the study lies in the type of care provided in the selected ward. Measurements should be performed in other hospital wards with a high level of complex and various order entries at different hours (intensive care units, emergency departments, etc.) along with acute and short-term care wards. The time period and the number of observed orders should also be increased. An automated process monitoring this activity could also be integrated in the HIS and study nurses behavior regarding future developments of the CPOE to avoid the Hawthorne effect (nurses could change their behavior when they know that they are being measured). In this study we wanted

to answer two different questions. First we wanted to verify the hypothesis that nurses tend to overestimate the time spent using the CPOE system. We showed that they work five times faster than their own estimation with a direct highly integrated CPOE system (Presco). This assessment also applies to an older system where they have to keyboard their orders from one system (Request) to another (Presco). With this legacy system, they still overestimate their time consumption by 33%. Secondly we wanted to document the return on investment of the development of a tight integration between CPOE and the laboratory information system. Such integration is often available, but while the cost of interoperability is frequently evaluated, the economic benefit of interoperability is little documented. Our data confirmed that building a tight interoperability allows to use the service three times as fast, saving an average of 26 seconds per order entry. Another interesting point is that the number of exams to process by nurses in Presco is not a major determinant of the total time spent. For a number of exams ranging from 1 to 26 the time spent will be between 45 to 60 seconds in the new system (90 to 480 without interoperability). This is a direct consequence of efforts put in ergonomics of the system and the broad interaction between computer scientists and physicians to design order sets well-tailored to daily medical activities. Finally, one can hope that the time gains evidenced in this research could be employed in numerous ways aiming to enhance the quality of care delivered in the hospital. Considering the aspect of analytic accounting, the average salary of the nurses involved in this study was 0.73 dollars per minute of working time. Building interoperability saved 2600 seconds (43 minutes) of working time for the 100 order sets studied. About 20'000 lab orders are generated by physicians each month using the CPOE, each order containing at least one analysis, but usually much more, this represents an a potential \$6.325 of working time equivalent saving per month.

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