Clinical Decision Support Tools for Order Entry

Laila Cochon and Ramin Khorasani

Contents

Abbreviations

AUC	Appropriate use criteria
CDS	Clinical decision support
CPOE	Computerized physician order entry system
EHR	Electronic health record
IT	Information technology

Abstract

Medical imaging has helped to transform healthcare and will continue to advance the understanding and treatment of disease. Despite the substantial benefits of medical imaging, there is wide variation in the use of imaging (especially high-cost imaging) and concern about it's inappropriate use persists. Inappropriate use may result in suboptimal quality of care and wasteand may harm patients by exposure to unnecessary ionizing radiation, the risks of over-diagnosis and over-treatment, including unnecessary additional tests and treatments provided in follow-up of incidental or ambiguous imaging findings.

Clinical decision support tools for order entry provide an opportunity to embed evidence/ clinical best practices in the workflow of providers requesting imaging examinations to reduce inappropriate use of imaging. In this chapter, we define clinical decision support for order entry, review trends in imaging use and describe general features of effective clinical decision support including experience from large-scale implementations. We conclude by reviewing some of the emerging challenges and opportunities for imaging clinical decision support and future directions.

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Key Points

- Despite the substantial benefits that medical imaging confers, there is wide variation in use of imaging (especially high-cost imaging) and concern about inappropriate use persists.
- Although reports on impact of imaging Clinical Decision Support (CDS) have been inconsistent, clinical decision support (CDS)-enabled interventions have been shown to improve adherence to evidence, including clinical practice guidelines, and to reduce the rate of inappropriate imaging and increase its yield.
- Imaging decision support is most effective when based on clinically relevant and trustworthy evidence, embedded in provider workflow, efficient, and actionable, and avoids redundant data entry.
- Beginning on January 1, 2020, the United States Protecting Access to Medicare Act (PAMA) will require ordering providers to consult appropriate use criteria (AUC) prior to ordering certain outpatient advanced diagnostic imaging tests (CT, MR, and nuclear medicine exams) for Medicare fee-for-service beneficiaries, as a requirement of payment for such services.
- PAMA presents a substantial opportunity to improve the quality and value of diagnostic imaging while reducing waste and improving patient experience.
- Imaging CDS as an Information Technology (IT) implementation alone is unlikely to optimize care. CDS-enabled multifaceted quality improvement interventions are more likely to improve clinical decision making.

  Future research is needed to evaluate the impact of various CDS interventions and help define best practices for design and implementation of this promising tool to promote evidence-based care.

1 Definitions

– Imaging CDS represents an online, iterative interaction between a user (ordering provider) and a computer software system to provide evidence-based feedback in real time (at the time of ordering) to improve clinical decision making (Fig. 1).
– A CDS application is comprised of two components, the "syringe" and the "medicine." The "syringe" refers to the information technology mechanism that interacts with the user and the CPOE system to deliver the evidence (i.e., the "medicine") to improve the ordering provider's clinical decision; the "medicine" refers to the evidence/clinical logic/rules embedded in CDS.
– AUC are defined as evidence-based criteria to enhance appropriate use of diagnostic imaging tests for a given condition/diagnosis. Their primary purpose is to aid in the clinical decision-making process, guiding the ordering physician to make the most appropriate treatment decision given a specific patient's clinical condition or presentation. The source and/or publisher of the AUCs presented to the user in the CDS application may include professional society guidelines, peer-reviewed publications, and clinical decision rules, or local best practices.
– Strength of evidence: The quality or grade of evidence underlying an AUC varies from evidence based on expert opinion only to evidence based on rigorous science. The grade of evidence is an important contributor to the "trustworthiness" of the AUC as defined by the Institute of Medicine (Ransohoff et al. 2013). The sources and strength of evidence presented in CDS should optimally be transparently available to the user at the time of clinical decision making (Fig. 2).

2 Trends in Imaging Use and Costs

Medical imaging has helped to transform health care and will continue to advance the understanding and treatment of disease (Tempany 2001; Jolesz and Blumenfeld 1994; Weissleder 1999). But despite the substantial benefits of medical imaging in many clinical situations, there is wide variation in the use of

