Radiology Order Entry With Decision Support: Initial Clinical Experience

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Purpose: To determine whether an appropriately designed computerized order entry system for radiology can be clinically accepted and influence ordering practices.

Materials and Methods: An intranet-based outpatient ordering and scheduling system was designed and implemented beginning in 2001. Indications used to request imaging have been standardized and keystrokes minimized by using menus. The system offers online scheduling and provides patient reminders, preparation instructions, and driving directions. Since November 2004, examination requests have been given utility scores on the basis of the indications provided. Comparative scores for other types of imaging examinations are displayed alongside the scores for the examinations requested. Physicians' performance is tracked, and senior clinicians counsel physicians with many low-scoring examinations. Data collected from the order entry system were used to evaluate rates of use, examinations with low "utility scores," and changes in the scores over the first year of use.

Results: The use of the order entry system has increased steadily, currently constituting 75% of all potential outpatient studies. Since the addition of decision support in November 2004, almost 72,000 examinations have been scored. The highest number of low utility examinations were imaging of the spine, either computed tomography or magnetic resonance imaging. The percentage of low utility examinations declined from 6% to 2% overall. The amount of the decline was greatest for primary care physicians and for those who interacted with the computer themselves rather than through office staff members.

Conclusions: Computerized order entry with decision support can be widely accepted by clinicians and can have an impact on ordering practices.

Key Words: Order entry, decision support, imaging, health care economics

INTRODUCTION

The United States outspends every other country in the world on health care, both in absolute terms and as a percentage of the gross national product. The costs of health care continue to increase, and the growth rate is accelerating. Between 1991 and 2001, spending on health care grew at an average per capita annual growth rate of 3.1% [1], but the annual growth rate in 2002 was 9.3% [2]. Despite the high rate of spending, the United States does not rank high in measures of national health [1] or patient satisfaction [3].

Some of the high costs can be attributed to a highly complex and fragmented payment system that entails high administrative expenses and weakens the market power of payers [1]. However, the increased utilization of health care services and the increasing costs of those services probably account for the majority of the cost increases. Overall, the utilization of diagnostic radiology has increased at a similar rate to that of health care costs as a whole, with a 3.1% compound annual increase in the period from 1992 to 2001. However, the use of high-tech and high-cost radiology services has increased dramatically in the past decade, as has been demonstrated for Medicare enrollees [4-9], privately insured groups [5,7,9], and individual institutions [10,11] (Figure 1).

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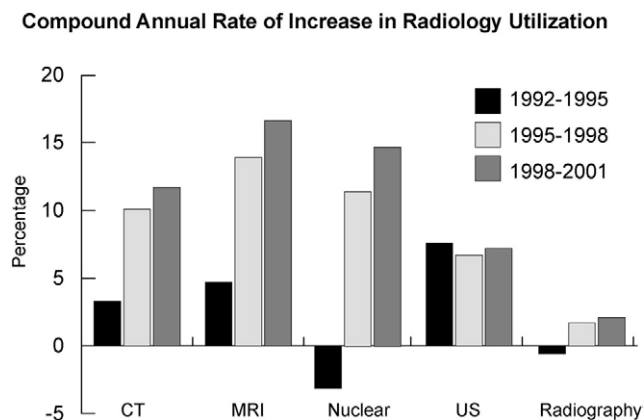
Compound Annual Rate of Increase in Radiology Utilization

Fig 1. Compound Annual Increases in Imaging Utilization per 1000 enrollees. The past ten years have seen a disproportionate increase in the high-cost imaging modalities. Whereas the use of radiography has been relatively flat, CT and MRI have increased by double-digit annual rates. Data from Bhargavan and Sunshine, 2005 [9]

This disproportionate increase in high-tech modalities has caused spending on radiology services to grow faster than overall utilization rates.

Some of this increased utilization is both beneficial and cost-effective [12] Moreover, a study by McGlynn et al [13] showed that underutilization may occur in certain circumstances. However, it is frequently asserted that a sizable percentage of diagnostic imaging is inappropriate. Such opinions are based on extrapolations from extremely limited data. Moreover, there is no simple definition of what is meant by appropriate use. For example, a true positive rate of 1% (or even less) may be appropriate in some circumstances but not others depending on the severity or importance of the condition that is being sought.

