Center for Evidence-Based Imaging

Ramin Khorasani, M.D., MPH
Distinguished Chair, Medical Informatics
Vice Chairman, Department of Radiology
Brigham and Women's Hospital

Clinical Decision Support for Imaging

December 2014 Update

BRIGHAM AND WOMEN'S HOSPITAL

Elizabeth G. Nabel, M.D.
President, Brigham and Women's Hospital and Brigham and Women's Faulkner Hospital

Steven E. Seltzer, M.D., FACR
Chairman, Department of Radiology
Brigham and Women's Hospital

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Clinical Decision Support for Imaging

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Cover design: Reiko O'Brien

BRIGHAM AND WOMEN'S HOSPITAL
HARVARD MEDICAL SCHOOL

Ramin Khorasani, M.D., M.P.H.
Vice Chair, Department of Radiology
Distinguished Chair, Medical Informatics
Director, Quality, Safety & Medical Imaging IT
Director, Center for Evidence-Based Imaging
Associate Professor of Radiology

November 10, 2014

Update on Clinical Decision Support for Imaging, Including Summary of Selected Publications

Section 218 of the Protecting Access to Medicare Act of 2014 (Public Law No: 113-93, signed into law on April 1, 2014) requires ordering providers to consult with Clinical Decision Support (CDS) for imaging for targeted ambulatory imaging services beginning January 1, 2017. This document presents an update on imaging CDS based on over 20 years of experience at Brigham and Women's Hospital, Brigham and Women's Faulkner Hospital, Dana Farber Cancer Institute and community care settings affiliated with Brigham and Women's Hospital in Boston.

This document is divided into three parts:

- An introduction with a brief overview and guide to references (summary of selected publications)
- List of select references (with copies of referenced publications if requested);
- A set of slides summarizing published data illustrating the impact of imaging CDS on the quality of care and waste at BWH and its affiliates;

Introduction

Medical imaging has helped transform healthcare and will continue to advance the understanding and treatment of disease. An expanding plethora of minimally invasive therapies as well as functional and molecular imaging capabilities continue to supplement a powerful arsenal of structural, anatomical and morphological diagnostic imaging tools. However, in parallel, there is concern that the inappropriate use of medical imaging creates waste and suboptimal quality of care,

including potential harm to patients from exposure to unnecessary ionizing radiation or unnecessary treatments provided as a result of incidental findings that may be discovered through imaging.

Imaging has also been identified as a driver for rising health care expenditures, although more recent reports suggest that utilization levels have moderated or even declined slightly. Interventions intended to address the cost of imaging have centered on reducing fee-for-service reimbursement rates for imaging (e.g., § 5102 (b) (2) of the Deficit Reduction Act of 2005) or requiring pre-authorization for imaging services through payer-mandated radiology benefit management programs. These interventions may have helped reduce payments for imaging services but such strategies are not primarily directed at improving the quality of patient care. Indeed, the predominant mechanism of action for pre-authorization programs may be the onerous and wasteful workflow intrusions based on opaque processes that may delay needed care for patients.

Substantial unexplained variation exists in how physicians use imaging services. Even when high quality evidence for optimal use of imaging exists, systems to educate, encourage, or if necessary enforce adoption of this evidence to enable evidence-based care are generally lacking.

Electronic clinical decision support (CDS), the iterative interaction of a user with the computer to enhance clinical decision making, promises to enable evidence-based practice, reducing unnecessary, unsafe or otherwise inappropriate testing to improve quality and reduce waste. Although best practices for implementation and adoption of evidence through CDS, including for imaging, can be debated, recent data shows a growing body of evidence for its effectiveness and impact.

Guide to References:

1. **General:**
    a. Definition/description of imaging decision support. (1–3)
    b. What makes imaging decision support effective? (2–4)
    c. Sources/types of evidence likely to be useful/effective. (2–5)

2. **Problem statement:**
    a. Over the last 2-3 decades, there has been significant growth in use of imaging, particularly of cross sectional imaging (e.g. inpatients and the ED). (6–8)
    b. **In many clinical settings imaging has measurable impact on outcome and/or** can be useful in changing patient management. (9,10)
    c. In other clinical settings, increasing use of imaging may not result in improvement in measurable outcome (11) and thus may be wasteful(12).
    d. There is substantial, likely unwarranted variation in providers use of imaging(13–15).
    e. A substantial portion of imaging may be unnecessary/redundant. (16) Although some of the repeat imaging may be due to radiologist's follow up recommendation, the majority occur in the absence of such recommendations. (16)
    f. Substantial variations among radiologists in follow up recommendations may further contribute to uncertainty and suboptimal imaging (17) even when evidence to support specific recommendations exists. (18)
    g. Thus, although imaging has had substantial impact in helping transform the practice of medicine, concerns about its inappropriate/suboptimal use are supported by evidence, resulting in suboptimal quality of care (e.g. potential risks of radiation exposure (19) and waste.
    h. Clinical Decision Support (CDS) is a major feature of national health information technology stage 2 meaningful use (20) regulation, and is recognized as key attribute of learning health systems by the institute of medicine (21). However, it is unclear whether the educational impact of CDS alone, even if based on high quality evidence, will eliminate or reduce unwarranted variation in practice. Indeed, we have found an increase in inter-physician variation in use of CT for pulmonary embolism in the ED after use of CDS. (22) The implication is that each provider may respond differently to evidence presented through CDS thus potentially increasing, rather than reducing inter-physician variation. We have also found that although education only CDS interventions based on high quality evidence increase adherence to evidence, a substantial portion of orders still deviate from evidence. For example, CDS increased adherence to evidence for CT in patients suspected of having PE or minor head trauma to 75%; with 25% of orders deviating from evidence. (23,24) Practice norms, leadership; synchronous (at the time of

order entry) and asynchronous (after exams have been performed such as benchmarking, academic detailing) consequences for ignoring evidence will likely be needed to potentiate the impact of educational interventions through CDS to reduce unwarranted variation in test ordering behavior to optimize quality improvement efforts. (22)

