The Effects on Clinician Ordering Patterns of a Computerized Decision Support System for Neuroradiology Imaging Studies

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***Objective**: To evaluate the impact of computerized ordering guidelines on clinician ordering patterns for neuroradiology imaging studies of the head.*
***Design**: A retrospective analysis was performed using a pre-post design. A 9-week control period was followed by an 8-week intervention period.*
***Subjects**: All clinicians who placed an order for either an MRI of the brain or a CT of the head on inpatients using a computerized order entry system.*
***Methods**: We designed, implemented, and evaluated a decision support system for the implementation of test ordering guidelines. Changes in ordering patterns were evaluated with a Chi-square analysis.*
***Results**: 742 tests were ordered in the pre-intervention period, while 704 studies were ordered after the intervention. A significant change in the distribution of tests ordered resulted from the intervention (p=0.048). Changes trended toward the guideline recommendations for all tests considered. 60% of users receiving a recommendation ordered the suggested study.*
***Discussion**: Our intervention successfully influenced clinician ordering patterns. Examination of detailed usage patterns may aid in further quality improvement of both the guidelines and the decision support tool used to implement them.*

Introduction

Radiologic tests are important in obtaining a diagnosis or following the clinical progression of disease. However, a high proportion of radiologic studies are ordered and obtained incorrectly.[1-3] Tests often have either a low probability of yielding clinically important information or are not the optimal imaging modality for the underlying clinical condition. CT of the head and MRI of the Brain are frequently misordered tests. Since these studies are ordered relatively infrequently, clinicians may not have the necessary experience to order the appropriate test type including whether to obtain the test with or without contrast medium. Thus, the study ordered may often be changed by an attending neuroradiologist after the patient arrives in the radiology department. Alternatively, tests may not be the optimal study for the patient's condition, requiring additional imaging. Increased patient costs, a delay in diagnosis and/or therapy, and decreased satisfaction may result. In addition, documented justification for the procedure is often inadequate, increasing the work required to obtain reimbursement for studies. Consultation with an attending neuroradiologist prior to ordering a brain imaging study would standardize test ordering, but would place an additional time burden on clinicians and be impractical to implement.

Clinical guidelines can be an effective tool in modifying physician ordering behavior. Studies have demonstrated increased rates of appropriate test ordering in response to guideline implementation[4, 5]. However, guidelines are often overlooked or ignored when they are not conveniently available to the ordering clinician at the time of decision making or are not integrated into normal clinical workflow. Computerized implementations of clinical guidelines presented at the time of decision-making and order entry have been shown to increase awareness of, and compliance with, recommendations[6, 7].

A team of five attending neuroradiologists from our institution developed paper-based guidelines for assisting clinicians in choosing an optimized imaging modality based on the patient's clinical acuity and the indication (sign, symptom, or known diagnosis) for obtaining the examination.

A computerized clinician order-entry system, WizOrder, has been developed an employed at VUMC.[8] Because the majority of orders are entered directly by physicians, this application allows decision support information to be delivered at the time of order entry. Incorporated within WizOrder is a programmable rules engine that generates HTML-based forms and can be used to develop decision support modules for the implementation of guidelines.[9] Using the rules engine, we developed and implemented a computerized decision support system incorporating the paper-based neuroradiology guidelines for the ordering of Head CT and Brain MRI examinations.

Methods

In this study, we evaluated the effects on ordering patterns for imaging studies of the head and brain after implementing ordering guidelines in a computerized decision support system.

Setting and Subjects: Vanderbilt University Medical Center (VUMC) is a 630 bed academic tertiary care hospital with approximately 31,000 admissions per year. All orders for inpatients are entered using WizOrder. The primary users of WizOrder are physicians (attendings, interns, residents, and fellows). Other staff, including nurses and medical receptionists, have the ability to enter verbal or written orders from physicians. Study participants

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were all users who entered an order via WizOrder for one or more Head CT or Brain MRI imaging examinations on an inpatient during the study period; all studies for Head CT or Brain MRI ordered were part of the analysis. This evaluation was approved by the VUMC IRB.

