



Randomized Clinical Trial of a Clinical Decision Support Tool for Improving the Appropriateness Scores for Ordering Imaging Studies in Primary and Specialty Care Ambulatory Clinics

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OBJECTIVE. The objective of our study was to evaluate whether the use of a clinical decision support (CDS) tool improved the appropriateness scores of orders for advanced imaging in clinical practice.

MATERIALS AND METHODS. We used a stepped-wedge, cluster randomized clinical trial to evaluate the effectiveness of a CDS tool in an integrated health care system. Clinicians entered structured indications for each CT and MRI order, and the indications were electronically scored against appropriateness criteria to assign an appropriateness score. We compared the proportion of orders with adjusted appropriateness scores of 7 or greater (on a 1–9 scale) before and after activation of best practice alerts (BPAs) triggered for orders with low or marginal appropriateness scores. Secondary outcomes included the rate per month of orders for advanced imaging and the proportion of orders for which the radiology department requested changes.

RESULTS. Between October 2015 and February 2016, 941 clinicians ordered 22,279 CT or MRI studies that met eligibility criteria. Before activation of the BPA, the mean proportion of appropriate orders (adjusted for time and clinic effect) was 77.0% (95% CI, 75.5–78.4%), which increased to 80.1% (95% CI, 78.7–81.5%) after activation ($p = 0.001$). There was no significant change in the rate of orders per month for advanced imaging. The proportion of order changes requested by the radiology department decreased from 5.7% (95% CI, 5.6–5.9%) before CDS implementation to 5.3% (95% CI, 5.1–5.5%) after CDS implementation ($p < 0.001$).

CONCLUSION. Using an evidence-based CDS tool in clinical practice was associated with a modest but significant improvement in the appropriateness scores of advanced imaging orders.

Expenditures for health care services are growing faster than the national gross domestic product [1]. In particular, the use of advanced imaging—such as CT, MRI, and PET—has rapidly increased over the past 2 decades [2–5]. Between 26% and 30% of diagnostic imaging procedures may be either unnecessary or inappropriate [5, 6]. Increases in the use of advanced imaging have raised concerns among legislators, regulators, payers, and patients and have resulted in scrutiny of the appropriateness of medical imaging services [2].

Inappropriate use of medical imaging leads to unnecessary health care expenditures and exposes patients to potentially hazardous ionizing radiation [4, 7]. In response to concerns about inappropriate use of advanced imaging in ambulatory care settings, the American College of Radiology (ACR) developed Appropriateness Criteria (AC) for

imaging studies based on specific clinical indications [8]. The ACR AC ratings range from 1 (least appropriate study) to 9 (most appropriate study) for a clinical indication.

To address the rising rate of imaging and the concomitant rise in unnecessary or inappropriate imaging studies, clinical decision support (CDS) tools are being incorporated into electronic medical record (EMR) systems to provide clinicians with evidence-based decision support at the time of ordering imaging studies. The Protecting Access to Medicare Act of 2014 directed the Centers for Medicare & Medicaid Services (CMS) to establish a program to promote the use of appropriate use criteria for advanced diagnostic imaging services [9]. This program requires the provision of appropriate use criteria during order entry and aims to engage medical informatics expertise and use rigorous evidence to improve quality, service, and affordability of advanced imaging [10].

Starting in January 2021, claims submitted to CMS without appropriate CDS documentation will not be reimbursed [11].

Despite the impending requirement for CDS use during clinician order entry for advanced imaging, few randomized trials have rigorously assessed methods to curb unnecessary or inappropriate imaging studies [12]. The aim of this study was to use a stepped-wedge, cluster randomized clinical trial to evaluate whether a point-of-care CDS tool improved the appropriateness scores of advanced imaging orders in primary and specialty care ambulatory clinics. Secondary outcomes included whether the CDS tool would change the rate of orders placed for advanced imaging and the proportion of advanced imaging orders for which the radiology department requested changes.

Materials and Methods

Study Setting

The study site was Kaiser Permanente Colorado (KPCO), an integrated health care delivery system that serves a patient population of more than 600,000 members in the Denver metropolitan area. This study was deemed to be quality improvement research by the KPCO institutional review board and not human subject research. The study period included September 2015 through August 2017. The health plan employed more than 6000 staff members and the medical group consisted of more than 1300 physicians during the study period. The system had 23 ambulatory medical office clinics in the Denver metropolitan area. The health system deployed commercial EMR software in 2004. Epic (Hyperspace Ambulatory) version 2014 was used from September 2015 to June 2016 and was updated to version 2015 in June 2016.