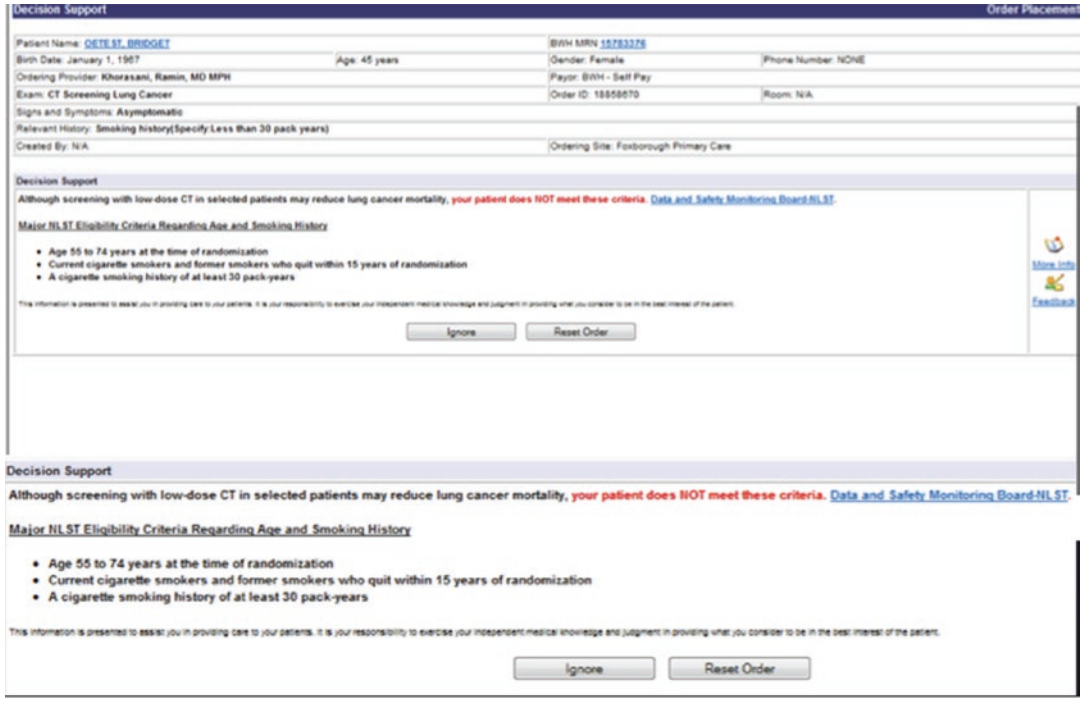

Fig. 1 Interactive CDS alert displays actionable advice to an ordering provider in the process of ordering a lung cancer screening CT on a 45-year-old asymptomatic women with <30 pack-year smoking history. These clinical attributes are necessary for CDS to determine if the patient will not benefit from screening based on available evidence

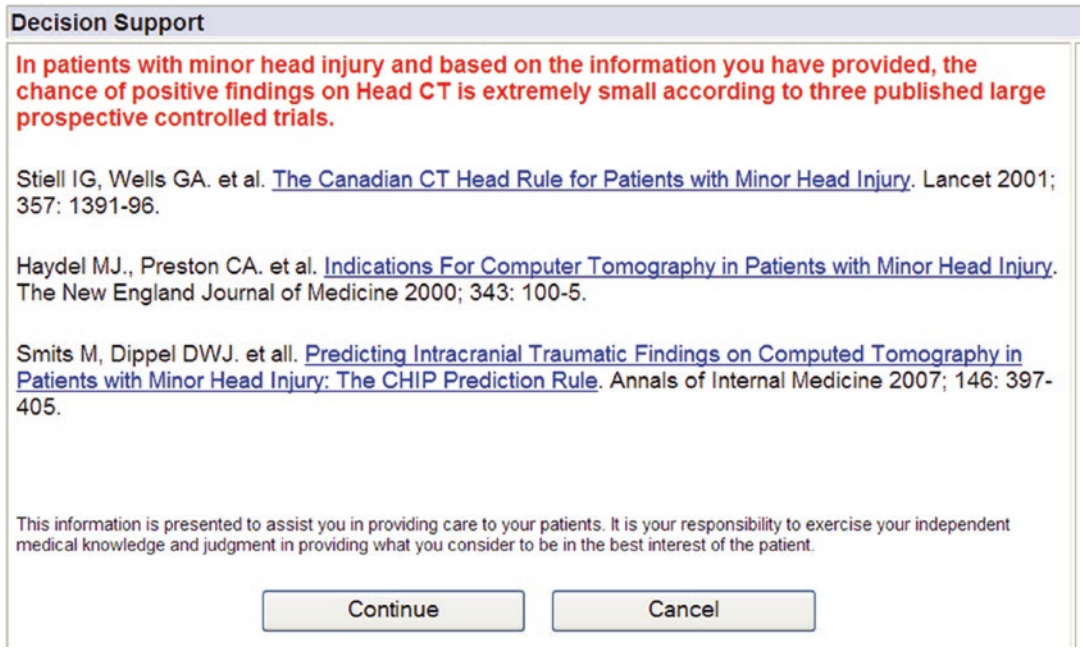

Fig. 2 CDS feedback provides sources of evidence to the ordering user

Type of service	Change in units of service per beneficiary		Change in volume per beneficiary		Percent of 2014 allowed charges
	Average annual 2009–2013	20013–2014	Average annual 2009–2013	20013–2014	
All services	**–0.1%**	**0.3%**	**N/A**	**0.4%**	**100%**
Imaging	**–0.9**	**–1.0**	**–2.3**	**–1.1**	**11.0**
Advanced–CT: other	1.2	4.2	0.3	3.2	1.6
Echography–heart	1.0	–0.5	–4.1	–1.5	1.1
Advanced–MRI: other	0.1	2.0	–1.7	1.0	0.9
Echography–other	3.8	1.9	3.0	1.9	0.9
Standard–musculoskeletal	–0.2	0.2	–0.7	–0.6	0.9
Standard–nuclear medicine	–7.7	–5.8	–11.6	–7.9	0.8
Standard–breast	0.5	–2.3	–0.4	–2.6	0.7
Imaging/procedure–other	–5.8	–4.2	–1.7	–1.5	0.6
Advanced–MRI: brain	–1.8	1.2	–3.7	–0.8	0.4
Advanced–CT: head	0.2	2.2	–1.2	1.6	0.4
Standard–chest	–2.6	–3.6	–3.0	–4.0	0.4
Echography–abdomen and pelvis	0.5	–1.2	0.3	–1.2	0.4