Study Design: We used a pre-post study design to examine the effect on ordering patterns for selected radiology studies after implementation of a computerized decision support system. The 9-week pre-intervention period (9/30/2000–12/4/2000) was followed by an 8-week post-intervention period (12/5/2000–1/30/2001). During the intervention period, the decision support module was the only means available for generating orders for the included tests.

Intervention: A list of common indications for ordering an imaging examination of the head or brain was created and mapped to ICD-9 codes. Sources for the list included prior free text indications provided at the time of order entry, historical ICD-9 coding data, and Local Medical Review Policy (LMRP) published guidelines for the included tests. The indications were categorized and submitted to a group of five attending neuroradiologists for review. For each indication, the group determined by consensus which imaging study would be the most appropriate to obtain, for both emergent and non-emergent clinical acuity. Table 1 lists the categories and the number of indications (ICD-9 codes) listed in each. An indication could appear in multiple categories.

Table 1: Classification categories, number of subcategories, and number of ICD-9 codes.

Category	# Subcat.	# Codes
Sign or Symptom	6	45
Stroke / Vascular	5	47
Neurological Disease	6	102
Tumor / Malignancy	5	84
Infection / Inflammation	5	85
Trauma	5	53
Procedures/Complications	3	19
Systemic Disease	3	19
Congenital Disease	2	36
Otolaryngology	5	53
Ophthalmologic	5	46
Drugs / Psychiatric	3	16

The decision support system (DSS) was triggered when one of the following five imaging modalities was ordered: Head CT without contrast, Head CT with contrast, Head CT with and without contrast, Brain MRI without contrast, and Brain MRI with and without contrast. Alternatively, the system could be initiated by selecting the "Brain Imaging Advisor." Our institution performs both a non-contrasted and a contrasted CT scan when a contrasted examination only is ordered. Thus, the DSS did not allow for the ordering of a CT of the Head with IV contrast only although prior to the intervention this could be ordered. For this reason, these two tests were grouped in the pre-intervention phase and were combined in all analyses.

The DSS was implemented as a series of HTML screens. Data were captured regarding the patient's clinical acuity and the indication for obtaining the study (selected from categorized lists). Each indication was mapped to an ICD-9 diagnosis code used to support billing, although these are not visible to the user. An "Other" text box was available on each category screen to allow free text entry of the indication at the user's discretion.

The final screen of the neuroradiology DSS is a common ordering page (Figure 1). The page consists of three sections: First, the acuity and indication selected by the user is presented for review and accompanied by the DSS recommended test. Indications entered as free text do not receive a recommendation. Second, a list of contraindications for the imaging modality and the use of intravenous contrast is displayed. In the pre-intervention period, this information was displayed only upon direct request. The third section of the final screen allows the user to choose which study to order. If a suggestion was given, this choice was defaulted. The user was able to override the recommendation and select any of the listed studies but had to type the reason for doing so. A separate text box was provided to allow any additional clinical information to be transmitted to the interpreting neuroradiologist.

Outcome Measures: We analyzed the distributions of tests ordered for the pre and post-intervention periods for all studies ordered and for only tests ordered where users received a recommendation (chose a listed indication). Also, the orders used to initiate the advisor were compared with the eventual orders placed. We reviewed and characterized user free text indications when these were not chosen from provided lists as well as user justifications for not accepting recommended tests.

Statistical Analysis: Chi-square tests were performed to evaluate changes in the distribution of ordering patterns and were used to compare the distribution of users types between the two study periods. Statistical testing was performed with Stata 6.0 software.

Results

During the pre-intervention phase, 742 total orders were placed for head or brain imaging studies. During the intervention period, 704 orders were placed using the DSS. Table 2 lists orders by each type of user. No difference between the distribution of user types before and after intervention was observed ($p=0.625$). At least 83% of orders were directly entered by physicians in both periods.

Figure 1: Screenshot of the decision support system final ordering screen.