Prior Efforts to Improve Appropriateness of Imaging Orders

Continued clinician education (i.e., continuing medical education) and quality improvement are an established part of the care delivery processes in KPCO. In 2013 and 2014, physicians received peer comparisons of imaging orders for patients with low back pain, headaches, or adnexal masses. All clinicians were encouraged to reflect on this information and determine if they were ordering too many or too few imaging studies for these conditions. These reports did not continue after 2014.

Clinical Decision Support Software and Best Practice Alert

In 2015, organizational leadership sought to improve the quality of imaging care and lower costs

by implementing CDS software (ACR Select, version 10, National Decision Support Company). This CDS version used ACR AC criteria to evaluate 4060 indications and make 98,700 recommendations for CT and MRI examinations. More than 1300 clinical scenarios in the CDS software were reviewed by KPCO primary care and specialist physicians for advanced imaging studies (CT and MRI studies) to ensure that mapping coincided with local organizational clinical guidelines. The CDS tool was incorporated into the EMR order entry system. At the time of order entry, ordering clinicians clicked check boxes to enter structured indications for the examination being requested. The CDS sent patient demographic information (age, sex), structured clinical indication or indications, the examination ordered, order date, and the ordering clinician information (department, facility, specialty) to the CDS vendor for analysis and returned an ACR Select appropriateness score.

The CDS system scored each order on a 1–9 scale. The ACR AC categorized orders as low utility (scores 1–3), marginal utility (scores 4–6), or appropriate (scores 7–9). In some cases, scores could not be assigned because of insufficient evidence or data mismatch (e.g., when there was an age-sex-indication mismatch or when the tool was unable to assign a score because of technical difficulties). When a low- or marginal-utility order was identified, the CDS tool had the capability to launch a best practice alert (BPA) that displayed recommendations for an alternative management strategy, such as a more appropriate imaging examination or examinations. Additionally, the CDS tool displayed links to primary source publications, which provided extensive analyses of the appropriateness of various imaging examinations for related clinical conditions. The BPA also displayed the relative radiation level for each imaging study ordered and for the alternative examination or examinations.

During continuing education sessions leading up to the implementation of the radiology CDS tool, the functional requirements of the ACR Select system were shown. These included instructions about how to associate a clinical condition or diagnosis with a radiology order and how to respond when BPAs were activated for an order with a low appropriateness score (i.e., continue with original order, change the order, or cancel the order altogether). This information was also included in an educational e-mail sent to physicians and other clinicians with ordering abilities in the EMR. Besides this demonstration, there were no specific instructions about how to use the CDS system and no formal direct educational effort concerning the radiology CDS system or direct feedback to clinicians outside the BPAs in the EMR.

Trial Design and Participants

The study used a stepped-wedge, cluster randomized design preceded by a run-in period. All 23 ambulatory clinics in the Denver-Boulder area were included in one of four clusters. The intervention, which was activation of the CDS BPA, was implemented sequentially at the cluster level. Eligible clinicians included all physicians (doctors of medicine or doctors of osteopathy) and nonphysicians (nurse practitioners, physician assistants, doctors of optometry, or doctors of podiatric medicine) who ordered advanced imaging studies.

Stepped-wedge cluster randomization was chosen for practical reasons because the activation of the tool to clusters of medical office buildings prevented contamination of the intervention by ensuring separation of parties using and those not using the CDS tool at a specific point in time. Clinicians could be assumed to adopt the intervention when their cluster did because they rarely practiced at sites other than their home clinic. The main outcomes were assessed at the level of the cluster (medical office building), clinician specialty, and clinician role (physician vs midlevel clinician).

Intervention

During the study period, users were asked to enter structured indications at the time of order entry through check boxes in the EMR interface. The original intent was to begin the so-called “run-in” period on September 15, 2015, but a software scoring problem delayed the beginning of the run-in period. During the updated run-in period (October 5–November 18, 2015), the CDS tool passed imaging orders to the scoring system without displaying BPAs. The ACR Select appropriateness score for each imaging study was stored by the CDS tool, but the score, recommended alternative examinations, and relative radiation doses of the imaging examinations were not displayed to the ordering clinicians.

