Effectiveness of Clinical Decision Support in Controlling Inappropriate Imaging

C. Craig Blackmore, MD, MPH, Robert S. Mecklenburg, MD, Gary S. Kaplan, MD

Background: Decision support systems for advanced imaging are being implemented with increased frequency and are mandated under some new governmental health care initiatives. However, evidence of effectiveness in reducing inappropriate imaging utilization is limited.

Methods: A retrospective cohort study was performed of the staged implementation of evidence-based clinical decision support built into ordering systems for selected high-volume imaging procedures: lumbar MRI, brain MRI, and sinus CT. Brain CT was included as a control. Imaging utilization rates (number of patients imaged as a proportion of patients with selected clinical conditions) and overall imaging utilization before and after the interventions were determined from billing data from a regional health plan and from the institutional radiology information system.

Results: The use of imaging clinical decision support was associated with substantial decreases in the utilization rate of lumbar MRI for low back pain (risk ratio, 0.77; 95% confidence interval, 0.87-0.67; $P =$ .0001), head MRI for headache (risk ratio, 0.76; 95% confidence interval, 0.91-0.64; $P =$ .001), and sinus CT for sinusitis (risk ratio, 0.73; 95% confidence interval, 0.82-0.65; $P <$ .0001). Utilization rates for the head CT control group were not significantly changed. There was a corresponding significant decrease in overall imaging volumes (all diagnoses) for lumbar MRI, head MRI, and sinus CT, with no observed effect for the head CT control group.

Conclusion: Targeted use of imaging clinical decision support is associated with large decreases in the inappropriate utilization of advanced imaging tests.

Key Words: Imaging utilization, appropriateness, computer decision support

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INTRODUCTION

Health care expenses in the United States continue to spiral upward, now representing more than 17% of the gross domestic product [1]. Imaging is one of the most important contributors to health care costs, encompassing more than 14% of Medicare Part B expenditures [2-4]. Although identified as the most significant advance in medicine in the past several decades [5], imaging has become a target for cost containment. A major driver for increasing imaging cost is the inappropriate utilization of advanced imaging, including CT and MRI [4,6-8]. Accordingly, health care providers are under increasing pressure to limit imaging to evidence-based applications.

Payers have initiated several approaches to control imaging utilization, including external authorization methods and clinical decision support systems [9]. Clinical decision support systems are point-of-order decision aids, usually through computer order entry systems, that provide real-time feedback to providers ordering imaging tests, including information on test appropriateness for specific indications. Such systems may be purely educational, or they may be restrictive in not allowing imaging test ordering to proceed when accepted indications are absent. Although data on the efficacy of imaging clinical decision support systems are limited [10], adoption is increasing and has spread to include state-level initiatives in Washington [11] and Minnesota [12]. Imaging clinical decision support systems can range from simple aids

Center for Health Care Solutions, Virginia Mason Medical Center, Seattle, Washington.

Corresponding author and reprints: C. Craig Blackmore, MD, MPH, Virginia Mason Medical Center, Department of Radiology, Mailstop C5-XR, 1100 Ninth Avenue, PO Box 900, Seattle, WA 98111; e-mail: craig.blackmore@vmmc.org.

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for small numbers of studies and indications to broad systems encompassing the thousands of possible pairs of indications and imaging procedures. To date, there are no published studies demonstrating decreased imaging utilization after implementation of imaging clinical decision support, though a decrease in the rate of growth of utilization of imaging has been reported. We hypothesized that imaging clinical decision support could decrease imaging utilization when targeted to select imaging studies and indications that included high volumes and high cost [13,14].

The objective of this investigation was to identify changes in imaging utilization associated with the initiation of an imaging management program based on clinical decision support for selected CT and MRI studies at a single integrated health care delivery system.

METHODS

The overall study design was a retrospective cohort evaluation of the effect of the staged implementation of a clinical decision support system on imaging utilization, with historical and concurrent controls. The study was granted a waiver from the institutional review board.

Setting

The study setting was Virginia Mason Medical Center, an integrated multidisciplinary health care network in the Pacific Northwest with approximately 450 physicians, 800,000 outpatient visits, 17,000 hospital visits, and 260,000 radiology examinations annually. The institution includes a central urban campus as well as multiple suburban satellite imaging and outpatient care centers.