3. Potential solutions:

a. *The 4 E's of CDS*: Effective imaging CDS should be configurable (based on many attributes-including the target provider/practice/care setting, the quality of evidence and the consequences of unwarranted variation from evidence based practice(3) to Educate and/or Encourage and/or Enforce (if needed) adoption of evidence into practice. (2)

b. Imaging CDS can be successfully and broadly implemented and adopted by providers in all care settings and can be integrated into the health IT infrastructure of health systems using existing IT integration standards. (25)

c. Earlier CDS educational interventions showed providers may be willing to change their imaging request but maybe unwilling to cancel their request. (26) (Implication: more stringent interventions with higher quality evidence would be needed to change ordering behavior)

d. More recently, educational features of imaging CDS based on high quality evidence resulted in 20% reduction in utilization and 69% increase in yield of Pulmonary Embolism CT (PE CT) in ED, with maximal benefit observed up to 2 years after implementation of CDS. (27) (Implication: educational benefits alone take a long time to optimize practice because providers can simply ignore the evidence if no perceived consequences from ignoring evidence.)

e. However, impact of educational imaging CDS on use of PE CT for inpatients based on the same high quality evidence used in the ED resulted in an immediate (over 2-4 weeks) and significant 12.3% reduction in use of PE CT(28) (Implication: same evidence deployed through CDS will have substantially different impact based on care setting and the ordering provider

f. When intervention with CDS for PE (23) or minor head trauma (24) was educational only, adherence to evidence improved from approximately 50% to 75%. (Implication: 1 in 4 PE CT varied from evidence post CDS. More stringent interventions such as consequences for ignoring evidence presented in CDS may further improve adherence to evidence.)

g. Combining high quality evidence with consequences for ignoring evidence in the form of technology enabled real-time peer to peer consultation and augmented by practice pattern variation reporting, resulted in 96% adherence to evidence and 12.3% adjusted reduction in use of Lumbar Spine MRI in primary care outpatients. (Implication:

consequences for ignoring evidence synergistically optimize impact of CDS to enhance adoption of evidence into practice.) (29)

h. Providers rarely 'game' imaging CDS. When electronic radiology requisition is considered an integral component of the electronic medical record and in mature implementations, providers rarely (<4%) enter erroneous clinical data to avoid onerous and intrusive computer interactions and alerts. (30)

i. Duplicate decision support (DDS), alerting ordering providers to the existence of a potentially redundant imaging study on patient's same body part using the same imaging modality in the previous 90 days resulted in 5% reduction of potentially redundant CT orders (40% of all CT orders across all care settings triggered the DDS)(31). (Implication: 95% of the DDS are ignored-future enhancements to DDS to reduce unnecessary alerts would be helpful to reduce the risk of alert fatigue)

j. Requiring ordering providers for a clinical justification to override duplicate decision support modestly but significantly enhanced the impact of duplicate decision support resulting in cancellation of 1 in 13 repeat CTs overall (32).

k. After decades of escalating high cost imaging use for inpatients; implementation of CDS was associated with a 21% reduction in use of CT per admission after adjusting for severity of disease from 2009-2012(33).

l. After 15 years of escalating use of high cost imaging in the ED; use of CDS was associated with 33% reduction in CT and 21% reduction in MRI per 1000 ED visits between 2007 and 2012. This was despite a significant increase in severity of disease for ED visits as measured by Emergency Severity Index (ESI)(34).

m. Provider-led, technology enabled, radiology medical management program (using (a) CDS, (b) real time peer-to-peer, and (c) practice pattern variation reporting) resulted in 12% reduction in high cost imaging, sustainable over 4 years, for a commercial payer population. (35) Such technology enabled provider led interventions may be important to reduce inappropriate use of imaging to improve quality and reduce waste, particularly as we move to new 'at risk' models of healthcare financing as exemplified by the Accountable Care Organizations. (36)

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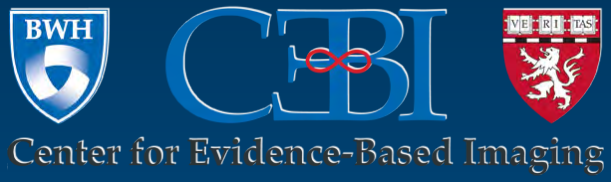

Center for Evidence-Based Imaging Evidence Summary Highlights Relevant to Imaging Clinical Decision Support

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Ramin Khorasani, MD, MPH
Vice Chair, Department of Radiology
Distinguished Chair, Medical Informatics
Director, Center for Evidence-Based Imaging
Brigham and Women's Hospital

Associate Professor of Radiology
Harvard Medical School
Boston, MA

Grant funding:
NIH 2010-2013
CMS 2011-2014

- Decision Support -

Iterative interaction of a user with a computer to improve decision making

References:

(1) Bates DW, *et al.* Ten commandments for effective clinical decision support: making the practice of evidence-based medicine a reality. J Am Med Inform Assoc. 2003;10(6):523–530

(2) Khorasani R, *et al.* Ten commandments for effective clinical decision support for imaging: enabling evidence-based practice to improve quality and reduce waste. AJR. 2014;203:945-951

Effective Imaging Clinical Decision Support: The *4 E's*

- **Efficient**
  - Embed evidence in workflow; reduce redundant data entry
- **Educate**
  - Quality of evidence matters; transparent source and strength of evidence; Any source, including local best practice; eliminate 'low value' alerts and alert fatigue
  - Brief, actionable, unambiguous
- **Encourage, Enforce adoption of evidence**
  - Consequences for ignoring evidence matter: 'accountability tools'

References:

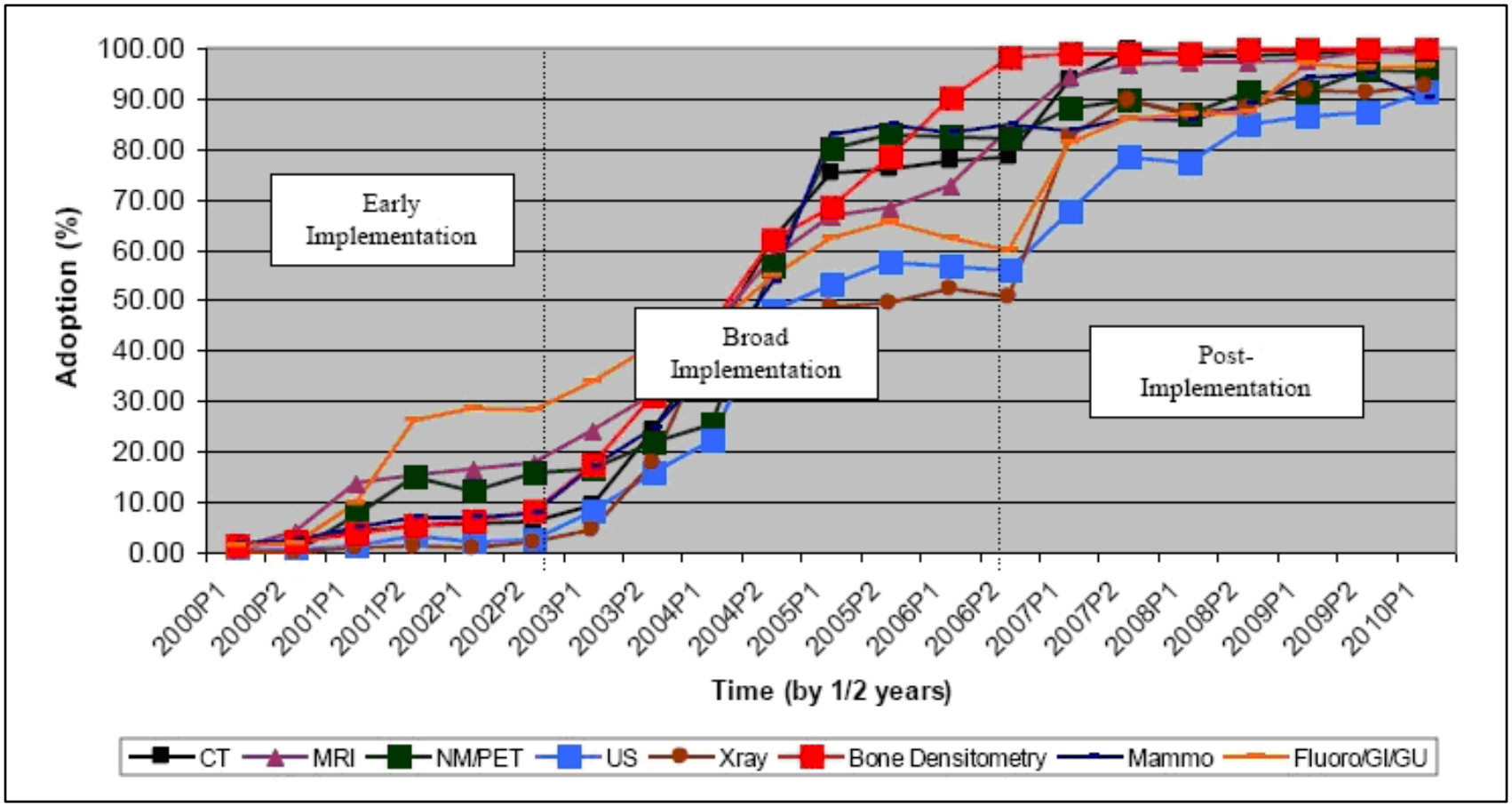
(1) Bates DW, *et al.* Ten commandments for effective clinical decision support: making the practice of evidence-based medicine a reality. J Am Med Inform Assoc. 2003;10(6):523–530

(2) Khorasani R, *et al.* Ten commandments for effective clinical decision support for imaging: enabling evidence-based practice to improve quality and reduce waste. AJR. 2014;203:945-951

Imaging computerized physician order entry (CPOE) and clinical decision support (CDS), integrated into the HIT infrastructure using existing standards, can be broadly adopted and meaningfully used

Reference:
Ip I, *et al*. Adoption and meaningful use of computerized physician order entry with an integrated clinical decision support system for radiology: Ten-year analysis in an urban teaching hospital. JACR. 2012;9(2):129-36.

CPOE Adoption by Imaging Modality 2000-2010



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Ip I, *et al*. Adoption and meaningful use of computerized physician order entry with an integrated clinical decision support system for radiology: Ten-year analysis in an urban teaching hospital. JACR. 2012;9(2):129-36.

Imaging CDS based on high quality evidence can reduce inappropriate use and increase yield of high cost imaging, improving quality and reducing waste

20% reduction in utilization and 69% increase in yield of pulmonary embolism CT in ED over 2 years (1)

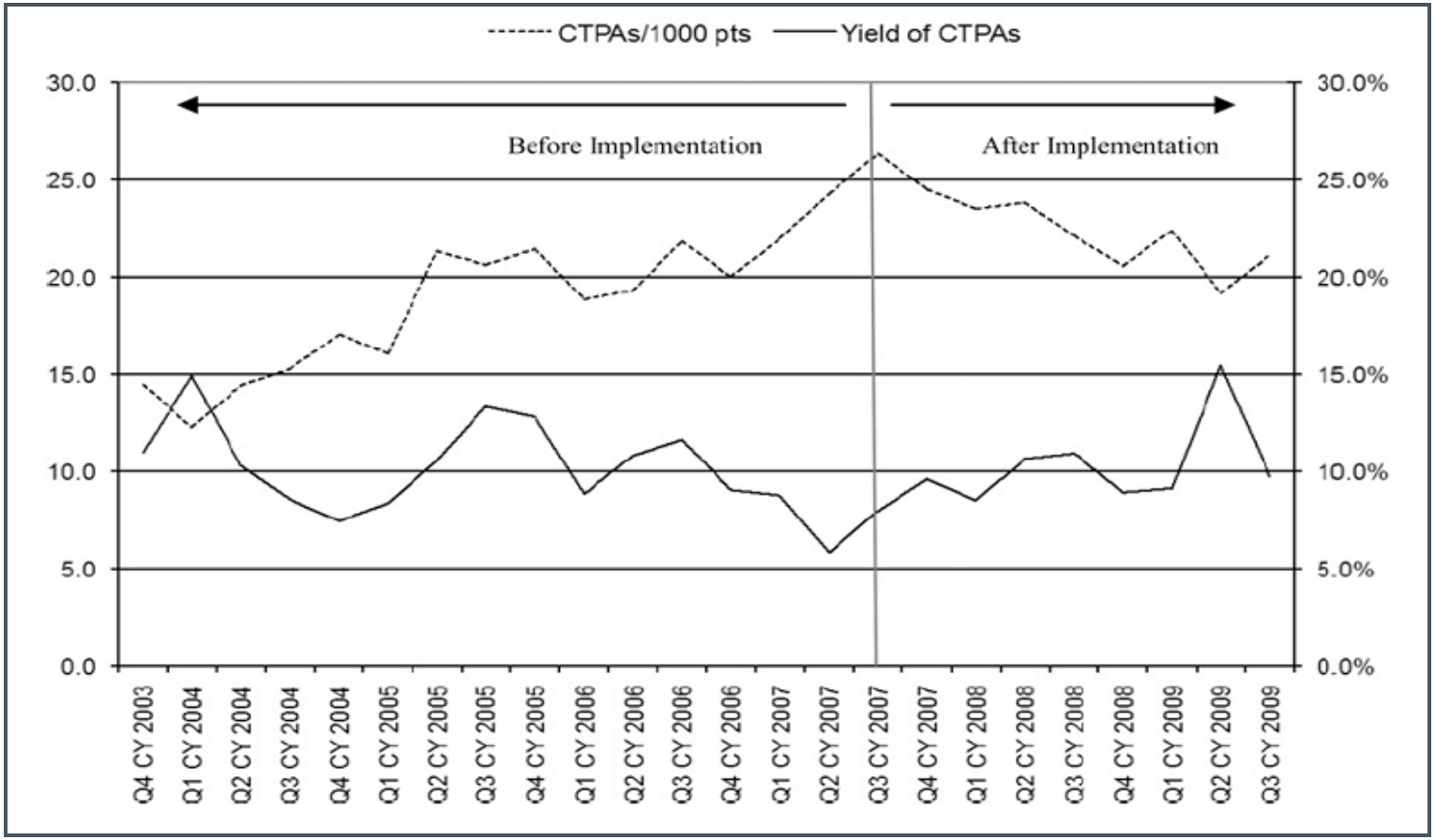
12.8% reduction in utilization of pulmonary embolism CT for inpatients in a 4 week intervention timeframe, with reduction in utilization sustainable over the ensuing 3 years (2)