Nonetheless, most radiologists would agree that inappropriate use does occur. It can be attributed to various factors. Self-referral by nonradiologists has grown at a particularly rapid rate [14,15]. Clinicians seem uncertain concerning current indications for imaging. A survey of internal medicine residents showed that fewer than half scored more than 50% when asked to correctly select the most appropriate diagnostic imaging examination for a series of clinical scenarios [16]. Another contributory factor is the practice of defensive medicine, which drives physicians to order imaging studies even when the possibility of a significant finding is remote. Imaging is increasingly being used as an alternative to physical examinations, especially in emergency settings [17], a practice that inevitably results in a low diagnostic yield [18]. Finally, patients' expectations also help drive the demand for imaging. Although possibly not contributing to med-

ical management, negative examination results may reassure a patient [17,19].

Not surprisingly, there is considerable pressure from health insurance companies and from Medicare to contain the costs of radiology [20,21]. Insurance companies may require authorizations from utilization management companies. Algorithms used to approve or deny coverage may be published or proprietary but usually lead to binary decisions to pay or not to pay. Such an approach does not permit comparison among imaging alternatives and provides no educational value. This transactional approach is highly time and labor intensive and is unpopular in the medical community.

In 1993, the ACR recognized the need for practice guidelines and set up a multidisciplinary panel to establish its Appropriateness Criteria® for a wide variety of clinical conditions. Because scientific outcome and assessment data were often not available, the panel used broad-based consensus techniques. The ACR Appropriateness Criteria® list possible radiologic examinations for given conditions, rated on a scale of 1 to 9, in which 9 is most appropriate [22].

Computerized physician order entry has been widely touted as a means of minimizing medical errors. Computerized physician order entry can also be used to enhance the process by which medical imaging is ordered. By using a standard set of indications whose appropriateness (or lack of it) is clear, the appropriateness of a request can be determined, and immediate feedback can be given to the ordering physician.

We developed a computerized physician order entry system for this purpose. The goal was to create a simple tool that would capture all information necessary for decision support, scheduling, examination performance, and International Classification of Diseases, 9th rev, coding, while maintaining simplicity and ease of use. We replaced the individual transaction approach with a "physician scorecard" that reflects each physician's overall performance in ordering examinations. Finally, rather than a go/no-go approach to a single order, our system simultaneously provides comparative scores for various examinations that might be ordered in the clinical context, thus serving as an educational aid and a patient management tool.

The radiology order entry (ROE) system was gradually phased into clinical use beginning in 2001. Decision support for all computed tomography (CT), magnetic resonance imaging (MRI), and nuclear cardiology examinations was added in November 2004. Plain films can be ordered using ROE, but plain-film utility numbers are offered only as comparison numbers when one of the high-cost imaging studies is ordered. The use of ROE and ROE with decision support (ROE-DS) is voluntary. Traditional methods

of ordering by written request, as well as telephone scheduling, continue to be offered. However, because of an agreement with several of our major insurance carriers, the use of the ROE-DS system replaces the need for telephone preauthorization and is strongly encouraged.

To establish whether an appropriately designed computerized order entry system for radiology can meet with clinical approval and influence ordering practices, we reviewed data from the first full calendar year of use after the introduction of decision support.

MATERIALS AND METHODS

System Design

An ordering physician is required to register as an ROE user at first use. The system subsequently identifies users by password-protected login. Office staff members, including nurses, physician assistants, and residents must identify the staff physicians with whom they work, after which they are permitted to order tests or to complete the scheduling of examinations ordered by physicians.

Radiology order entry has both mandatory and optional fields. Required information includes patient identification, specific examination selection, and indication(s) for the test. Medical record numbers are used to identify patients, with demographics obtained electronically from the radiology information system. The examination selection captures all information that is essential to specify a test. For example, extremity imaging must specify the side, and spine imaging must specify the level.

Indications for each examination are offered as a list of check boxes. These are grouped into 3 categories: signs and symptoms, known diagnoses, and abnormal previous tests. At least 1 item must be selected to proceed; multiple indications are permitted. The listed indications are examination specific and were derived from historical billing data and expert opinion.