After the run-in period, the CDS BPA was activated for users in the first cluster of clinics (cluster 1), followed by activation of the CDS BPA at 2- to 4-week intervals in the remaining clusters (clusters 2–4). If the ACR Select appropriateness score was in the low or marginal category (scores 1–6), the software suggested a more appropriate imaging study. The ordering clinician could then proceed with the original order, choose one of the suggested alternative imaging examinations, or cancel the order completely. After February 22, 2016, the CDS BPA was activated in all clinics.

Appropriateness scores for advanced imaging orders were collected for the run-in period when the CDS BPA was Off, the stepped-wedge period (November 19, 2015–February 22, 2016) when the

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TABLE 1: Clinic Clusters, Adult Population in Each Cluster, and Number of Advanced Imaging Orders

Cluster No.	Total No. of Adults at Start of Study	No. of Advanced Imaging Orders (No. of Unique Members With an Imaging Order)					Period Before CDS BPA Activation, Stepped-Wedge Period, and Maintenance Period (September 2014–August 2017)
		Run-In Period ^a (October 5–November 18, 2015)	November 19–December 2, 2015	December 3, 2015–January 6, 2016	January 7–20, 2016	January 21–February 22, 2016	
1	116,838	<i>1584 (1374)</i>	426 (374)	1089 (958)	580 (504)	1202 (1034)	NA
2	98,019	<i>2297 (2044)</i>	<i>606 (554)</i>	1507 (1360)	781 (690)	1625 (1447)	NA
3	112,117	<i>1485 (1318)</i>	<i>420 (398)</i>	<i>1009 (904)</i>	480 (434)	1104 (1004)	NA
4	86,255	<i>1907 (1688)</i>	<i>509 (455)</i>	<i>1380 (1227)</i>	<i>712 (641)</i>	1576 (1394)	NA
All clinics in clusters 1–4							215,822 (116,283)

Note—Italics indicated clinical decision support (CDS) best practice alert (BPA) was inactive (Off), and boldface indicates that CDS BPA was active. NA = not applicable.
^aDuring the updated run-in period, the CDS tool passed imaging orders to the scoring system without displaying BPAs. The appropriateness score for each imaging study was stored by the CDS tool, but the score, recommended alternative examinations, and relative radiation doses of the imaging examinations were not displayed to the ordering clinicians.

CDS BPA was active for only select clinics, and at all sites after the completion of the intervention (February 23, 2016–August 31, 2017) to assess the sustainability of the intervention (Table 1).

Outcomes

The primary outcome was the proportion of ACR Select appropriateness scores of 7 or greater before and after activation of the CDS BPA. Secondary outcomes included the rate per month of advanced imaging orders before and after activation of the CDS BPA as well as the proportion of orders in which the radiology department requested changes. In the primary analysis, we evaluated primary and secondary outcomes at the cluster level. Secondary analyses assessed differences using a predefined alpha value of 0.05 between primary care clinicians and specialty clinicians, between physicians and nonphysicians, between medical departments, and between clinician roles (physician vs midlevel clinician).

Sample Size and Randomization

Randomization of the ambulatory clinics into clusters was performed using the SAS rannum function (SAS Studio software, release 3.7, Enterprise edition) without stratification or a priori decisions. Allocation was based on clusters and concealed at the cluster level. Blinding was not performed. The size of each of the four clusters is reported in Table 1.

Statistical Methods

We analyzed the ACR appropriateness score as a binary variable: appropriate (score 7–9) versus low or marginal utility (score 1–6). The significance of the CDS BPA activation was examined in generalized mixed models with the binary

indicator for whether an imaging test received an acceptable score as the outcome. The primary exposure variable was a binary variable for whether the CDS BPA was inactive (Off) or active, and the model also included a variable for time. All four clusters were included in analyses, and a categorical variable identifying clinic location within the four randomized clusters of the stepped-wedge design was included as a random effect [13]. The impact of activating the CDS BPA was evaluated by analyzing scores before and after BPA activation. We

also examined an interaction term for the CDS BPA inactive-active variable with time to test the rate of slope change. To show patterns over a longer time, we estimated rates of imaging tests in monthly intervals with counts of tests in the numerator and the number of members covered by the health system in the denominator. We graphed these monthly estimates using generalized mixed models with a linear spline and knot for the intervention start. Subgroup analyses were performed where appropriate.