Reference:

(1) Raja AS, *et al*. Effect of Computerized Clinical Decision Support on the Use and Yield of CT Pulmonary Angiography in the Emergency Department. Radiology 2012;262(2):468–474

(2) Dunne R. *et al.* Effect of evidence-based clinical decision support on the use and yield of CT pulmonary angiography for hospitalized patients . Radiology 2014. In press

CT Pulmonary Angiography (CTPA)
Use and Yield Before and After CDS Implementation in the ED



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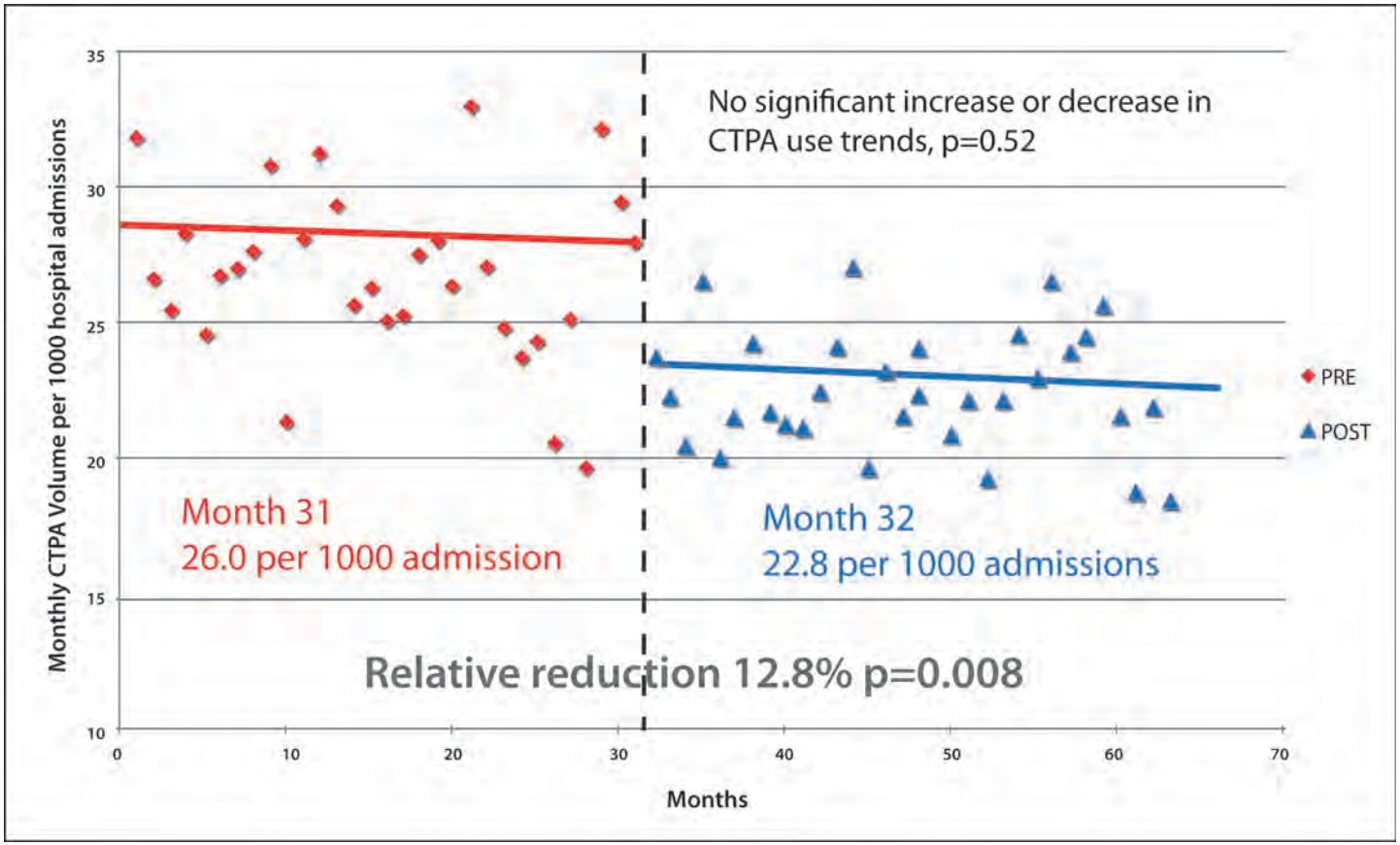
CT Pulmonary Angiography (CTPA) use for Inpatients Before and After CDS Implementation



Reference:
Dunne R. *et al.* Effect of evidence-based clinical decision support on the use and yield of CT pulmonary angiography for hospitalized patients . Radiology 2014. In press

Imaging CDS enables automated measurement of provider adherence to evidence without the need for resource-intensive chart review

Imaging CDS based on high quality evidence (education-only intervention) significantly improved documented provider adherence to an evidence-based National Quality Forum imaging measure from 57% to 76% (CT imaging in patients suspected of having pulmonary embolism)

Reference:
Raja AS, *et al*. The Use of Decision Support to Measure Documented Adherence to a National Imaging Quality Measure. Acad Radiol 2014; 21:378-383.