Intervention

Lumbar MRI, head MRI, and sinus CT were identified as frequently performed, high-cost procedures with high variability in utilization [2,14,15] and with at least some medical evidence to guide appropriate utilization [16]. Accordingly, these procedures were targeted for the initial implementation of the decision support system, rather than a more global approach. The intervention was based on a set of locally derived evidence-based decision rules for when imaging is appropriate. These decision rules were developed by Virginia Mason providers from the involved specialties after review of national and international evidence-based guidelines and primary literature and were vetted extensively in the institution before implementation. The system was not designed to be comprehensive but rather to focus on areas where there was potential for improvement, which we defined as high variability, high utilization, and medical evidence to enable guideline development.

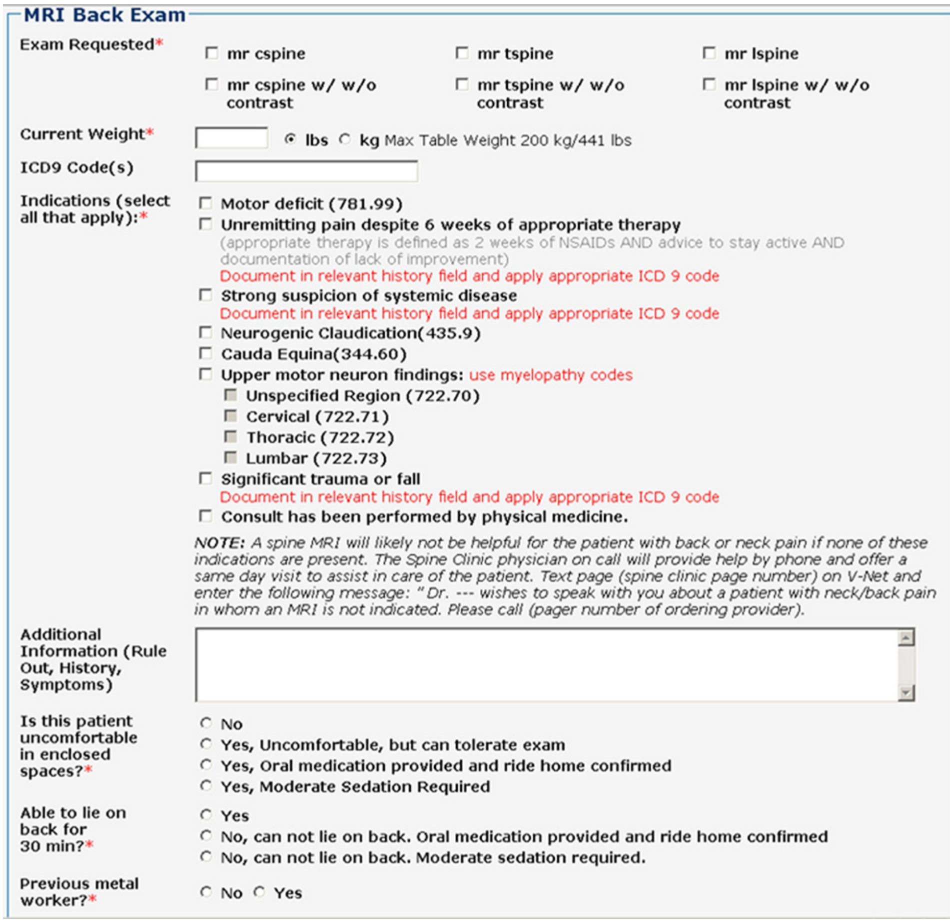
The actual imaging intervention was built around several assumptions: (1) that physician education alone is insufficient to change practice, (2) that patient and provider expectations mandate that an alternative be offered if imaging is denied, and (3) that the intervention should occur at the point of care, to avoid disrupting care.

