APPENDIX 2 - DISCUSSION

We also report the association of inpatient CPOE with decreased overall radiology examinations. Unlike our laboratory test orders, which had a duplicate alert at the time of ordering for the end user, duplicate radiology orders were noted and cancelled by the radiology staff. It appears that the reason for the increase in duplicate radiology orders was one of workflow. Before CPOE implementation, there was a single chart for written orders for each patient. Thus, it was easy to see if a radiology examination had been ordered, and if another was ordered in error, the unit clerk likely would recognize the error and not enter the test into the system. Had the duplicate alert for radiology orders been in place for end users after CPOE, we likely would have found fewer erroneously ordered examinations and, therefore, fewer cancellations. The end result in each case was similar: fewer tests/examinations were completed. There are few centers who have reported a decrease in completed radiology tests. One report from England showed an increase in repeated ordering of computed tomography tests, but a reduction in overall computed tomography tests in an inpatient setting.[1] As stated previously, we included several mechanisms to ensure end users could easily order all tests, including radiology examinations, and also included a "X-Ray Other" order to enter free text if the discrete order could not be located.

We believe that a major factor in the decreased number of laboratory tests and radiology examinations completed was that providers were held electronically accountable for their orders by virtue of CPOE. Before CPOE, providers wrote orders on paper and gave them to the unit clerk to manage—it was no longer the provider's problem. A similar sentiment was expressed in a study interviewing users regarding their attitudes to the electronic medical record: "Somehow it has changed the psyche of people, they are more aware of what they are putting in the chart. It's almost like they didn't really care what they wrote on paper, but now it's electronic and people can read everything."[2] The 18% reduction in laboratory tests we demonstrated is even greater than the 13.7% reduction anticipated by CITL. However, they attributed this reduction mainly to redundancy from the lack of access to prior test results.[3] Our providers had easy access to electronic laboratory and radiology results before our EHR implementation via a legacy system. Anecdotally, our providers' feedback after CPOE implementation supported our concept of electronic accountability and

did not indicate that the duplicate laboratory alert had a major effect on laboratory test reductions; however, we would like to have demonstrated that laboratory alerts appeared less often than our observed laboratory test reduction in order to support our concept.

Adverse drug events are associated with increased length of stay, increased costs[4,5] and an increased risk of death.[4] As stated previously, several reports show a reduction in medications errors after CPOE implementation,[6-9] with 1 recent study[10] showing a decrease in hospital-wide mortality. However, not all studies have been encouraging. Han et al[11] reported an unexpected increase in pediatric mortality in the 5 months after implementing CPOE, although others[12] using the same commercially available product, did not report such a finding. Further, some evidence suggests that CPOE may even trigger new types of medication errors.[13] Still others have shown that adverse drug events persist even after CPOE has been implemented.[14]

Our medication events were self reported, so staff willingness to report, as well as possible bias toward not reporting due to time constraints when learning to use the new system, are certainly possible reasons our medication error rate was lower; however, errors did not decrease until the post-CPOE period (not in the immediate post-EHR period when the nurses and pharmacists were learning the new system). Our increased *near miss* reporting also argues for a true benefit.

There are few published reports in the literature which examine overall implementation costs and demonstrate return on investment. These calculations are complex, and involve both direct and indirect costs.[15] Some have shown a positive return on investment in certain aspects in ambulatory settings.[16-18] A study tracking implementation costs of an EHR over three pediatric intensive care units found that costs were 35% higher than expected, with personnel costs contributing to 83% of the actual cost overrun.[19] In an attempt to quantify the impact of implementing hospital EHRs over an entire state, a simulation model using cost estimates of hospitals in Iowa found that for many smaller hospitals it would be fiscally difficult to adopt CPOE.[20] We did not calculate overall cost or return on investment for our inpatient implementation.

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