Source: MedPAC analysis of claims data for 100 percent of Medicare Beneficiaries

Fig. 3 Imaging utilization among medicare beneficiaries. Source: MedPAC analysis of claims data for 100% of Medicare Beneficiaries

imaging (especially high-cost imaging) and concern about inappropriate use persists. Inappropriate use may result in waste (Hendee et al. 2010) and suboptimal quality of care, and may harm patients by exposure to unnecessary ionizing radiation (Sodickson et al. 2009; Smith-Bindman et al. 2009; Lin 2010) or unnecessary additional tests and treatments provided in follow-up of incidental or ambiguous imaging findings (Black 1998; Welch et al. 2011).

Imaging has been identified as a potential driver for rising United States healthcare expenditures although recent reports suggest that utilization levels have moderated or even declined slightly. In 2003, approximately 206 million imaging services were provided to a total of 34.8 million Part B Medicare beneficiaries. By 2006, that number increased 58.4% to 326 million services for 35.9 million beneficiaries (Harvey 2012). By 2013–2014, across all services, Medicare volume per beneficiary grew by 0.4%; but at −1.1% for imaging services (Fig. 3). The Medicare Payment Advisory Commission observed that "While the imaging decrease continues the downward trend we have seen since 2009, use of imaging services remains much higher than it was in 2000" (Medicare Payment Advisory Commission 2016).

In a population-based study utilizing data for one million to two million patients annually from 1996 to 2010 in six large integrated health systems across the United States, the number of CT scans tripled over the study period, to 149 per 1000 patients in 2010, while the number of MRIs quadrupled, to 65 per 1000 patients in 2010 (Smith-Bindman et al. 2012). However, almost all of that growth occurred between 1996 and 2006, and after that time, overall slowing (MRI), or stabilization (CT) in medical imaging utilization was observed. It should be noted that increase in utilization does not necessarily equate waste. For example, increased use of abdominal CT in the emergency room for patients suspected of acute appendicitis has reduced the negative appendectomy rate, particularly for women. In one study, the use of CT was associated with a >10-fold decline in the negative appendectomy rate (portion of appendectomies with a normal appendix at pathology), from >20% to less than 2% (Raja et al. 2010). Future research is needed to explicitly evaluate the impact of imaging in various clinical settings so that quality and value deliberations focus on evidence of clinical impact rather than utilization rates of imaging.

Wide, likely unwarranted, variation also exists in the utilization of CT and MRI across the United States (Fig. 4). For 34 million Medicare