The imaging intervention was a mandatory series of questions at the point of care in the imaging order system that confirmed adherence to the institutional evidence-based imaging indications (Figure 1). Providers ordering studies were required to check appropriate boxes corresponding to approved imaging indications. Failure to document compliance with approved indications would prevent the online order from being activated. The intervention was systemwide but was limited to outpatient imaging (excluding the emergency department). The imaging clinical decision support intervention was accompanied by an institutional educational effort including e-mails, small conferences, and personal communication. Additional periodic audits were performed with communication with any providers who ordered imaging but had not documented appropriate indications in the medical record. The evidence-based imaging protocols for MRI for low back pain and head MRI for headache were implemented in 2005. The protocol for sinus CT for suspected sinus disease was implemented in 2007.

Because of patient and provider expectations, alternatives to imaging that might be beneficial to patients were also offered, with information provided in the order entry system. For lumbar back pain, physical therapy was offered, with availability of same-day or next-day consultation with a (nonoperative) spine specialist. For headache and sinus disease, prompt neurologist or allergist consultation was available. The subspecialist consultants were authorized to override the clinical decision support system when they considered imaging clinically indicated.

Data Sources

To determine the effectiveness of the intervention in decreasing inappropriate imaging utilization, we used *International Classification of Disease,* 9th ed., *Clinical Modification* (ICD-9-CM) and Common Procedural Terminology® (CPT®) codes to interrogate the data records of a large regional health insurance carrier to determine the rates of relevant imaging for patients with specified diagnoses cared for in our system. Data were available for January 1, 2003, through December 31, 2009. For each of the clinical conditions (low back pain, headache, and sinusitis), we identified corresponding sets of ICD-9-CM codes. For the patients with the clinical scenarios defined by the codes, we used CPT codes to determine the utilization of relevant imaging. For the low back pain, the included ICD-9-CM codes were 344.6,


MRI Back Exam

Exam Requested*
- mr cspine
- mr tspine
- mr lspine
- mr cspine w/ w/o contrast
- mr tspine w/ w/o contrast
- mr lspine w/ w/o contrast

Current Weight* [ ] lbs / kg Max Table Weight 200 kg/441 lbs

ICD9 Code(s)

Indications (select all that apply):*
- Motor deficit (781.99)
- Unremitting pain despite 6 weeks of appropriate therapy
  (appropriate therapy is defined as 2 weeks of NSAIDs AND advice to stay active AND documentation of lack of improvement)
  Document in relevant history field and apply appropriate ICD 9 code
- Strong suspicion of systemic disease
  Document in relevant history field and apply appropriate ICD 9 code
- Neurogenic Claudication(435.9)
- Cauda Equina(344.60)
- Upper motor neuron findings: use myelopathy codes
  - Unspecified Region (722.70)
  - Cervical (722.71)
  - Thoracic (722.72)
  - Lumbar (722.73)
- Significant trauma or fall
  Document in relevant history field and apply appropriate ICD 9 code
- Consult has been performed by physical medicine.

NOTE: A spine MRI will likely not be helpful for the patient with back or neck pain if none of these indications are present. The Spine Clinic physician on call will provide help by phone and offer a same day visit to assist in care of the patient. Text page (spine clinic page number) on V-Net and enter the following message: "Dr. --- wishes to speak with you about a patient with neck/back pain in whom an MRI is not indicated. Please call (pager number of ordering provider).

Additional Information (Rule Out, History, Symptoms)

Is this patient uncomfortable in enclosed spaces?*
- No
- Yes, Uncomfortable, but can tolerate exam
- Yes, Oral medication provided and ride home confirmed
- Yes, Moderate Sedation Required

Able to lie on back for 30 min?*
- Yes
- No, can not lie on back. Oral medication provided and ride home confirmed
- No, can not lie on back. Moderate sedation required.

Previous metal worker?* No / Yes

Fig 1. Sample imaging clinical decision support tool for low back pain and lumbar MRI.

720, 721.3, 721.42, 721.5 to 721.9, 722.10, 722.32, 722.52, 722.73, 722.83, 722.93, 724.02, 724.2 to 724.9, 846, and 847.2 to 847.4. For lumbar MR, the included CPT codes were 72148, 72149, and 72158, encompassing all lumbar MR examinations. For headache, the included ICD-9-CM codes were 307.81, 339, 346, and 784.0. The associated CT and MR codes were 70450, 70460, 70470, 70541, 70551, 70552, and 70553, encompassing all head MR and CT examinations. The sinusitis ICD-9-CM codes were 461, 473, and 478.1. The sinus CT CPT code was 70486, which included all CT sinus studies.