Imaging CDS enables unambiguous automated measurement of provider adherence to evidence without the need for resource-intensive chart review

Imaging CDS based on high quality evidence (education-only) significantly improved documented provider adherence to an American College of Emergency Medicine (ACEP) endorsed Choosing Wisely Campaign measure from 49% to 76% (CT imaging in patients with Minor Traumatic Brain Injury)

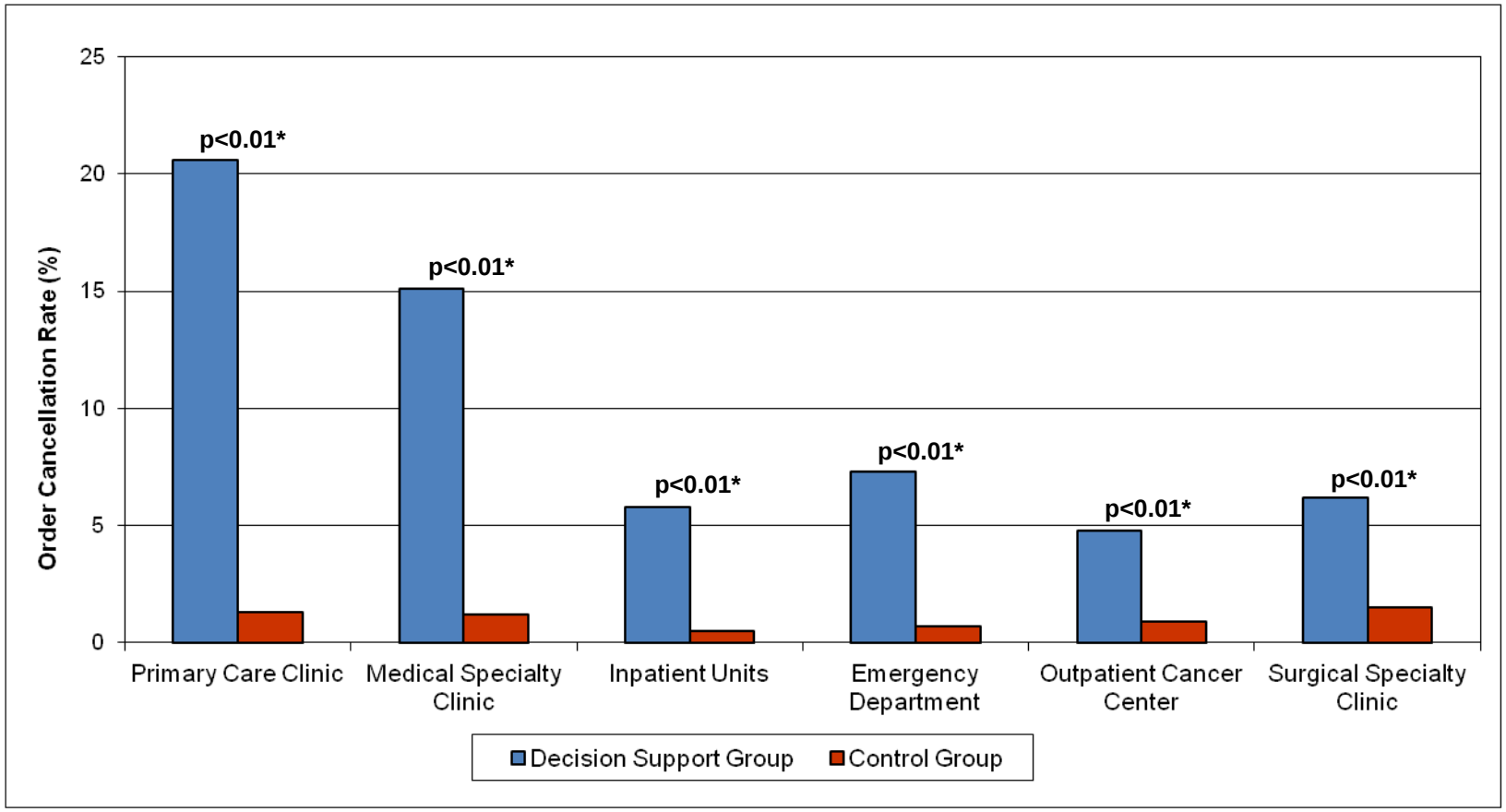
Reference:
Gupta A, *et al*. Effect of clinical decision support on documented guideline adherence for head CT in emergency department patients with mild traumatic brain injury. J Am Med Inform Assoc. 2014;21(2):347-51

Repeat imaging decision support, which can be ignored by the provider, significantly reduces repeat testing

(5% of all repeat CTs; ~2% of ALL CTs are cancelled)

Reference:
Wasser EJ, *et al*. Impact of a Real-Time Computerized Duplicate Alert System on the Utilization of Computed Tomography. JAMA Intern Med. 2013 Apr 22;1–2