All indications correspond to International Classification of Diseases, 9th rev (ICD9), codes. Suspected diagnoses alone ("rule out") are not sufficient for ordering (although an alternative means for communicating this information is provided). The length of the list is minimized by eliminating duplicative and overly specific terms. A continuous process of revision has accompanied clinical use as requested terms are added and unused items are deleted.

Optional check boxes are available for certain common communications, such as the use of contrast, specific examination protocols (or views), and in some instances, conditions to rule out. A free-text field is provided for unstructured communication. However, neither the optional fields nor the free-text field can substitute for the selection of one of the mandatory check boxes.

On completion of the required fields, the order entry system offers appointments at all of our clinical sites, patient reminder slips, driving directions, and patient preparation instructions.

Decision Support

Once a user indicates that an order is complete, the ROE-DS system provides instantaneous decision support obtained from a lookup table that lists a numerical "utility score" for the test being ordered. Comparative scores for alternative imaging that might be considered are also provided. Information used to generate the score includes the test being requested, the age and sex of the patient (obtained through the medical record system), and the indications provided with the request. If multiple indications are offered, the score for the highest level indication is provided. Specific combinations of indications may result in scores that are higher than for each one individually.

Decision support is provided for all CT, MRI, and nuclear cardiology requests. The creation of the appropriateness scores was begun by consulting the ACR Appropriateness Criteria®. However, ROE begins with symptoms, not disease conditions, and the decision support links have been modified and expanded substantially, currently numbering approximately 10,000 reason-test pairs. Both systems use the same 9-point scale, with 1 being lowest and 9 being highest. Numbers are generally grouped into categories, with 1 to 3 representing "low utility" (shown in red), 4 to 6 representing "moderate utility" (yellow), and 7 to 9 representing "high utility" (green).

When faced with low utility scores, clinicians may chose to modify their requests by offering more information, to cancel the examinations, to order examinations of different types, or to proceed with the orders. If they elect to proceed, they are required to complete a form that documents their reasons. All changes to ROE orders are tracked by the system. Physicians who order more than a few examinations with low utility scores are contacted by one of the senior clinical leaders (not a radiologist) and counseled about the importance of appropriate ordering. This method of utilization management was accepted by our major insurance carriers as an alternative to telephone authorization.

The utility values were created and are maintained by a physician panel that includes radiologists and clinicians (both specialists and primary care doctors). The composition of the panel varies for each examina-
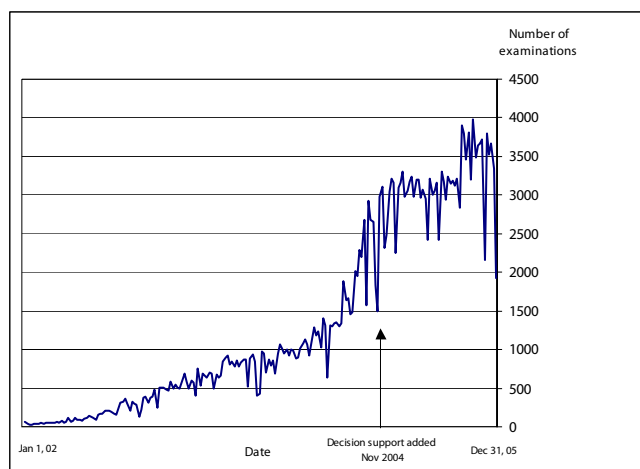
Fig 2. Following introduction of the electronic order-entry system there was a period of linear growth in use (January 2002-November 2004) as clinicians preferentially switched from conventional paper requisitions. However, the addition of Decision Support and electronic insurance preauthorization in November 2004 lead to a rapid increase in use.

tion and examination type. Thus, neuroradiologists, neurosurgeons, neurologists, and primary care doctors review the indications for head CT and head MRI; orthopedic surgeons, musculoskeletal radiologists, and primary care doctors review the indications for extremity CT and MRI; and so on.

Evaluation of Impact

The frequency with which the ROE system was used (the number of orders per week) was evaluated both before and after the addition of the decision support function.