Total volumes of imaging were also determined from the radiology information system (IDX Imagecast 10; GE Healthcare, Fairfield, Connecticut) on the basis of the CPT codes detailed above. These volumes are irrespective of payer.

Data Analysis

Primary analysis was a comparison of the rate of imaging in the years preceding the intervention with the rate of imaging in the years after the intervention, for the single commercial payer. For imaging rate, the numerator was the number of patients imaged, and the denominator was the total number of patients with a given clinical condition. Imaging rate rather than absolute number of studies was used in the primary analysis to control for temporal variation in the number of patients evaluated with a given clinical condition. We assessed for significant change in imaging rate after the intervention, adjusted for temporal trends, using the likelihood ratio test to compare linear regression models of rate as a function of year vs rate as a function of year and intervention. Estimates of the absolute magnitude in decrease in imaging rate after the intervention were made by comparing the imaging rate in the year before the intervention with the average imaging rate in the years after the intervention, using χ^2 analysis. For the magnitude analysis, the actual year of intervention was excluded. Similar analysis was also performed for head CT as an internal control and also to ensure that there was no substitution of head CT for head MRI after the intervention. Because there was no intervention for head CT, for the analysis, the intervention year for head CT was considered to be 2005, the year of the head MR intervention.

Secondary analysis included the determination of changes in trends and overall volumes of the specific imaging studies associated with the intervention,

Table 1. Imaging volume, patient volumes, and imaging rate

Study	2003	2004	2005	2006	2007	2008	2009
Lumbar MRI for low back pain	261	292	402	290	296	329	355
Head MRI for headache	149	165	224	171	186	186	191
Sinus CT for sinusitis	285	321	522	497	448	355	305
Head CT for headache	100	100	143	130	142	147	143
Headache patients	1,062	1,111	1,684	1,559	1,535	1,699	1,682
Sinusitis patients	2,164	2,123	3,502	2,838	2,812	2,623	2,525
Low back pain patients	2,303	2,302	3,373	3,114	3,117	3,342	3,497
Lumbar MRI rate*	0.113	0.127	***0.119***	0.093	0.095	0.098	0.102
Brain MRI rate*	0.140	0.148	***0.133***	0.110	0.121	0.110	0.114
Sinus CT rate*	0.132	0.151	0.149	0.175	***0.159***	0.135	0.121
Head CT rate*	0.094	0.090	0.085	0.083	0.093	0.087	0.085

Note: Data on patients from a single regional commercial payer. Numbers in boldface italics represent the year of intervention (no intervention in the head CT control group).
*Rate is defined as the number of patients with a given procedure divided by the total number of patients with a specific clinical condition.

throughout the network (for all purchasers and for all diagnoses). Overall volumes were not adjusted for clinical condition but provide an estimate of overall effect of the intervention on health care utilization and cost. We assessed for significant change in overall volume of imaging studies after the intervention, adjusted for temporal trends, using the likelihood ratio test to compare linear regression models of volume as a function of year vs volume as a function of year and intervention. Finally, we assessed for temporal change in imaging rate and imaging volume before and after the intervention using linear regression.

Results are expressed as the risk ratio (RR) for imaging, with a value of <1.0 indicating decreased imaging after the intervention. In addition, results are reported as a percentage change (reduction) in imaging. Statistical analysis was performed using Stata version 10 (StataCorp LP, College Station, Texas).