Impact of Decision Support on Repeat Imaging



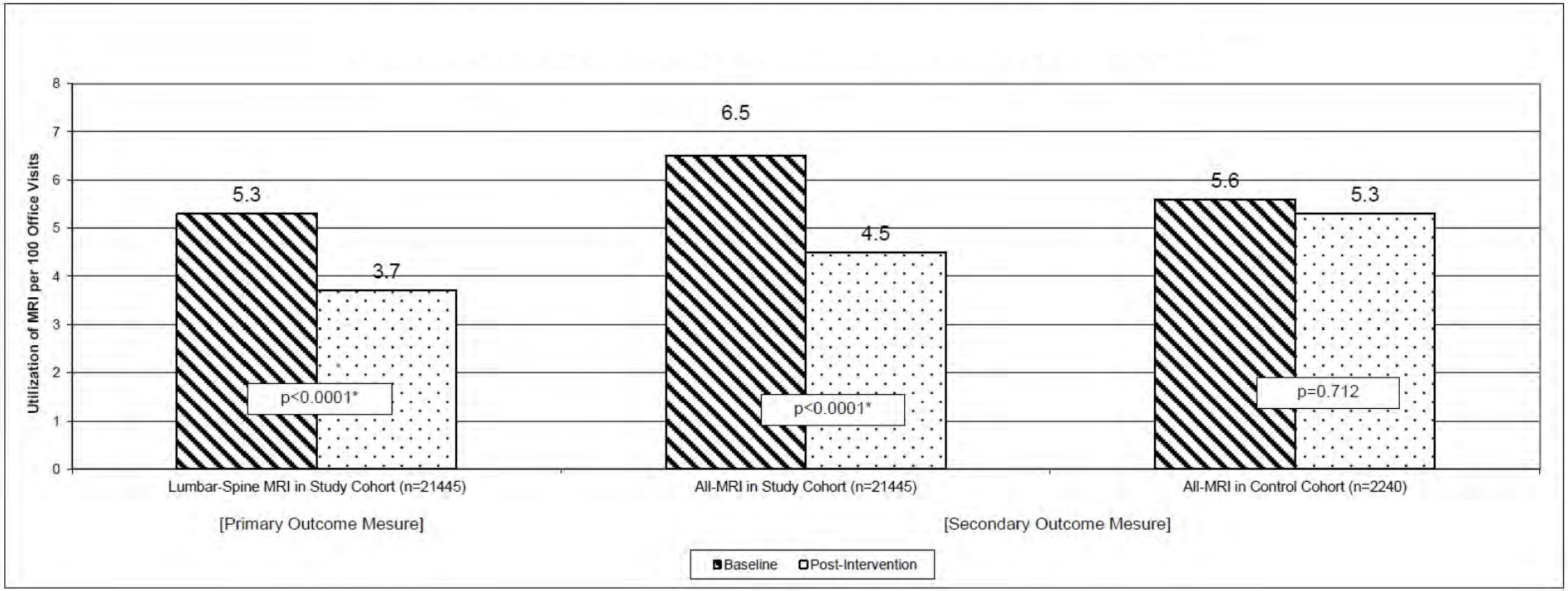
Reference:
Wasser EJ, *et al*. Impact of a Real-Time Computerized Duplicate Alert System on the Utilization of Computed Tomography. JAMA Intern Med. 2013 Apr 22;1–2

Imaging CDS based on high quality evidence, *combined with accountability tools*, improves adoption of evidence and reduces overuse of high cost imaging

***96% adherence** to American College of Physicians guidelines, **12.3% reduction** in utilization of Spine MRI in patients with low back pain initially seen by primary care*

Reference:
Ip IK, *et al*. Impact of IT-Enabled Intervention on MRI Use for Back Pain. Am J Med. 2014;127(6):512-8

Utilization of Magnetic Resonance Imaging in Back-Pain Related Primary Care Office Visits



Reference:
Ip IK, *et al*. Impact of IT-Enabled Intervention on MRI Use for Back Pain. Am J Med. 2014;127(6):512-8

Analysis of Tertiary Outcome Measures in the Study Cohort

Outcome Measure	Preintervention	Postintervention	% Change	*P*-Value
Lumbar spine MRI ordered by any outpatient providers within 30 days of index primary care visit	753 (8.9%)	1009 (7.8%)	-12.3%	.0023†
Lumbar spine MRI ordered by specialty clinics within 30 days	188 (2.2%)	352 (2.7%)	+22.7%	.0292†
Lumbar Spine MRI ordered by primary care outpatient providers within 30 days	565 (6.7%)	657 (5.1%)	-23.9%	<.001†
Follow-up PCP visit within 30 days	855 (10.1%)	1224 (9.4%)	-6.9%	.080†
Guideline adherence rate in the use of lumbar spine MRI based on manual chart review	78/100 (78%)	96/100 (96%)	+23.1%	.0002†

MRI = magnetic resonance imaging; PCP = primary care physician.
*Due to the design of the National Ambulatory Medical Care Survey, tertiary outcome measure was not possible in the control cohort.
†Denotes statistical significance.

Reference:
Ip IK, *et al*. Impact of IT-Enabled Intervention on MRI Use for Back Pain. Am J Med. 2014;127(6):512-8

Repeat imaging decision support, requiring a clinical justification to override before CDS can be ignored (an accountability tool), resulted in avoidance of 1 in 13 (7.5%) of repeat CTs

Reference:
O'Connor SD, Sodickson AD, Ip IK, Raja AS, Healey MJ, Schneider LI, **Khorasani R**. Requiring clinical justification to override repeat imaging decision support: impact on CT use. AJR. 2014;203(5):W482-9

Predictors for Dropping Repeat CT Orders (n=28,420 orders)

	Odds Ratio (95% Confidence Interval)	**p-value**
Override justification requirement present(reference=absent)	1.26 (1.14-1.39)	<0.0001
Care Setting (reference=Cancer Center)		<0.0001
Primary Care	6.87 (5.11-9.15)	<0.0001
Emergency	2.80 (2.32-3.35)	<0.0001
Inpatient	1.74 (1.51-2.02)	<0.0001
Specialty	1.63 (1.42-1.88)	<0.0001