The utility scores generated for each examination ordered since the inception of the system through the first full year of use were also retrieved from the ROE system, along with the name of the requesting physician, the physician's specialty, the date, the modality, and the examination type. Individual scores were grouped and summarized by examination type and modality. We identified those examinations with low utility scores that are most frequently ordered and the specialty groups most likely to request examinations with low utility scores.

The decision support scores for orders placed directly by physicians were compared with those placed on their behalf by assistants (nurses, residents, etc), and the overall frequency with which individual physicians logged in to the system was evaluated as a function of time. The impact of the ROE-DS system was assessed by following the change in the frequency of low utility examinations over the months after introduction.

Changes in the median scores were tested for significance ($P < .05$) using the Kruskal-Wallis test, and changes in the

chance of receiving a low utility score over time were tested for significance using the method of logistic regression (using SAS version 9.1; SAS Institute Inc., Cary, NC).

Reasons cited by requesting physicians for "proceeding on red" were tabulated and summarized.

RESULTS

There was a steady increase in use of the ROE system, beginning immediately at its inception and accelerating after the addition of decision support in fall 2004. This trend has continued up to the present. At the current rates of use (approximately 3,500 to 4,000 examinations per week), the ROE system handles 75% of our eligible outpatient order volume. Figure 2 shows the growth in use over time.

To date, 71,996 high-cost imaging studies have been subject to ROE-DS. These requests came from a broad range of clinical services. Although the surgical specialties were well represented, oncologists, neurologists, or internal medicine physicians ordered the majority of high-cost examinations (Figure 3).

Most examination requests were scored as appropriate. The overall median utility score was 8 (high utility), although there was some variation across modalities. There were statistically significant changes in the median scores over time ($P < .0001$). A breakdown by modalities is shown in Table 1. The greatest percentage of low utility scores (examinations with utility scores of 1 to 3) occurred with nuclear cardiac imaging. However, because of much larger volume, MRI had the greatest number of such cases.

There was very substantial variation by specific examination type, outweighing the variation due to modality.
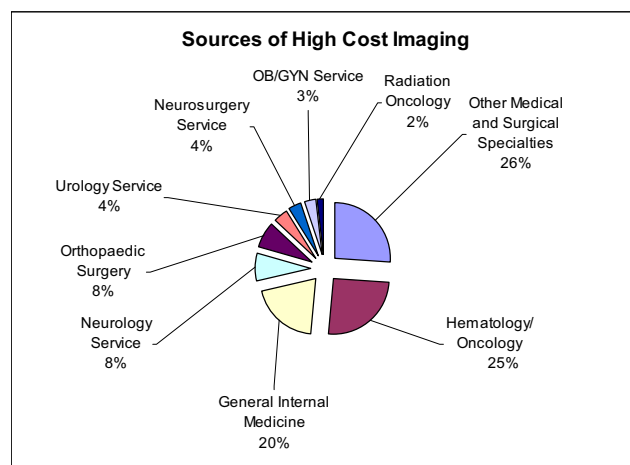

Fig 3. Sources of requests for high-cost imaging subject to Decision Support. The majority of requests originate from general medicine and the medical specialties.

Table 1. Volume and mean utility score by modality

Modality	Average Score	Number of Orders	% of Total Orders	Low Utility Scores (1–3)
CT	Mean 8.1 Median 8	43,995	61%	1%
MRI	Mean 7.7 Median 8	25,200	35%	5%
Nuclear cardiology	Mean 7.0 Median 8	2,801	4%	6%
Total		71,996	100%	

Note: Although the highest percentage of low utility scores occurred with nuclear cardiac imaging, the greatest number of cases were MRI. CT = computed tomography; MRI = magnetic resonance imaging.

Examinations of the spine (MRI and CT combined) constituted more than half of the total in the low utility range (Table 2).

As the data became available, telephone calls were made to individual physicians and to physician leaders belonging to groups with high frequencies of low utility examinations. The importance of controlling unneces- sary imaging was emphasized, and doctors were encour- aged to interact with the system themselves to learn about imaging recommendations.