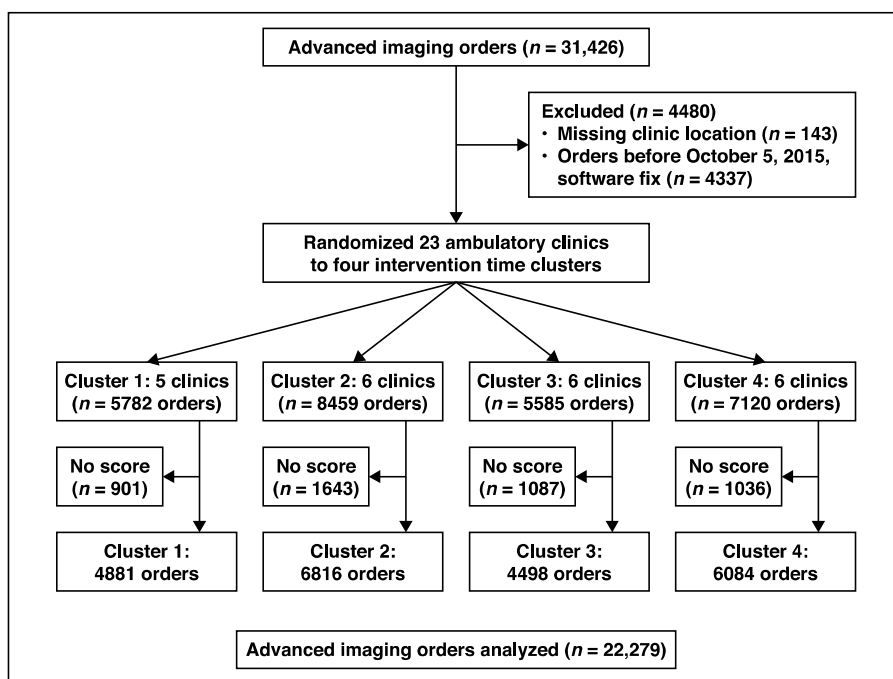


Fig. 1—Consolidated Standards of Reporting Trials (CONSORT) flow diagram for stepped wedge cohort of advanced imaging orders placed between September 15, 2015, and February 22, 2016.

TABLE 2: Characteristics by Clinic Cluster

Characteristic	Cluster 1	Cluster 2	Cluster 3	Cluster 4
No. of adults with an imaging order	4041	5728	3876	5146
Mean age of adults with an imaging order (y)	56.4	57.3	56.6	56.7
Female patients (%)	57.7	56.5	58.4	57.0
No. of ordering clinicians	171	506	379	335
No. of primary care ordering clinicians	121	118	113	130

Results

Stepped-Wedge Time Period: October 5, 2015–February 22, 2016 (Including Run-In Time Period)

We extracted data from 31,426 orders for CT or MRI studies during the stepped-wedge study period (Fig. 1). We excluded records with missing clinical location ($n = 143$) and other records with uncalculated ACR Select scores ($n = 4337$). We analyzed data for a total of 22,279 (70.9%) imaging orders during the stepped-wedge period (October 5, 2015–February 22, 2016).

Imaging studies were ordered by 941 clinicians, of whom 77.8% were physicians and 22.2% nonphysicians. Primary care physicians ordered 49.5% of all imaging studies. The 17,786 unique adult patients had a mean age of 56.7 years, and 57.3% were female patients. A structured indication was included in 89.3% of all imaging orders placed during the run-in period, and this increased to 92.9% ($p < 0.001$) at the end of the stepped-wedge time period.

Baseline characteristics for each cluster are presented in Table 2. When the CDS BPA was inactive, clinicians had an adjusted proportion of appropriateness scores of 7 or greater (adjusted for time and random clinic effect) of 77.0% (95% CI, 75.5–78.4%), which increased to 80.1% (95% CI, 78.7–81.5%) after CDS BPA activation ($p = 0.001$). That improvement extrapolated to approximately 80 more appropriate imaging studies per month.