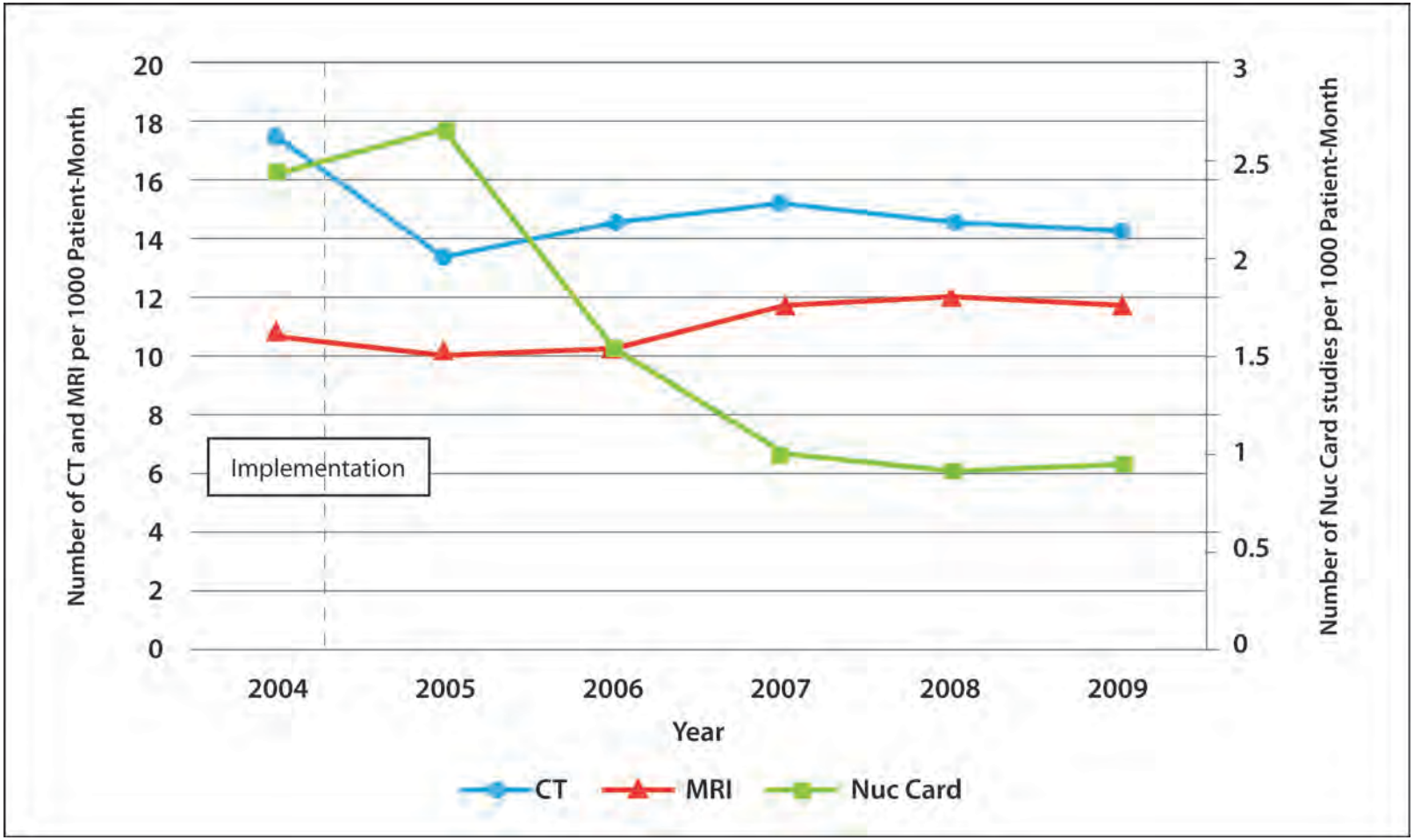
Reference:
O'Connor SD, Sodickson AD, Ip IK, Raja AS, Healey MJ, Schneider LI, **Khorasani R**. Requiring clinical justification to override repeat imaging decision support: impact on CT use. AJR. 2014;203(5):W482-9.

Outpatient Imaging

A physician-lead, CDS-enabled Radiology Medical Management program resulted in a 12% sustained reduction (over 4 years) in ambulatory high cost imaging in a commercial payer population

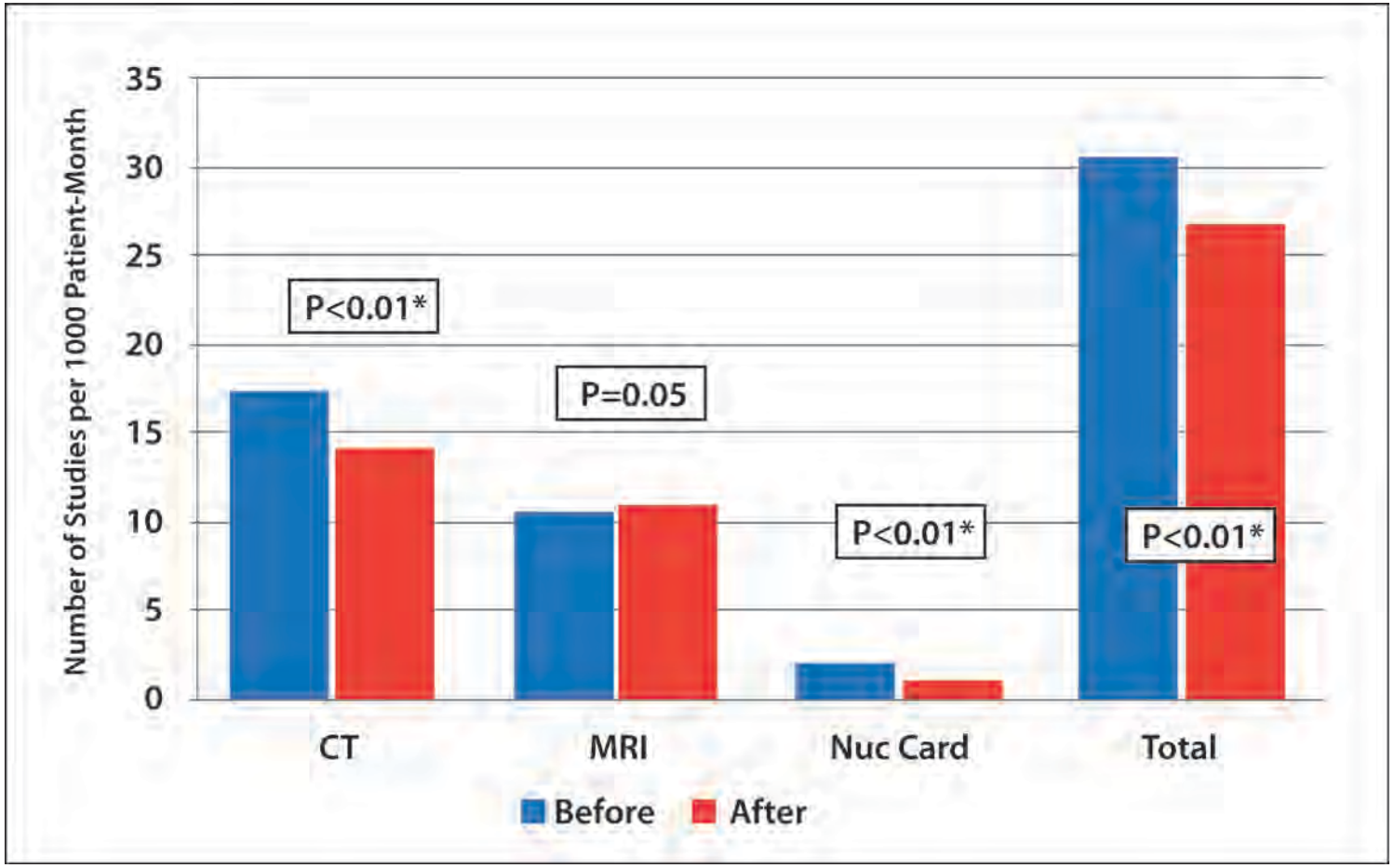
Reference:
Ip IK, *et al*. Impact of provider-led, technology-enabled radiology management program on imaging. Am J Med. 2013 Aug;126(8):687–92.