Overall, the aggregate low utility rate declined continu- ously from 6% during the first month of use to 2% by the end of the 12th month when measured across all specialties and physicians ($P < .0001$). There was a decrease in the red

Table 2. Examinations with the highest number of low utility ratings

Examination	Examination Count	Average Utility Score	Number of Low Utility Scores	% of Examinations With Low Utility Scores	% of Total Hospital Low Utility Examination
Spine MRI	6,654	Mean 7.8 Median 9	788	12%	20%
Extremity MRI	5,449	Mean 8.0 Median 9	295	5%	8%
Spine CT	1,154	Mean 5.6 Median 5	231	20%	6%
Head CT	2,575	Mean 5.4 Median 5	181	7%	5%
Nuclear cardiology	2,801	Mean 7.0 Median 8	156	6%	4%
Face or sinus CT	869	Mean 7.0 Median 8	91	10%	2%
Abdominal or pelvic MRI	1,215	Mean 6.2 Median 6	52	4%	1%
Extremity CT	971	Mean 6.3 Median 7	49	5%	1%
Chest MRI	202	Mean 5.1 Median 5	37	18%	1%
Kidney adrenal genito- urinary MRI	318	Mean 6.3 Median 6	27	8%	1%
Total	22,208		1,907		49%

Note: The highest percentage of low utility examinations occurred with spine computed tomography (CT), but because of much greater overall numbers, spine magnetic resonance imaging (MRI) resulted in the largest number of low utility requests. These 10 examinations together accounted for almost half of all the low utility examinations ordered, with the top 5 examinations responsible for 43%.
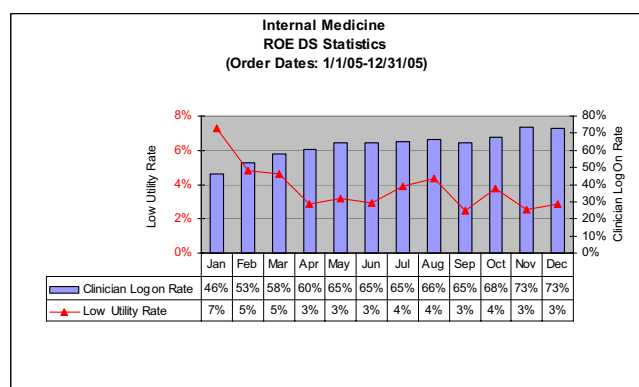
Fig 4. Changes in the rate of "low utility" orders plotted against the physician log on rate for the department of Internal Medicine. Notice the inverse relation between the direct use by the physician and the frequency with which low utility examinations are ordered.

rate for both primary care and specialists, with the rate of low utility scores changing inversely relative to the change in personal login rate (Figure 4). A logistic regression on the data in Figure 4 showed that there was a significant change over time for both the number of red orders and clinician login ($P < .0001$) in both cases.

Our efforts to have physicians interact with the system were much more successful with primary care physicians than with specialists. Over the year, the former increased their personal login rate from 33% to 73%, whereas the specialists continued to use support staff members for placing orders. (Neurologists increased from 5 to 12% and orthopedists from 2% to 5%.)

In 91% of cases that received low utility scores, the users proceeded to schedule the examinations. The reasons cited by the requesting physicians for proceeding to order low utility examinations are summarized in Table 3. In some cases, the receipt of a low utility score caused the immediate cancellation or abandonment of a request for imaging. Of 866 red results, 168 users cancelled the orders (19.4%).

DISCUSSION

Our work demonstrates that electronic order entry with decision support can be made to work on a large scale in a manner that is acceptable to clinicians and that decision support can have an impact on ordering practices.

Clinical acceptability is demonstrated by the increasing use of the ROE system before November 2004. At that time, the use of the ROE system was entirely voluntary, and the increasing rate of use is attributable to users' preference for ROE compared with conventional ordering methods. After that time, because of the need for electronic preauthorization and the increasing number of

performance-based contracts, the use of ROE was strongly encouraged by physician leadership. Users have reported high levels of satisfaction with the convenience and ease of use of the web-based system of examination-specific indications.