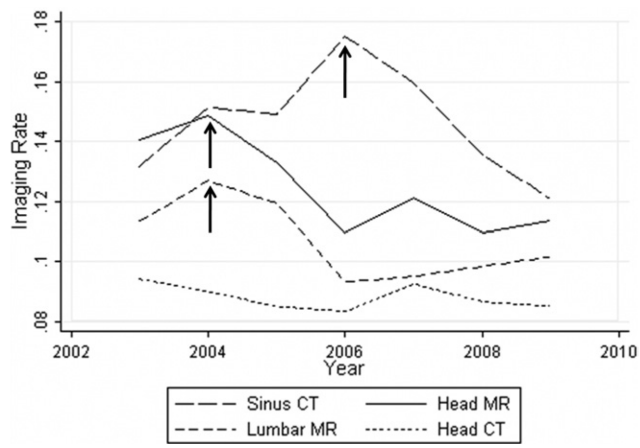


Fig 2. Imaging rates vs time for patients with disease-specific billing codes from a single regional payer. Arrows indicate the year before the intervention.

RESULTS

We found clinically and statistically significant decreases in utilization rates for the targeted procedures after the intervention. Table 1 details the raw counts of imaging procedures, as well as the counts of patients with the corresponding diagnoses and the rate of imaging among affected individuals before and after the intervention. The rates of imaging after the intervention were 23.4% lower for low back pain lumbar MRI (RR, 0.77; 95% confidence interval [CI], 0.87-0.67; $P <$ .001), 23.2% lower for headache head MRI (RR, 0.76; 95% CI, 0.91-0.64; $P = .001$), and 26.8% lower for sinusitis sinus CT (RR, 0.73; 95% CI, 0.82-0.65; $P <$ .001). The peak rate occurred in the year before the intervention for all 3 imaging procedures (Figure 2). The decrease in imaging rate was significant in the multiple regression analysis after adjustment for temporal trend for lumbar MRI ($P = .001$), head MRI ($P = .05$), and sinus CT ($P = .003$), with a nonsignificant result for the head CT control group ($P = .88$).

After the intervention-associated decline, the rate of MRI of the lumbar spine increased at approximately 3% per year (RR, 1.003; 95% CI, 1.002-1.004; $P = .007$), while there was no evidence of an increase in rate for head MRI (RR, 1.000; 95% CI, 0.99-1.01, $P = .99$). Postintervention trend analysis for head MRI, head CT, and lumbar MRI was limited by the small sample size (4 years). Sinus CT could not be explored for trend after the intervention.

For the head CT control group, we identified no significant change in the rate of imaging (RR, 0.97; 95% CI, 1.21-0.78, $P = .37$) after the head MRI intervention (no head CT intervention was performed). There was also no trend in head CT rate in the years after the intervention (RR, 1.0; 95% CI, 0.99-1.01, $P = .96$).

Secondary analysis revealed that the decision support intervention was also associated with decreases in the overall volumes of lumbar MRI, head MRI, and sinus CT studies, regardless of diagnosis. For head MRI, the volumes after the intervention were significantly lower in the regression model ($P < .0001$) after adjustment for temporal volume trends and continued to decrease after the intervention by 162 studies per year (95% CI, 88-236; $P = .01$). For lumbar MRI, adjusted volumes after the intervention were significantly lower ($P = .005$) than before the intervention, with no significant change in subsequent years (estimated subsequent decrease, 34; 95% CI, decrease 279 to increase 210, $P = .60$). For sinus CT, there was a significant decrease in adjusted volumes after the intervention ($P = .010$), with insufficient data to assess for a further decrease. For the head CT control group, there was no significant change in overall volume associated with the time of the head MRI intervention ($P = .52$).

DISCUSSION

Clinical decision support is potentially an ideal method for improving the evidence-based use of imaging. Clinical decision support tools have the desired properties of being educational, transparent, efficient, practical, and consistent [4]. However, data on the effectiveness of clinical decision support is limited. Prior investigation has focused on the use of a global system encompassing virtually all CT and MRI studies and indications and has demonstrated only a relative attenuation in the rate of increase in imaging utilization. However, in the prior report, actual imaging utilization of both CT and MRI continued to grow [10].

In this report, we detail a significant and sustained decrease in the utilization of targeted advanced imaging studies through the use of clinical decision support based on a simple set of locally derived evidence-based imaging guidelines. Our approach has several important innovations from other reports of imaging clinical decision support systems [9,10] that may have contributed to success. We targeted areas of high and potentially inappropriate utilization, concentrating effort where there is potential for benefit rather than globally applying computer decision support to all higher imaging, as others have advocated [9,10]. Also, we incorporated denial of imaging for inappropriate indications, preventing orders that did not meet evidence-based indications from proceeding in the computer order entry system. Finally, we offered the provision of alternate resources, in the form of prompt specialist consultation or therapy, where indicated.