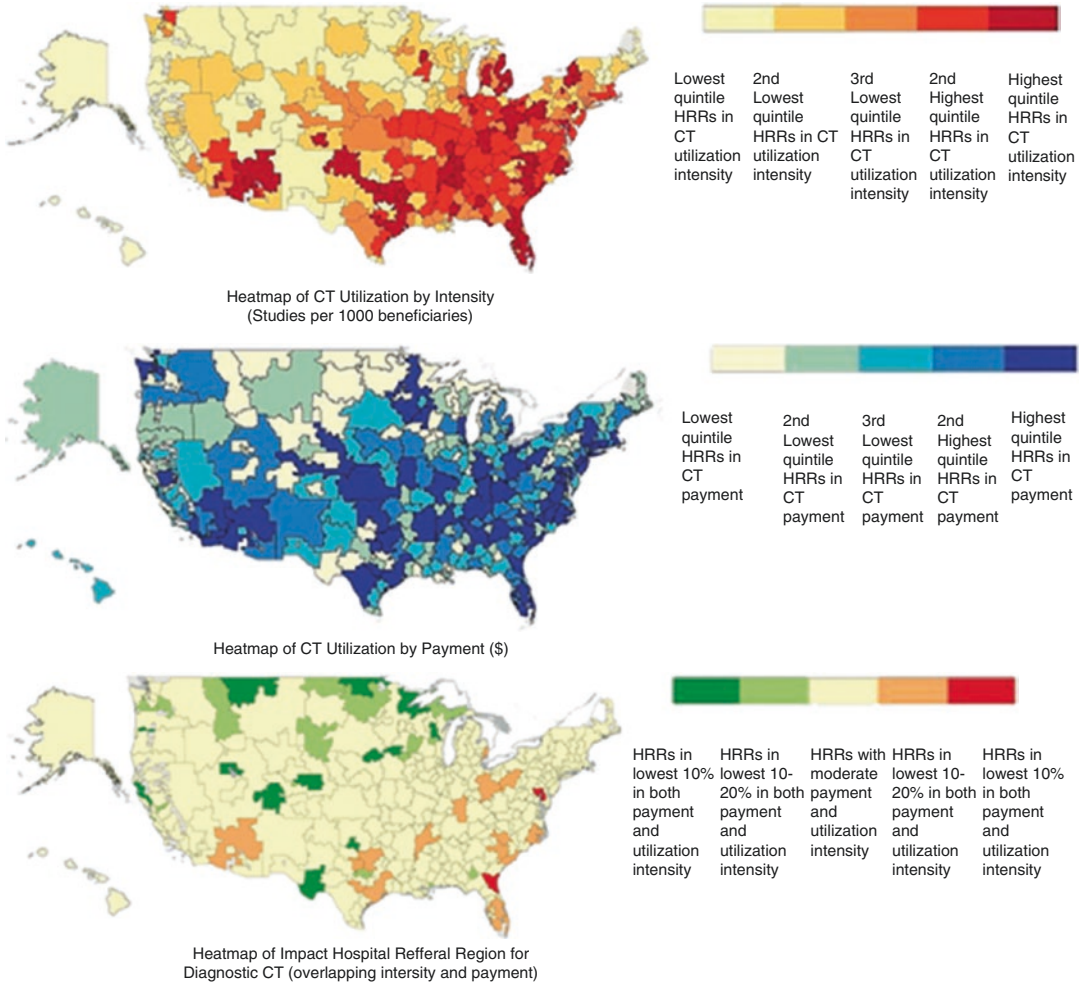

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Fig. 4 Heat map of CT utilization by intensity (#tests per 1000 Medicare beneficiaries) and by payment, as well as by impact (defined as high utilization *and* payment), demonstrates substantial, likely unwarranted, variation among the 600 Health Referral Regions in the United States (Ip et al. 2015a)

beneficiaries, 124 million unique diagnostic imaging services (totaling $5.6 billion) were performed in 2012. The average adjusted CT utilization intensity ranged from 330.4 studies per 1000 beneficiaries in the lowest decile to 684.0 in the highest decile (relative risk, 2.1); adjusted MR imaging utilization intensity varied from 105.7 studies per 1000 beneficiaries to 256.3 (relative risk, 2.4) (Ip et al. 2015a). The most common CT and MRI procedures were head CT and lumbar spine MRI.

3 General Features of Effective Clinical Decision Support During Radiology Order Entry

Best practices for implementation of imaging CDS are debated and remain uncertain. However, experience to date from implementation of CDS in various domains including in imaging highlights a number of key features (Khorasani et al. 2014; Bates et al. 2003; Ip et al. 2013)

1. *Efficient*: CDS should be optimally embedded in provider workflow. Every computer "mouse click," scroll, or new screen counts should be vigilantly minimized. The speed at which the user gets through the workflow also matters. Redundant data entry in CDS, whether from need to reauthenticate in the CDS application (enter username and password separately from the EHR) or reenter clinical information already captured elsewhere within the EHR, is a major source of user frustration, contributing to provider burnout, (Health Affairs 2017) and creates additional risk of a user entering erroneous data in CDS just to get through the workflow in a busy clinical practice. A clinically useful electronic radiology requisition should optimally capture and communicate the patient's relevant signs and symptoms, known diagnoses, differential diagnostic considerations, and targeted laboratory results necessitating the imaging procedure being requested (e.g., "left lower quadrant pain, 5 days' duration, fever, elevated WBC count, ?diverticulitis"). Relying solely on a single billing *ICD-9*- or *ICD-10*-coded data in the EHR will likely be inadequate to convey the clinical indication and justification for an imaging examination (the primary purpose of CPOE) and thus may hinder a clinically effective CDS program. Any data obtained as part of the imaging CDS interaction should flow back to the EHR and the physician's note when relevant. Such clinical workflows may be implemented by a single-vendor solution, or will require enhanced interoperability between the EHR and imaging CDS system, a feature generally lacking and suboptimally pursued by most vendors to date.

   System design must enable the ordering physician to act on CDS recommendations efficiently. A suboptimal integration of imaging CDS systems with EHR products can result in confusing and inefficient workflows when ordering providers attempt to modify or cancel an imaging order based on a CDS recommendation. For example, if the CDS recommendation is to change a head CT order to a head MRI order, then the provider should be able to accept the recommendation (i.e., click "Accept") while viewing the CDS recommendation. The provider's Accept action while interacting with CDS should then automatically cancel the head CT order and generate a new head MRI order with the same clinical information entered for head CT in the EHR without any further requirement for the user to interact with CDS for the new MRI request. Workflow inefficiencies encourage the ordering provider to ignore the imaging CDS recommendation, creating waste and resulting in suboptimal quality of care.
2. *Educational (rather than punitive) and evidence-based:* Effective imaging CDS interactions need to provide a clinically useful experience in a very limited time span in the middle of provider workflow. This requires the educational experience, and more specifically the clinical content of the CDS alert visible on the computer screen to the user, to have some unique features.
   (a) The clinical feedback must be *clinically valid*. This requires thoughtful integration between the clinical data entered in the EHR and that shared with the CDS application. For example, it has become popular to launch a CDS alert based on a structured indication (a clinical indication selected from a predetermined menu in the EHR) while allowing a user to then enter free text comments to communicate the clinical reason for the examination to the radiologist. Figures 5 and 6 highlight the challenge of presenting a clinically valid alert to the user if the structured indication is broad, ambiguous, or does not otherwise describe the patient's presentation adequately to help determine appropriateness of the order.
   (b) The clinical feedback presented in the CDS should be clinically relevant and "**trustworthy**." Evidence delivered through imaging CDS essentially represents a practice or institution's standard of care and should be consistent with the best practices the clinical leadership can support. The Institute of Medicine has published standards for developing practice guidelines (Institute of Medicine (US) Committee on Standards for