The increase in appropriateness scores for orders entered by physicians (ACR Select BPA Off, 78.0%; ACR Select BPA On, 80.7%) and for orders entered by nonphysicians (ACR Select BPA Off, 73.8%; ACR Select BPA On, 76.9%) was comparable (interaction test of ACR Select BPA by clinician type, $p = 0.86$). The rate of appropriateness scores for advanced imaging orders placed by primary care physicians ($n = 13,904$) increased from 76.0% (95% CI, 74.8–77.2%) to 80.1% (95% CI, 78.7–81.5%) before and after activation of the CDS BPA, respectively ($p < 0.001$). The rate of appropriateness scores for

advanced imaging orders placed by specialists ($n = 8375$) did not change significantly before and after activation of the CDS BPA (before vs after, 79.4% [95% CI, 77.8–80.9%] vs 80.4% [95% CI, 78.7–82.2%]; $p = 0.44$).

Intervention Sustainability

To evaluate long-term imaging trends, we examined imaging orders over the 3-year time period that began 12 months before the initial run-in time period of the stepped-wedge intervention and ended on August 31, 2017. The slope for the rate of imaging orders per month over time before CDS BPA activation was 0.092 (95% CI, -0.023 to 0.206), suggesting a gradual upward trend in imaging orders. The rate of imaging orders did not change significantly after CDS BPA activation; the slope in the subsequent period was 0.035 (95% CI, -0.07 to 0.078; slope change, $p = 0.14$) (Fig. 2).

The mean number of imaging orders was 10.85 (95% CI, 10.37–11.32) per 1000 member-months before CDS BPA activation (September 2014–September 2015) and 11.14 (95% CI, 10.85–11.43; $p = 0.21$) after activation (October 2015–August 2017).

The proportion of change order requests made by radiologists to clinicians decreased from 5.7% (4321/75,280; 95% CI, 5.6–5.9%) in the 12 months before CDS implementation to 5.3% (2232/42,383; 95% CI, 5.1–5.5%) in the 12 months after CDS implementation ($p < 0.001$).

Discussion

In this stepped-wedge, cluster randomized clinical trial, we found that the use of ACR Select criteria through a CDS tool and BPA resulted in a modest but statistically significant improvement in appropriateness scores for advanced imaging orders in outpatient ambulatory practices. The improvement was smaller in magnitude than the few prior evaluations of CDS tools, in part because baseline appropriateness scores were higher. As a multispecialty practice that is part of an integrated care delivery model, KPCCO has dedicated extensive efforts to promote the ACR AC and Choosing Wisely [14] recommendations for imaging appropriateness. The willingness of KPCCO cli-

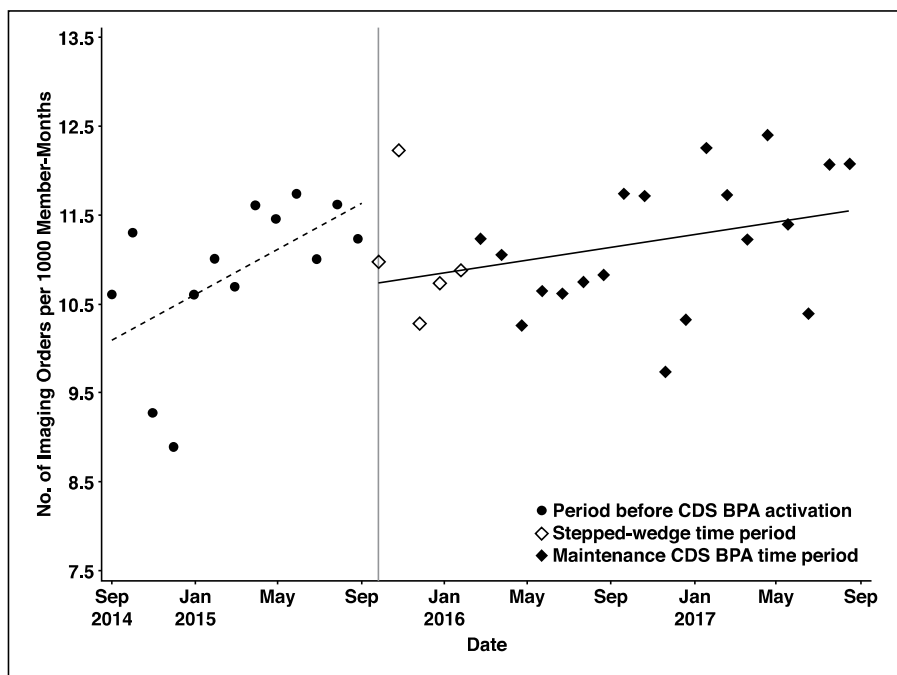


Fig. 2—Plot shows rate of imaging orders before, during, and after clinical decision support (CDS) best practices alert (BPA) activation. Vertical line shows time point for activation of CDS BPA. Difference in slopes for imaging orders per month before CDS BPA activation (dashed line) and after CDS BPA activation (solid diagonal line) was not significant ($p = 0.14$). Sep = September, Jan = January.