The study setting likely had a substantial effect on the success of the program. The intervention was performed at Virginia Mason Medical Center, a multispecialty integrated health care network, with all providers being salaried employees of the institution. Thus, financial incentives and risks were shared by the entire institution and providers. Although the providers received no direct financial incentive or avoidance of precertification, there was pressure on the institution from local commercial payers to take an active role in limiting the overutilization of imaging. The clinical decision support intervention, coupled with rapid access to appropriate clinical care, increased the quality and efficiency of providing care at the institution, potentially providing overall benefit despite decrease in radiology volumes. This overall institutional benefit allowed radiology to participate in practice improvements that may have resulted in decreased radiology reimbursement. However, it is also clear that to the extent that financial incentives in the health care system are based on volumes and reward inefficiency through overutilization, the overall institution could be at a financial disadvantage as a result of providing better quality, more evidence based care.

A second advantage to being a multispecialty network is that most referrals for imaging were from within the system, enhancing the ability to influence physician ordering behavior. The elimination of unnecessary imaging was defined by the institution as a component of quality, motivating providers to support the mandatory clinical decision support program. Also, the concept of evidence-based medicine had wide penetration throughout our institution, with a concordant high acceptance of evidence-based imaging protocols. In addition, the institutional culture, with a pervasive focus on efficiency and Lean health care management methodology [17], provided a framework to enable relatively rapid change.

There have been important challenges in the implementation of the imaging clinical decision support system. Although built using evidence-based medicine methodology, our protocols were often limited by the availability of quality data and nationally accepted evidence-based guidelines. Accordingly, global evidence was applied locally through the work of institutional evidence-based medicine teams, relying on local provider expertise only where evidence was lacking [18]. However, because our protocol development process was local, critical buy-in from stakeholders was achieved in the development stage, enhancing implementation throughout the network.

We acknowledge the limitations of this analysis. The study was performed retrospectively with data from only 7 years because earlier data are not available within our data systems. Temporal events independent of our intervention may affect the rates of imaging, and although we did adjust for year in the regression analyses, residual confounding may exist. The use of head CT as an internal control provided some reassurance that there was not a generalized trend toward a decrease in imaging utilization over the study time frame, as we observed no significant change in head CT rate and volume during the study period. In addition, the fact that the CT sinusitis intervention occurred 2 years after the lumbar and brain MR interventions, but with similar results, lends strength to the argument that the decrease in imaging is a function of the intervention. Finally, national trends in the time frame of this study have reported continued substantial increases in imaging volumes, in sharp contrast to our decreases [19,20]. We also acknowledge that other factors in addition to the clinical decision support likely contributed to the success of our program, including the Hawthorne effect, peer pressure, and the fact that the results of our periodic audits would potentially be available to the referring physician's employer.

Also, the analysis was based on administrative data without patient identifiers. Therefore, we were not able to directly evaluate the appropriateness of imaging for each subject. It is possible that inappropriate utilization continues. We also lack the ability to confirm that the decrease in utilization is appropriate. However, given that the computer order entry intervention is based on the best available evidence, we have confidence that appropriateness of imaging has been improved. It is also possible that patients in whom imaging was not performed at our institution sought care elsewhere. This would provide an argument for more global adoption of evidence-based imaging protocols but not lessen the significance of our results in improving care at our institution.

With clinical decision support or other barriers to image ordering, there is always the potential that providers will "game" the system, developing ways to continue to order inappropriate studies. We did not audit individual requests of imaging to determine the outcome when a request was initially denied by the system. However, we report our results in terms of imaging rate and total volume of imaging studies. Unlike appropriateness scores or other intermediate metrics, imaging rate and total imaging volume represent actual utilization outcomes that cannot be "gamed" by altering indications or other techniques.