It was never anticipated that all outpatient examinations would be ordered by this method. Some examinations and procedures are not available in the ROE system. For example, interventional procedures require direct consultations with radiologists and are not included. In addition, physicians outside of our institution may wish to refer patients but not have access to the ROE system. Therefore, approximately 25% of potential appointments are withheld from the ROE system. The retention of this capability has also been important to handle circumstances that could not be accommodated by the ROE system for various reasons. Although there have been very few cases that could not be accommodated by the relatively brief lists of indications, some do occur. For example, some clinicians persist in ordering imaging studies for screening (with no clinical indications). Because the ROE system requires that an indication be specified, the retention of the conventional ordering and scheduling system allows such cases to be handled on an individual basis. Allowing for these few exceptions, virtually 100% of available appointments are scheduled through the ROE system.

We believe that one of the important features of our system leading to its clinical acceptance is the immediate availability of appointments. The time required to interact with the computer is somewhat greater than would be required to complete a paper request, but the time saved in scheduling the appointment more than compensates for this.

Perhaps equally important are the ongoing efforts to manage and adapt the system. All requests for new indi-

Table 3. Reasons given by clinicians for proceeding with orders for low utility examinations		
Reasons for Proceeding on Red	**Number**	**%**
Disagree with guidelines	204	25
Other imaging was tried and unhelpful	52	6
Other imaging would take too long to obtain	42	5
Recommended by a specialist	446	55
Patient demand	73	9
Total	817	100
Note: The total of reasons and cancellations exceed 866 because some users gave more than 1 reason.		

cations to be added to our lists are considered and answered. If a new indication is appropriate; can be translated into an International Classification of Diseases, 9th rev, code; and does not duplicate already available indications, it is added. Decision support for new indications is developed by our physician panel. If requesting physicians indicate disagreement with our decision support criteria, their reasons are evaluated carefully, and changes are made as recommended by the expert panels.

Computerized order entry has previously been shown to decrease the number of errors in medication orders and the number and cost of ordered laboratory tests [23]. It has also been found to enhance radiology workflow for imaging requests during off hours. When computerized physician order entry was implemented, patients were more likely to arrive prepared for examinations, and special instructions were conveyed more effectively to technologists [24]. Although computerized methods to aid in the selection of examinations have been proposed [25,26], few decision support systems have been implemented for radiologic use. Nevertheless, some benefits have been reported, including improved compliance with guidelines and decreased numbers of orders for radiography of the upper gastrointestinal tract [27]. A trend toward better compliance with guideline recommendations has been demonstrated for head MRI and CT [28]. However, successful experiences are not universal. For example, cancellation rates in response to critiques were very low for orders of abdominal radiography, although many ordering physicians accepted suggestions for alternate studies [29].

Most utilization management systems attempt to control utilization by acting as gatekeepers, one transaction at a time. Such programs are time consuming and expensive to run. In addition, it is difficult for such systems to take into account the inevitable exceptions to rules and guidelines. Such methods also fail to distinguish between clinicians who frequently place inappropriate orders and those who rarely or never do so.

The increasingly common pay-for-performance programs, in which providers are rewarded financially for achieving contractual goals [30], often put radiologists in the role of gatekeepers [31]. We think that this is not the best approach. It may strain consulting relationships and result in conflicts of interest for radiologists. Furthermore, the appropriate peer group for a clinician is that of other clinicians in the same specialty. The approach of having a senior clinician other than a radiologist review the appropriateness of ordering has been more successful and less contentious. Our utilization scorecard provides data that make this possible.

It is clear that our system has had an impact on the way in which imaging studies are ordered, as shown by the declining number of low utility examinations. It is less

clear whether this represents a change in utilization practices. Perhaps physicians have learned that they must provide information that they otherwise would have withheld. For example, a spine examination would receive a low utility score if the request only indicated "back pain" but would be considered appropriate if the physician also provided the information that the patient had "abnormal extremity sensations." Improved communication of this type is beneficial even if the rate of utilization is not affected. However, we have no way to determine the veracity of the history provided, and it is possible that some physicians are "gaming" the system. It is also unclear whether there is an optimum number for this score. It is very unlikely that it can or should be zero, because no scoring system can anticipate all of the complexities of clinical interactions. Future work will apply tools that have been developed to compare the rate of positive findings for examinations with high and low utility scores and permit comparisons among physicians [32].

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