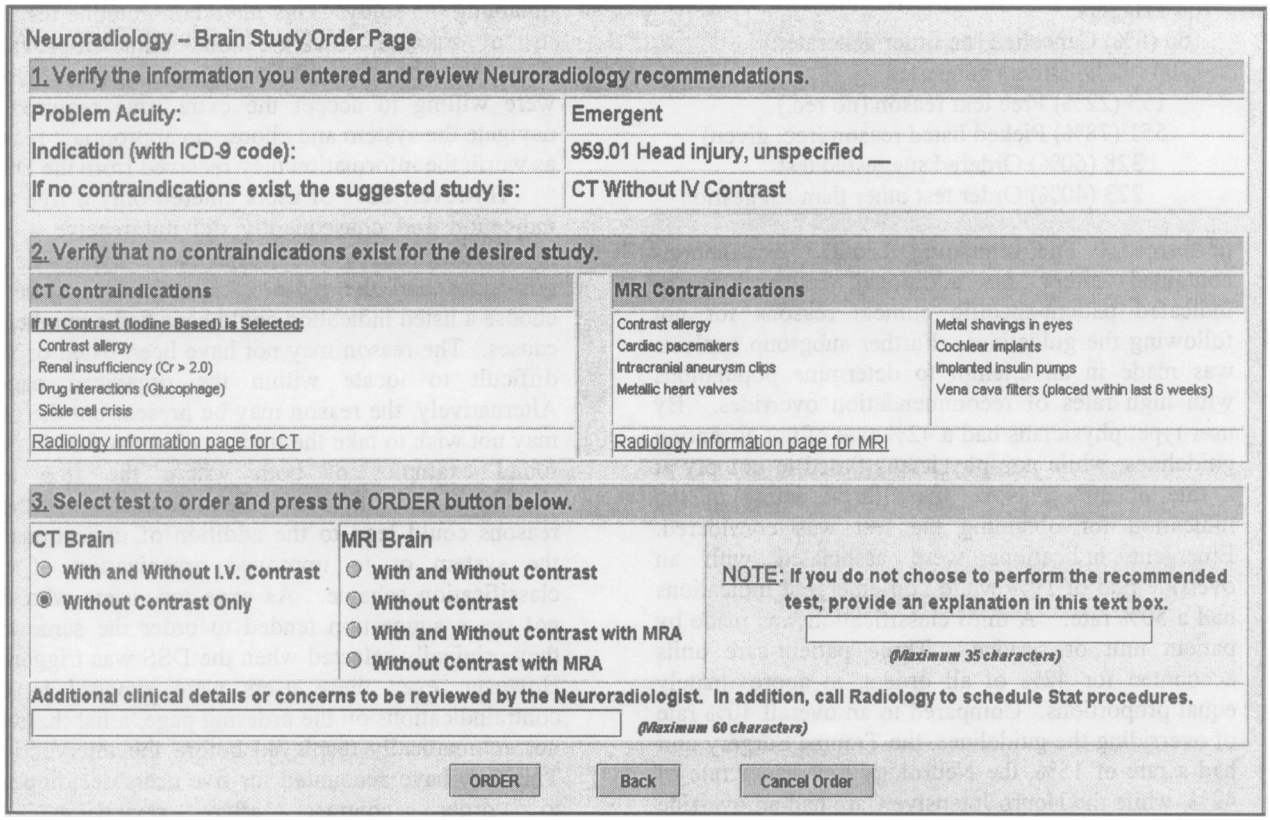


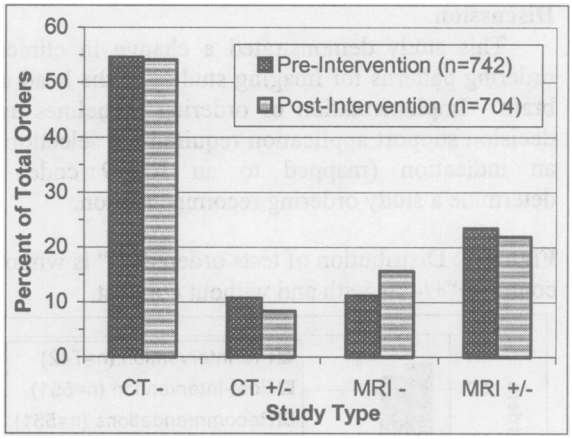
Figure 2 shows the distribution of orders for each study type by study period. There was a significant difference in these distributions (p=0.048). Overall, the percentage of Brain MRI studies without contrast increased while the utilization of the other three studies decreased.