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nicians to embrace these recommendations before implementing the decision support software likely contributed to a high baseline rate of imaging appropriateness scores. We also found a very high rate (> 90%) of use of structured indications submitted with imaging orders. This high level of cooperation with the intervention also suggests that clinicians were engaged and adaptable to new workflows. Our study suggests that organizations that already focus education and operational efforts toward appropriate imaging may experience less incremental benefits from implementation of CDS software than practices with a lower baseline rate of imaging appropriateness or fewer resources devoted to appropriateness education and policy creation.

We observed an increase in appropriateness scores of advanced imaging orders from 77.0% to 80.1%. Huber et al. [15], also found that use of a commercial radiology CDS program for CT, MRI, PET and sonography was associated with an increase in appropriateness scores for 17.5% of studies (from 64.5% before the intervention to 82% after the intervention). This increase is greater than in other studies in which relatively few orders were able to be scored. Moriarity et al. [16] evaluated CDS in the inpatient setting and found that the CDS tool assigned an appropriateness category score to just 19.8–24.8% of the orders for advanced imaging. Similarly, Hussey et al. [17] found that CDS systems identified a relevant appropriateness criteria rating for 33.5–36.7% of orders placed for advanced imaging. Our experience suggests that our software, implementation, training, or engagement resulted in a much higher rate of orders submitted for advanced imaging being assigned an appropriateness score.

Prior investigations of the impact of imaging CDS have produced inconsistent results. In studies examining the use of advanced imaging for specific conditions or limited body sites, CDS showed the capacity to significantly reduce imaging utilization [18–20]. Sstrom and colleagues [21] documented substantial decreases in outpatient CT volume coincident with implementation of radiology order entry supplemented by decision support as well as less substantial decreases in outpatient MRI utilization. The Medicare Imaging Demonstration project [22] also found slight decreases in the rate of imaging utilization; however, this project also reported no evidence that CDS had a meaningful effect on advanced imaging volume [22].

Our study had several strengths. The stepped-wedge cluster randomized design allowed us to evaluate a rigorous, phased implementation of the CDS in a real-world setting. The study included all clinicians who ordered imaging studies in KPCO ambulatory care settings. This allowed us to study the differential effect of the CDS tool on primary care, specialist, and midlevel practitioners. We were able to continue data collection beyond the end of the stepped-wedge phase of the study to analyze the longer-term sustainability of the CDS tool. Although our study did not assess the clinical impact of increasing imaging appropriateness, we did see a small but significant decrease in the percentage of order change requests for advanced imaging studies. The decrease in unwarranted and low-utility examinations appeared to increase available slots for more appropriate imaging studies.

This study also had limitations. The study occurred within a single integrated health care delivery system, and its findings may not be generalizable to other clinical settings. The incentives and priorities for ordering clinicians, the radiologists, and the health care system are different than for a fee-for-service system. We did not assess whether this statistically significant increase in appropriateness scores led to improvement in patient care or clinical outcomes.

The rates for ordering advanced imaging during the stepped-wedge time period decreased slightly (nonsignificantly) but then subsequently rose at a non-statistically significant lower rate during the postintervention period than during the preintervention period. It remains uncertain how this rate of growth would compare with the rate if we had not implemented this software as well as how this rate of growth compares with increases in the utilization of advanced imaging in other health care systems. Additional research is needed to determine if the increasing rate of imaging studies (even if they are more appropriate) leads to better patient management and clinical outcomes.

In conclusion, we found that primary care clinicians responded to CDS by a modest increase in the appropriateness scores of image ordering even when baseline appropriateness scores were high. CDS systems hold promise to improve the quality of image ordering in clinical practice and may have impacts on patient outcomes and organizational efficiency that deserve further investigation.