Our data were acquired in the real world of quality improvement, so we lack the ability to randomize or to perform a multicenter controlled study. Furthermore, the limited number of institutions with a focus on Lean process and quality may restrict the generalizability of our results. However, we do provide evidence of the potential value of targeted imaging clinical decision support and provide an example of a successful approach. Finally, as of this report, we have implemented imaging clinical decision support only for a limited number of imaging studies and indications. However, a large proportion of advanced imaging, and likely a large portion of the potential for improvement, occurs in a relatively limited number of high-use, high-cost procedures [14,15].

In conclusion, we demonstrate that the implementation of imaging clinical decision support for selected high-utilization imaging procedures can have a substantial effect on imaging rate and volume in an integrated multidisciplinary health care network. The use of such systems can aid the elimination of unnecessary imaging, increasing both patient safety and quality and decreasing health care costs.

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REFERENCES

1. Truffer CJ, Keehan S, Smith S, et al. Health spending projections through 2019: the recession's impact continues. Health Aff (Millwood) 2010;29:1-8.
2. Levinson DR. Office of Inspector General report: growth in advanced imaging paid under the Medicare physician fee schedule. Washington, DC: Office of Inspector General; 2007.
3. Medicare Payment Advisory Commission. Report to Congress: variation and innovation in medicine. Washington, DC: Medicare Payment Advisory Commission; 2003.
4. Bernardy M, Ullrich CG, Rawson JV, et al. Strategies for managing imaging utilization. J Am Coll Radiol 2009;6:844-50.
5. Fuchs VR, Sox HC. Physicians' views of the relative importance of thirty medical innovations. Health Aff (Millwood) 2001;20:30-42.
6. Hillman BJ. Foreword. In: Medina LS, Blackmore CC, eds. Evidence based imaging: optimizing imaging for patient care. New York: Springer; 2006:vii-viii.
7. Reinhardt UE, Hussey PS, Anderson GF. US healthcare spending in an international context. Health Aff (Millwood) 2004;23:10-25.
8. Lehnert BE, Bree RL. Analysis of appropriateness of outpatient CT and MRI referred from primary care clinics at an academic medical center: how critical is the need for improved decision support. J Am Coll Radiol 2010;7:192-7.
9. Rosenthal DI, Weilburg JB, Schultz T, et al. Radiology order entry with decision support: initial clinical experience. J Am Coll Radiol 2006;3:799-806.

10. Sistrom CL, Dang PA, Weilburg JB, Dreyer KJ, Rosenthal DI, Thrall JH. Effect of computerized order entry with integrated decision support on the growth of outpatient procedure volumes: seven-year time series analysis. Radiology 2009;251:147-55.

11. An act relating to diagnostic imaging service; adding a new chapter to Title 70 RCW; and declaring an emergency. In: Revised Code of Washington. 61st ed. 2009.

12. High-technology diagnostic imaging initiative executive summary. Available at: http://www.icsi.org/health_care_redesign_/diagnostic_imaging_35952/htdi_executive_summary_35959/. Accessed March 23, 2010.

13. Institute of Medicine. 2009 Institute of Medicine workshop series: lowering costs and improving outcomes. Washington, DC: National Academies Press. In press.

14. Mecklenburg RS, Kaplan GS. The marketplace collaborative project. Seattle, Wash: Center for Health Care Solutions at Virginia Mason; 2008.

15. Washington State agency utilization—advanced imaging priority. Available at: http://www.hta.hca.wa.gov/documents/StateAgencyUtilization-AIPriority.pdf. Accessed March 9, 2010.

16. Medina LS, Blackmore CC. Evidence based imaging: optimizing imaging for patient care. New York: Springer; 2006.

17. Bush RW. Reducing waste in US healthcare system. JAMA 2007;297:871-4.

18. Clancy CM, Cronin K. Evidence-based decision making: global evidence, local decisions. Health Aff (Millwood) 2005;24:151-62.

19. Smith-Bindman R, Miglioretti DL, Larson EB. Rising use of diagnostic imaging in a large integrated health system. Health Aff (Millwood) 2008;27:1491-502.

20. Parker L, Levin DC, Frangos A, Rao VM. Geographic variation in the utilization of noninvasive diagnostic imaging: national Medicare data, 1998-2007. AJR Am J Roentgenol 2010;194:1034-9.

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