Usage patterns of the DSS in the intervention period are detailed in Table 3, and further analysis was performed on each subgroup. Only those users who selected a listed indication received a guideline recommendation. An indication was chosen in 551 out of 704 (78%) ordering sessions, while 153 users entered only a free text reason for ordering a study. Figure 3 shows the ordering patterns of the subgroup who received recommendations. Also shown are the guideline recommendations for the indications selected by those users. For this subset, a significant difference in ordering patterns after DSS implementation (p=0.001) was observed. For all image study types, the change in frequency of tests ordered trended towards the recommended tests.

Table 2: Orders entered by user type.

User Type	Pre		Post	
MD	617	83%	596	85%
Nurse	102	14%	84	12%
Receptionist	14	2 %	18	3%
Med Student	3	< 1%	3	< 1%
Other	6	1%	3	< 1%
Total	**742**	**100%**	**704**	**100%**

Figure 2: Distribution of tests ordered. "-" is without contrast; "+/-" is with and without contrast.



Overall, 223 out of 551 (40%) of users who received a recommendation chose to order a non-recommended study. An examination of their free text reasons revealed that 34/223 (15%) of users indicated the decision was made by another person (attending or fellow, per radiology consult, or by a physician giving a verbal order); 18/223 (8%) users indicated that the suggested study had already been

Table 3: Usage Patterns of the DSS

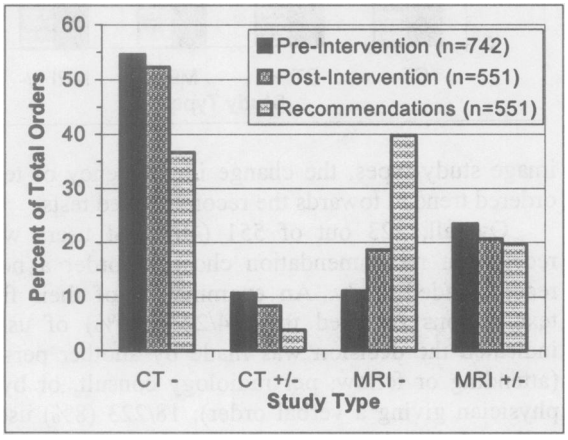
764 Triggers
60 (8%) Cancelled (no order generated)
704 (92%) Orders generated
153 (22%) Free text reason (no rec.)
551 (78%) Picked listed reason (rec. given)
328 (60%) Ordered suggested test
223 (40%) Order test other than suggestion

performed. The remaining 176/223 explanations contained either no additional information or indicated patient-specific clinical reasons for not following the guidelines. Further subgroup analysis was made in an attempt to determine populations with high rates of recommendation overrides. By user type, physicians had a 42% rate of not accepting guidelines, while non-physicians failed to comply at a rate of 30%. Next, the clinical acuity of the indication for obtaining the test was considered. Emergent indications were associated with an override rate of 19% while non-emergent indications had a 50% rate. A third classification was made by patient unit or service. Three patient-care units accounted for 42% of all orders, in approximately equal proportions. Compared to an overall 40% rate of overriding the guidelines, the Trauma Surgery unit had a rate of 15%, the Neurology unit had a rate of 42%, while the Neuro Intensive Care had an override rate of 51%. Patients in the latter two units are managed by the Neurology, Neurosurgery, and Anesthesiology services.

Discussion

This study demonstrated a change in clinician ordering patterns for imaging studies of the head and brain. Implementation of ordering guidelines as a decision support application required the selection of an indication (mapped to an ICD-9 code) to determine a study ordering recommendation.

Figure 3: Distribution of tests ordered. "-" is without contrast; "+/-" is with and without contrast.