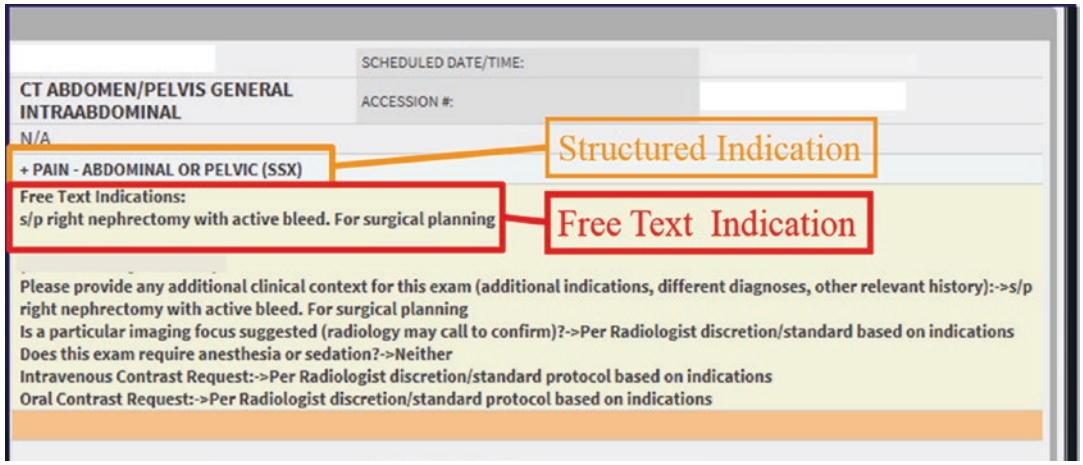

Fig. 5 An electronic requisition for an abdominal CT highlights the potential discrepancy between structured and free text indications selected by the ordering user in the EHR. Providing feedback on the appropriateness of this request based on the selected structured indication alone will likely be viewed as clinically irrelevant by the ordering user

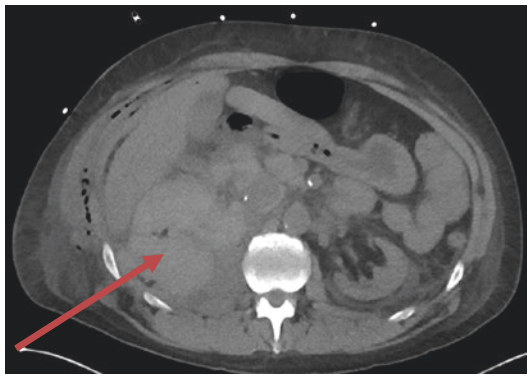

Fig. 6 An image from the CT scan requested in Fig. 5 demonstrated hemorrhage in the right nephrectomy bed (*arrow*)

Developing Trustworthy Clinical Practice Guidelines 2011) which highlight the importance of assessing the strength of each unique piece of evidence or recommendation, (Ransohoff et al. 2013) using the "level of evidence" and "grade of recommendation" frameworks (OCEBM Levels of Evidence - CEBM [Internet] 2009; Grade Definitions - US Preventive Services Task Force [Internet] 2012) as a key factor in determining the trustworthiness of the clinical recommendation. Grading evidence is also useful when comparing overlapping or potentially conflicting evidence from multiple sources. The strength of evidence is also essential to inform policy makers, healthcare delivery systems, and providers as to the relative merit of each recommendation embedded in imaging CDS. Finally, ordering providers are more likely to modify their clinical decision based on strong evidence or those endorsed by national professional societies and local thought leaders to represent institution's best practices.

(c) The alert's educational content must be **brief, unambiguous, and actionable** (suggesting an alternate decision to the one the user is contemplating in the ordering process). Given the need for efficient workflow, the use of ambiguous or elaborate language to communicate recommendations can confuse and frustrate busy providers and decrease system effectiveness. Presenting low-value information (superfluous information not directly relevant to the immediate ordering decision being executed by the user) can create alert fatigue and may even cause providers to ignore relevant CDS recommendations by simply learning to click "ignore" each time a CDS alert displays without making the time to consume the information being presented.

