# An Electronic Safety Screening Process during Inpatient Computerized Physician Order Entry Improves the Efficiency of Magnetic Resonance Imaging Exams

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**Rationale and Objectives:** Delays between order and magnetic resonance (MR) exam often result when using the conventional paper-based MR safety screening process. The impact of an electronic MR safety screening process imbedded in a computerized physician order entry (CPOE) system was evaluated.

**Materials and Methods:** Retrospective chart review of 4 months of inpatient MR exam orders and reports was performed before and after implementation of electronic MR safety documentation. Time from order to MR exam completion, time from MR exam completion to final radiology report, and time from first order to final report were analyzed by exam anatomy. Length of stay (LOS) and date of service within the admission were also analyzed.

**Results:** We evaluated 1947 individual MR orders in 1549 patients under an institutional review board exemption and a waiver of informed consent. Implementation of the electronic safety screening process resulted in a significant decrease of 1.1 hours (95% confidence interval 1.0–1.3 hours) in the mean time between first order to final report and a nonsignificant decrease of 0.8 hour in the median time from first order to exam end. There was a 1-day reduction ($P = .697$) in the time from admission to the MR exam compared to the paper process. No significant change in LOS was found except in neurological intensive care patients imaged within the first 24 hours of their admission, where a mean 0.9-day decrease was found.

**Conclusion:** Benefits of an electronic process for MR safety screening include enabling inpatients to have decreased time to MR exams, thus enabling earlier diagnosis and treatment and reduced LOS.

**Key Words:** Electronic health record; patient safety; Magnetic Resonance Imaging; order; CPOE.



Time to completion of inpatient magnetic resonance (MR) imaging exams was thought to prolong the inpatient length of stay (LOS) in our hospital (1,2). While this is a multifactorial problem, completion of the conventional paper MR Safety Screening Form (3–5) was identified to cause delays. Specific activities contributing to these delays included neglecting to complete the paper form, forgetting to fax the completed form to radiology,

**Acad Radiol 2013;** 20:1592–1597

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http://dx.doi.org/10.1016/j.acra.2013.09.006

and changes in the hospital service so the original ordering provider is no longer available to answer questions about the patient. The desire to improve safety with a patient-level overview of implant, medical, and surgical history motivated imbedding the MR safety screening process into the computerized physician order entry (CPOE) and requiring completion before placing the MR exam order. We also sought to reduce the time to the final report and hopefully enable earlier care decisions and treatment implementation, as well as improve patient outcomes (1,2).

To date, there have been no published reports of an electronic implementation of the MR safety screening process. Here, we describe the observed impact of creating an electronic replacement for the standard paper screening method in the inpatient care environment. We hypothesized that the electronic MR safety screening would result in decreased time from order to MR exam completion and decreased time from first order to final report.

## MATERIALS AND METHODS

### *Electronic MR Safety Screening Process*

The goal of the electronic process was to create a patient-level implant and contrast agent risk repository, similar to that used for allergies or immunization history. The workflow and design highlights of the electronic MR safety screening process are presented in Table 1. While the electronic workflow was designed to be similar to the paper process, steps unique to the electronic process are 2, 4, 5a, and 5c. The paper process required the completed form to be faxed to radiology in lieu of step 4 and often required nursing involvement (Supplemental Table 1).

The electronic MR safety screening tool is composed of five sections: (1) contraindicated implanted devices (Supplemental Figure 1, red section), (2) implanted devices that may undergo an MR exam under specific conditions (conditional implants) and risk factors for a contrast agent reaction (Supplemental Figure 1, yellow section), (3) information needed by the MR technologist or radiology nurse (Supplemental Figure 1, light blue section), (4) a convenient patient-level health summary to review and update recent pertinent lab values, allergies, past medical history, and past surgical history (Supplemental Figure 2), and (5) a verification/validation section for both the ordering provider as well as for the radiology MR team (Supplemental Figure 3). If a YES answer is recorded in the contraindicated device section, the remainder of the tool blanks out and an MR exam cannot be ordered (Supplemental Figure 4). If a YES answer is recorded in the conditional or informational section (Supplemental Figure 5), a text box for device documentation pops up. Gender-specific questions are posed as patient-appropriate (Supplemental Figure 6). An error message box appears and the order is prevented from being signed (hard stop) if a question was overlooked, device documentation not performed, allergies not reviewed within 24 hours, or the safety tool not validated within 24 hours of order signing.

The electronic MR safety screening tool was rolled out in a phased manner, beginning with a small pilot study in the neurological intensive care unit (neuro-ICU) starting in late December 2010 and with full inpatient implementation completed by April 2011.

### *Statistical Analysis*

An institutional review board exemption for quality improvement purposes and a waiver of written informed consent were obtained. Four months of inpatient MR exam orders and radiology reports were evaluated: November 2010 (preimplementation) April, May, and June 2011 (postimplementation). The data were extracted using SQL (SQL 2003; Microsoft, Redmond, WA); thereafter, it was analyzed in ACCESS and EXCEL (Office 2007; Microsoft) and SAS (version 9.2; SAS Institute, Cary, NC). The following quantitative data were analyzed: time from first order to exam end, time from first order to final report, time from exam end to final report, LOS, timing of the exam within the hospital admission (date of service, DOS), level of care at discharge, level of care decrease (move from ICU to stepdown or standard floor) following the MR exam, and the number of orders requesting nursing to assist with completion of the MR safety screening process.

Linear regression analyses were performed for each of the dependent variables. Since the distributions of the dependent variables were skewed right, the variables were transformed by adding 0.5 and then taking the natural logarithm. To control for differences in patient mix before versus after implementation, a multivariable model was used. The predictor variables in the models were intervention (binary variable: pre versus post), patient age (continuous), gender (binary), race, type of procedure (categorized as brain: any head, carotid, or neck exam including angiography; spine: cervical, thoracic or lumbar; chest: pulmonary, cardiac, aorta; abdomen: abdomen, pelvis; or musculoskeletal: any joint or soft tissue extremity exam), and the two-way interaction between anatomy and intervention. Spine exams were rarely ordered independent from brain exams. When spine MR or brain MR or MR angiography was ordered and performed at the same time, they were classified as brain exams. All MR exams from the neuro-ICU pilot were of the brain. If the interaction between anatomy and intervention was not significant at the .05 level, then it was removed from the model. Generalized estimating equations were used to account for the fact that many patients had multiple MR studies. From the fitted model, 95% confidence intervals (CIs) were constructed for the mean change with the intervention. A significance level of .05 was applied for all analyses.

Similar analyses were performed for the comparison between postintervention months. In these linear regression models, the predictor variables were time (categorized as 1, 2, or 3 months postintervention, patient age (continuous), gender (binary), race, procedure anatomic region (brain, spine, chest, abdomen, or musculoskeletal), and the two-way interaction between anatomy and time).