Overall, 78% of users selected a coded reason for obtaining the study. This intervention alone resulted in a marked increase in clinician-provided documentation required for billing purposes. Users were willing to accept the extra time required to navigate the system and choose an appropriate reason as worth the information they received from the DSS.

However, 22% of users entered only a free text indication and consequently did not receive a test recommendation. They effectively bypassed the guidelines and the main intervention. Failure to choose a listed indication could have had a number of causes. The reason may not have been listed or was difficult to locate within the organized pages. Alternatively, the reason may be present but the user may not wish to take the time or effort to find it. We found examples of both within the free text indications given by users. Detailed analysis of these reasons could lead to the addition of indications to the system or to improved organization of the classification scheme. As expected, users who did not see a suggestion tended to order the same test they originally selected when the DSS was triggered. However, even these users were exposed to the contraindications on the ordering page, a list that was not automatically displayed before the intervention. This may have accounted for five users deciding not to order contrast after reviewing the contraindications.

Next, we excluded this group and considered only orders placed when the user was presented with an ordering suggestion. Again, there was a change from baseline ordering patterns, with greater statistical significance than when all orders were considered. For all imaging studies, the proportion of tests ordered fell between the baseline and the recommendations (Figure 3). This demonstrates that the computerized guideline implementation was effective in influencing test ordering patterns.

Of all users receiving a guideline recommendation, 60% ordered the suggested test while 40% chose to order some other study. Those overriding the guidelines may have done so for a number of reasons. First, our guidelines are generalized and do not factor in the many complex aspects of an individual patient's condition. This may have accounted for the observation that tests ordered for non-emergent indications were associated with a lower rate (50%) of guideline compliance. Emergent indications may have a more standardized workup than non-emergent conditions. In addition, recommendations did not take into account previous studies obtained. Text explanations stated that the recommended test had already been performed in 8% of cases. One potential source of variability was patients who had an imaging study performed before admission, such as in the clinic or emergency

department. Inpatient examinations may have been guided by results of previous studies rather than simply by the patient's clinical indication.

Second, there may be a preference for a certain imaging modality by physician or specialty. The group of experts who developed the guidelines were clinical neuroradiologists. Their preferences may have differed from other specialists. Evidence for this influence is found by comparing rates of overrides by patient unit. Increased non-compliance with recommendations was observed in areas where specialists (neurologists and neurosurgeons) would be familiar with ordering these imaging studies. Their lower rate of compliance might reflect general ordering preferences or habits of the particular service or practice group, or possibly indicate important aspects not yet represented in our DSS. The guidelines could be modified to reflect the opinions of an interdisciplinary team of experts, rather than only neuroradiologists. This may improve the quality of the recommendations for less experienced clinicians.

A third factor effecting guideline compliance was identified. Recommendations must be provided at the time of the decision making process by the decision maker. While this is often the case with clinician order entry, users such as nurses or medical receptionists may not possess the autonomy to decide which study to order. This may even be the case when the majority of users are clinicians, as in our study. Interns or residents could have received instructions from a superior to make a specific order. Evidence of someone other than the user making the ordering decision was reported as a reason for overriding a recommended study in 15% of the orders where the guidelines were given but not followed.

Results obtained from the initial implementation of these guidelines will be useful in directing future DSS development. An understanding of why users fail to choose coded indications will lead to refinement of the user interface and indication lists. Identifying patterns of accepting or overriding recommendations will lead to further guideline improvement. More research may reveal a demographic of clinician who benefits most from this type of decision support intervention. These may represent users who more infrequently order imaging studies, or are in earlier stages of clinical training.

Conclusions

This study was successful in showing that a computerized implementation of guidelines for head and brain imaging studies influenced ordering patterns. As expected, this change was most pronounced for users who supplied all required information to the decision support system. Increased documentation needed for billing purposes was also observed. Users' free text reasons for ordering tests and their comments when overriding guideline recommendations were recorded and analyzed. These may be useful in further quality improvement of both the guidelines themselves and the computer decision support tool used to implement guidelines.

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