3. *Targeted*: Effective CDS should require interactions by ordering clinicians, and enable targeted interventions on providers focusing on subgroups of ordering providers who would benefit most from a specific CDS alert. It should be obvious that if a proxy is transcribing an ordering provider's request into the EHR, effectiveness of CDS will be compromised. Also, a highly subspecialized practitioner may not need to interact with the evidence in his or her area of expertise. For example, presenting CDS for use of head MRI to a stroke neurologist may only create frustration for the user and undermine the effectiveness of CDS.
4. IT intervention alone, even if based on strong evidence, is unlikely to optimize ordering practices**.** Consequences of ignoring clinically valid, trustworthy CDS alerts may include required synchronous (at the time of order) peer-to-peer consultation (Ip et al. 2014) or asynchronous feedback (practice pattern variation reports comparing a provide to his or her colleagues) (Raja et al. 2015). Such multifaceted CDS-enabled quality improvement initiatives (including consequences of ignoring alerts) are more likely to reduce inappropriate use of imaging (Raja et al. 2015; Ip et al. 2013; O'Connor et al. 2014; Weilburg et al. 2017; Blackmore et al. 2011). It is thus more helpful to think of effective CDS implementation as a clinical transformation initiative rather than an IT implementation alone. Large-scale CDS-enabled utilization management and medical management interventions (Ip et al. 2013; Weilburg et al. 2017) have shown significant impact on the use of high-cost imaging in large academic medical centers.
5. *Measure, monitor impact*, and adjust CDS interventions based on desired outcomes of improving appropriateness of imaging. Assuming impact is likely to eliminate the possibility of sustainable clinical improvement in your practice.

4 Effectiveness of Clinical Decision Support in Radiology

Effective imaging CDS enables measurable reduction of inappropriate or low-utility and unsafe or otherwise unnecessary imaging while minimizing disruption to provider workflow and productivity. Effective imaging CDS also measurably increases the adoption of evidence in clinical practice where warranted.

The literature on the impact of imaging CDS is mixed. One of the earliest imaging CDS interventions on use of abdominal X-rays on inpatients from two decades ago (Harpole et al. 1997) showed that providers were unwilling to cancel their order but were more willing to modify their request (e.g., change supine KUB order to supine and upright KUB including the hemidiaphragms if clinical concern is perforated viscus). The first description of Web-enabled ambulatory CPOE and CDS in 2001 (Khorasani 2001) was followed by early reports of impact (Ip et al. 2013; Sistrom et al. 2009), as well as meaningful use and adoption (Ip et al. 2012) (Vartanians et al. 2010) across the healthcare enterprise by pioneers and early adopters of this approach at Brigham and Women's Hospital (BWH) and Massachusetts General Hospital (MGH) at Harvard Medical School in Boston. Both institutions, members of Partners Healthcare System, instituted multifaceted CDS-enabled interventions (including CDS, distribution of feedback reports on use of high-cost imaging to ordering providers, and financial incentives to ordering providers to reduce high-cost imaging) as part of a pay-for-performance contract with several local payers in Massachusetts to avoid onerous payer-initiated pre-authorization programs beginning in 2005. A study at Virginia Mason using CDS-enabled, targeted (to specific clinical conditions) multifaceted interventions with local best practices embedded as evidence in imaging CDS showed significant reduction in use of lumbar spine MRI, head MRI, and sinus CT (Blackmore et al. 2011). Tables 1–3 summarize the results of several select interventions at

Table 1 CDS implementation and high-cost imaging use at BWH

Setting	Outcome
Outpatients (2005–2009)	12% decrease in high-cost imaging/1000 member-months, sustained over 4 years in a commercial payer population (Ip et al. 2013)
Emergency department (ED) (2007–2012)	33% decrease in CT; 21% decrease in MRI per 1000 ED visits (Raja et al. 2014a)
Inpatient (2009–2012)	21% decrease in CT/1000 admissions; adjusted for severity of disease (Shinagare et al. 2014)
Overall	7.5% decrease in repeat CTs (approx. 22% of all CTs are repeated within 90 days) (O'Connor et al. 2014; Wasser et al. 2013)

Table 2 Impact of effective CDS based on high-quality, condition-specific evidence *"Choosing Wisely"*

Setting	Outcome
CT for suspected pulmonary embolism (ACEP)	ED use decreases 20%; yield up 69% over 2 years (Raja et al. 2012)/inpatient use decreases 13% over 1 month, then stable (Dunne et al. 2015)
MRI for low back pain (ACP)	Outpatients: MRI use decreases 30% on the day of primary care provider (PCP) visit; 12.3% within 30 days of index PCP visit (Ip et al. 2014)
CT for minor traumatic brain injury (ACEP)	13.4% decrease in use of CT in ED (Ip et al. 2015b)

ACEP American College of Emergency Physicians, *ACP* American College of Physicians

BWH to help highlight broad conclusions on the impact of imaging CDS on use of high-cost imaging.