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References

1. [No authors listed]. National health expenditure fact sheet. Washington, DC: Centers for Medicare & Medicaid Services, 2017
2. U.S. Government Accountability Office website. Report to congressional requesters. Medicare Part B imaging services: rapid spending growth and shift to physician offices indicated need for CMS to consider additional management practices. www.gao.gov/products/GAO-08-452. Published June 13, 2008. Accessed March 2019
3. Medicare Payment Advisory Commission. Statement of Glenn M. Hackbarth: options to improve Medicare's payments to physicians. 67.59.137.244/documents/051007_Testimony_MedPAC_physician_payment.pdf 67.59.137.244/documents/051007_Testimony_MedPAC_physician_payment.pdf. May 10, 2007. Accessed July 2, 2019.
4. Smith-Bindman R, Miglioretti DL, Johnson E, et al. Use of diagnostic imaging studies and associated radiation exposure for patients enrolled in large integrated health care systems, 1996–2010. *JAMA* 2012; 307:2400–2409
5. Mazimba S, Grant N, Parikh A, et al. Comparison of the 2006 and 2010 cardiac CT appropriateness criteria in a real-world setting. *J Am Coll Radiol* 2012; 9:630–634
6. 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; 7:192–197
7. Miglioretti DL, Johnson E, Williams A, et al. The use of computed tomography in pediatrics and the associated radiation exposure and estimated cancer risk. *JAMA Pediatr* 2013; 167:700–707
8. American College of Radiology website. Appropriateness Criteria. www.acr.org/Clinical-Resources/ACR-Appropriateness-Criteria. Accessed March 2019
9. Centers for Medicare & Medicaid Services website. Appropriate Use Criteria Program. www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/Appropriate-Use-Criteria-Program/index.html. Published 2014. Modified February 21, 2019. Accessed March 2019
10. American Medical Informatics Association website. AMIA offers new directions for CMS innova-

- tion. www.amia.org/news-and-publications/press-release/amia-offers-new-directions-cms-innovation. Published November 21, 2017. Accessed March 2019
11. Medicare Program, Medicare Shared Savings Program. Accountable Care Organizations—Pathways to Success. Final Rules. Fed Regist 2018 Dec 31;83(249):67816–8082. www.federalregister.gov/documents/2018/08/17/2018-17101/medicare-program-medicare-shared-savingsprogram-accountable-care-organizations-pathways-to-success. Published August 17, 2018. Accessed July 2, 2019
 12. Oren O, Kebebew E, Ioannidis JPA. Curbing unnecessary and wasted diagnostic imaging. *JAMA* 2019; 321:245–246
 13. Hussey MA, Hughes JP. Design and analysis of stepped wedge cluster randomized trials. *Contemp Clin Trials* 2007; 28:182–191
 14. Choosing Wisely website. Our mission. www.choosingwisely.org. Accessed July 2, 2019
 15. Huber TC, Krishnaraj A, Patrie J, Gaskin CM. Impact of a commercially available clinical decision support program on provider ordering habits. *J Am Coll Radiol* 2018; 15:951–957
 16. Moriarity AK, Klochko C, O'Brien M, Halabi S. The effect of clinical decision support for advanced inpatient imaging. *J Am Coll Radiol* 2015; 12:358–363
 17. Hussey PS, Timbie JW, Burgette LF, Wenger NS, Nyweide DJ, Kahn KL. Appropriateness of advanced diagnostic imaging ordering before and after implementation of clinical decision support systems. *JAMA* 2015; 313:2181–2182
 18. Raja AS, Pourjabbar S, Ip IK, et al. Impact of a health information technology-enabled appropriate use criterion on utilization of emergency department CT for renal colic. *AJR* 2019; 212:142–145
 19. Blackmore CC, Mecklenburg RS, Kaplan GS. Effectiveness of clinical decision support in controlling inappropriate imaging. *J Am Coll Radiol* 2011; 8:19–25
 20. Zafar HM, Ip IK, Mills AM, Raja AS, Langlotz CP, Khorasani R. Effect of clinical decision support-generated report cards versus real-time alerts on primary care provider guideline adherence for low back pain outpatient lumbar spine MRI orders. *AJR* 2019; 212:386–394
 21. 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; 251:147–155
 22. Timbie JW, Hussey PS, Burgette LF, et al. Medicare imaging demonstration evaluation report for the report to Congress. *Rand Health Q* 2015; 5:4

FOR YOUR INFORMATION

The reader's attention is directed to the commentary on this article, which appears on the following pages.