5 Experience from Large Scale Implementation of Imaging CDS

Concerned with the potential contribution of high-cost imaging to the rising costs of health care, Congress enacted the Medicare Improvement for Patients and Providers Act (MIPPA) in 2008 (Medicare C for, Baltimore MS 7500 SB, Usa M 2013). MIPPA mandated that the Centers for Medicare and Medicaid Services (CMS) undertake a demonstration project (named Medicare Imaging Demonstration or MID) in lieu of a federal pre-authorization program for high-cost imaging. The MID was designed as a 2-year demonstration and launched in October 2011 to assess the impact of preselected professional society guidelines embedded in CDS on use of ambulatory high-cost imaging for outpatient Medicare fee-for-service patients (Medicare the USC for, Boulevard MS 7500 S, Baltimore, Baltimore M 21244 7500 SB, Usa M 21244 2017). Designed as an alternative to prior authorization, the MID project evaluated the impact of two processes on use of 12 high-cost image procedures for ambulatory fee-for-service Medicare patients: a) CDS that was primarily based on AUC created by the American College of Radiology and the American College of Cardiology, and b) practice

Table 3 Impact of CDS-enabled Interventions on documented adherence to evidence

Imaging/condition	Reference	Type	Control (%)	Intervention (%)	*P*-value
Head CT/ED minor trauma (ACEP)	Gupta JAMIA 2014 (Gupta et al. 2014)	Education only	49	76	<0.001
Chest CT/ED PE (NQF)	Raja Acad Rad 2014 (Raja et al. 2014b)	Education only	57	76	<0.01
Chest CT/ED PE (NQF)	Raja AJR 2015 (Raja et al. 2015)	Add MD feedback	78	85	<0.05
LS MRI/ambulatory (ACP)	Ip Am J Med 2014 (Ip et al. 2014)	Add peer to peer, MD feedback	78	96	<0.005

pattern variation reporting to providers. MID was carried out across five geographically and organizationally diverse groups of practices (conveners). With 139,757 orders placed by 3916 physicians at 363 practice sites from October 2012 to September 2014, it was the largest implementation of CDS for imaging to date.

Pooled national data across all conveners was analyzed independently by the RAND corporation and the results were submitted by CMS to Congress in the fall of 2014 (Medicare Imaging Demonstration Evaluation Report to Congress [Internet] 2014). There was no significant change in utilization of high-cost imaging when comparing post-CDS intervention data to pre-intervention (control) among MID participants or when comparing utilization of high-cost imaging in the post-intervention MID practices to concurrent controls selected by CMS and RAND from practices that were not enrolled in the MID. Most orders (63.3% of orders during the baseline period and 66.5% during the intervention period) were unable to be matched by the CDS systems to appropriateness criteria (Hussey et al. 2015). There was a slight (though not statistically significant) improvement in observed appropriateness of imaging as assessed by CDS scores (11.1% of orders were scored inappropriate during baseline vs. 6.4% during the intervention period; 73.7% of baseline orders were scored appropriate vs. 81.0% during the intervention period).

A subsequent analysis of MID data from a single convener including data from delivery systems in three states (Massachusetts, New York, and Pennsylvania) showed that nearly 99% of CDS alerts were ignored by ordering providers. Providers were >20 times more likely to modify an order than to cancel it, similar to a previously published study in 1997 (Harpole et al. 1997). However, actionability of alerts, as well as prior experience with CDS, were identified as important predictors of provider response to CDS alerts (Ip et al. 2017). Actionable alerts (those that could generate an immediate order behavior change in the ordering physician) had a tenfold higher rate of modification (8.1 vs. 0.7%; $p < 0.0001$) or cancellation (0.2 vs. 0.02%; $p < 0.0001$) compared with orders with nonactionable alerts. Orders from institutions with preexisting imaging CDS had a sevenfold lower rate of cancellation or modification than was seen at sites with newly implemented CDS (1.4 vs. 0.2%; $p < 0.0001$).

Although reports of impact of imaging CDS implementation are not entirely consistent, some general conclusions can be made.

1. Imaging CDS-enabled interventions can improve adherence to evidence (Table 3), including clinical practice guidelines, reduce inappropriate use of imaging (Ip et al. 2013, 2015b; Blackmore et al. 2011; Vartanians et al. 2010), increase its yield (Raja et al. 2012; Dunne et al. 2015), and improve quality of care and patient experience. However, there is little empirical evidence that imaging CDS alone, as an IT implementation, will reduce inappropriate use of imaging. Multifaceted CDS-enabled clinical quality improvement interventions, such as those including ordering provider feedback, will likely be needed to improve appropriate use of imaging (Ip et al. 2013; Weilburg et al. 2017).
2. It is likely that CDS based on higher grades of evidence or endorsed by national professional societies *and* supported by local thought leaders as clinical best practices will have higher impact on altering ordering provider behavior. However, more research is needed to understand best practices for design and implementation of imaging CDS to improve its clinical impact while reducing unnecessary distractions for ordering providers.

6 Emerging Challenges and Opportunities for Imaging Clinical Decision Support

In an effort to improve quality of health care and reduce waste through meaningful use of health IT, CDS was a fundamental component of Stage II of the meaningful use criteria for health information technology (HIT) set out in the federal Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 reg-

ulations (Health Information Technology for Economic and Clinical Health (HITECH) Act 2009; Jha 2010; Blumenthal and Tavenner 2010). More recently, Section 218b of the Protecting Access to Medicare Act (PAMA) of 2014, aptly named Promoting Evidence-Based Care, requires that healthcare ordering providers use approved CDS systems to consult specified AUC when ordering certain ambulatory advanced imaging procedures (Table 4) as a requirement for payment for such services to furnishing providers (for both technical and professional components of radiology services) (Protecting Access to Medicare Act of 2014 2014). Per the resulting CMS regulations, beginning on January 1, 2019, PAMA will require ordering providers to consult AUC prior to ordering outpatient CT, MR, and nuclear medicine exams for certain "priority clinical areas" for Medicare fee-for-service beneficiaries. PAMA represents a major opportunity for radiology practices to create value in health care but many implementation challenges remain (Hentel et al. 2017). Under these regulations, no radiology practice will receive Medicare payment for these "certain" advanced imaging procedures unless the claim submitted to CMS for payment includes documentation of ordering provider consultation with a certified CDS mechanism containing AUCs created by a qualified provider-led entity (QPLE).

CMS has created a process for certifying CDS mechanisms (the IT tool or the "syringe"), and a separate process for creation of the AUCs (the "medicine" or the rules to be embedded in CDS)—by delegating the creation of AUCs to QPLEs.

Table 4 CMS priority clinical areas (Hentel et al. 2017)

• Coronary artery disease (suspected or diagnosed)
• Suspected pulmonary embolism
• Headache (traumatic and nontraumatic)
• Hip pain
• Low back pain
• Shoulder pain (to include suspected rotator cuff injury)
• Cancer of the lung (primary or metastatic, suspected or diagnosed)
• Cervical or neck pain

CMS has created an annual application process for national professional societies and other provider-led entities (such as healthcare delivery systems) to receive delegated authority from CMS to become a QPLE. QPLEs have the authority to publish AUCs which if implemented, at least for the priority clinical areas identified by CMS, will allow any provider group to meet PAMA requirements. As of mid-2017, there are 16 QPLEs. Each must meet rigorous requirements, including literature review, multidisciplinary expert panel review of existing literature, grading of each unique piece of evidence in the AUC set using a well-accepted evidence grading framework, and publication of the AUC set in a public website for public scrutiny.

CMS intends to expand the clinical priority areas over time. The priority clinical areas are also intended to be targets for identifying outlier ordering providers, and to potentially expose such outliers to additional pre-authorization programs beginning in 2020. Based on the imaging program experience, CMS may extend the program beyond imaging.

Successfully implemented and adopted, these new regulations have the potential to help improve quality of care, promote evidence-based practice, and reduce waste. However, national implementation of such a program faces several challenges (Hentel et al. 2017). These challenges include enhancing and operationalizing the claims submission process between providers and CMS, establishing the process for private radiology practices who receive imaging requests from many varied referring provider practices, each of which may decide on implementation of a different CDS mechanism based on their own EHR, or conceivably a different set of rules ("medicine") as envisioned under PAMA and its related regulations. As written, the regulation's workflow burden resides primarily in the referring provider domain while the financial burden resides solely in radiology. Attempts to align these varied incentives would likely be helpful in achieving the intended goals of the law.

7 Future Direction

Despite substantial progress in use of imaging CDS to enable evidence-based practice to improve quality and reduce waste, much remains unknown. It remains unclear whether in the current healthcare environment, imaging CDS will achieve its promise of enabling evidence-based practice beyond the leading healthcare delivery institutions which have demonstrated its early effectiveness. It is crucial that maturation of imaging CDS solutions accelerates, buoyed by the looming opportunity created under PAMA. Several streams of improvements and innovation are worth highlighting below.

1. Workflow interactions between EHR vendors and CDS mechanisms need much improvement. Efficient and clinically relevant CDS alerts require sharing of a patient's clinical presentation (beyond a billing code) among systems exposed to providers. It is unclear whether such CDS functions will be ultimately incorporated into EHR modules or whether interoperability standards, many of which exist already, will spur much-needed innovations and improvements in the CDS vendor space. Workflow optimization must consider the impact of each "click" and "scroll," and each distraction, on provider burnout.
2. Policies and regulations, including healthcare financing changes to pay for value rather than volume, would be helpful to align the diverse and at times conflicting incentives of all stakeholders, most importantly including patients, to motivate the needed clinical transformation for promoting evidence-based care.
3. Funding for research to accelerate creation of evidence-based decision rules, using either traditional methodologies (Gupta et al. 2014; Stiell et al. 1992; Wells et al. 2001; Alper et al. 2017) or promising new avenues such as machine learning, deep learning, or artificial intelligence, is sorely needed to improve the usefulness of CDS to clinicians.
4. A public repository of transparently graded (CEBM 2009), publicly available evidence, akin to an "iTunes" library for music, could accelerate the creation of AUCs by QPLEs, may help improve collaboration among QPLEs, identify knowledge gaps in current literature, and allow QPLEs and end users to compare AUCs from different publishers of AUCs when such rules contradict or overlap. Such initiatives can focus on the accumulation, curation, organization, and functionalization of medical evidence rather than on the creation of new evidence (Lacson et al. 2016; Yan et al. 2016).
5. Evaluation of the impact of implementations will be critical in understanding best practices for design and implementation of imaging CDS. Resourcing assessment of impact and sharing results publicly and in peer-reviewed literature will help advance this important tool in effectuating the promise of health information technology in healthcare delivery.

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