Trend of High-cost Imaging Over Study Period



Reference:
Ip IK, *et al*. Impact of provider-led, technology-enabled radiology management program on imaging. Am J Med. 2013 Aug;126(8):687–92.

Intensity of High-cost Imaging Before and After Provider-led Radiology Management Program



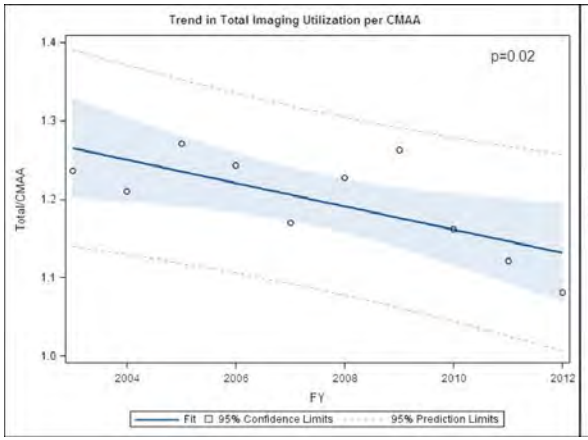
Reference:
Ip IK, *et al*. Impact of provider-led, technology-enabled radiology management program on imaging. Am J Med. 2013 Aug;126(8):687–92.

Inpatient Imaging

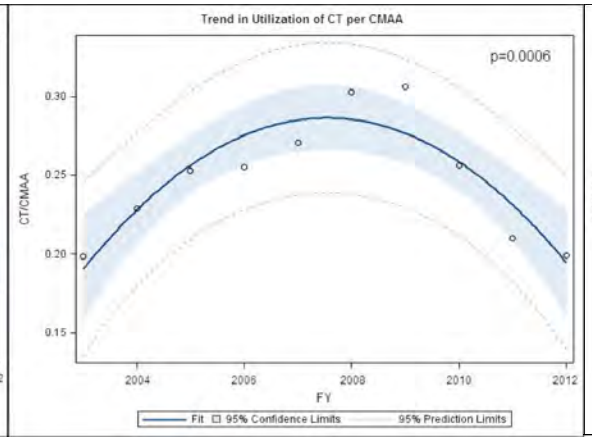
After decades of increasing use, we observed 21% reduction in inpatient CT/severity of disease adjusted admissions between 2009-2012

Reference:
Shinagare AB, *et al*. Inpatient. Imaging Utilization: Trends of the Past Decade. American Journal of Roentgenology. 2014 Mar;202(3):W277–W283.

Trends in Utilization of Imaging Modalities Per Case-mix-adjusted Admission (CMAA) FY2003-2012



Total



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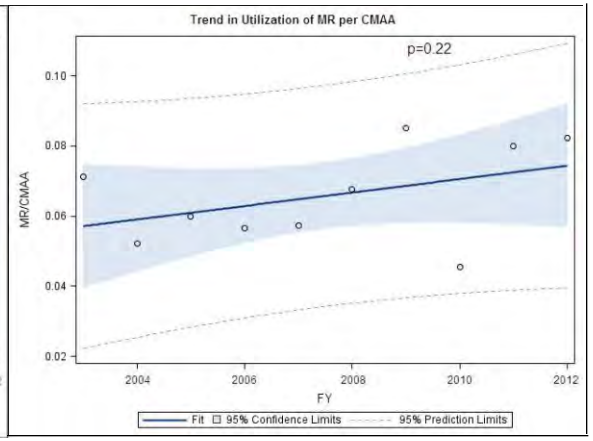
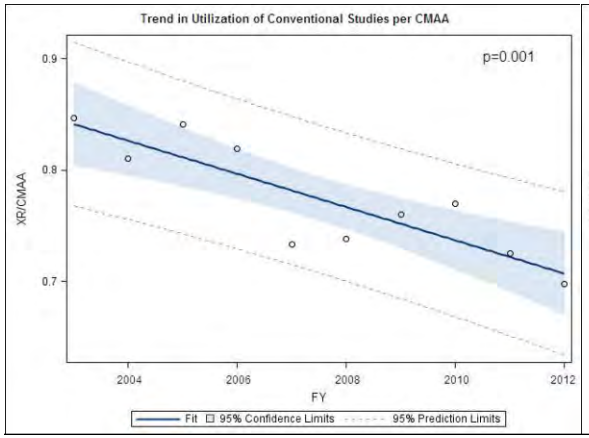
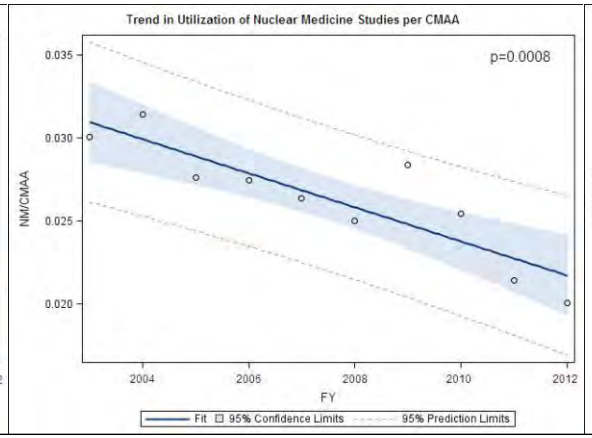


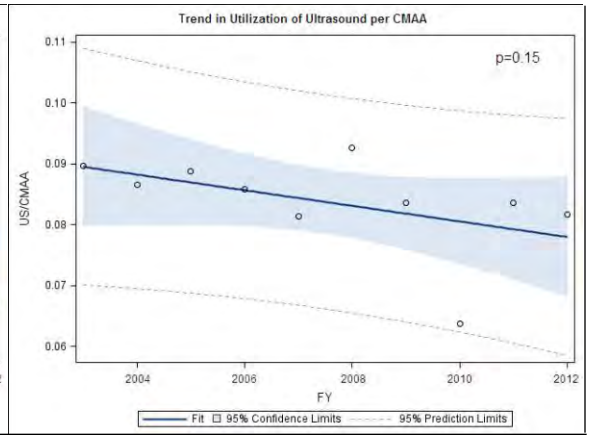
MRI



X-Ray

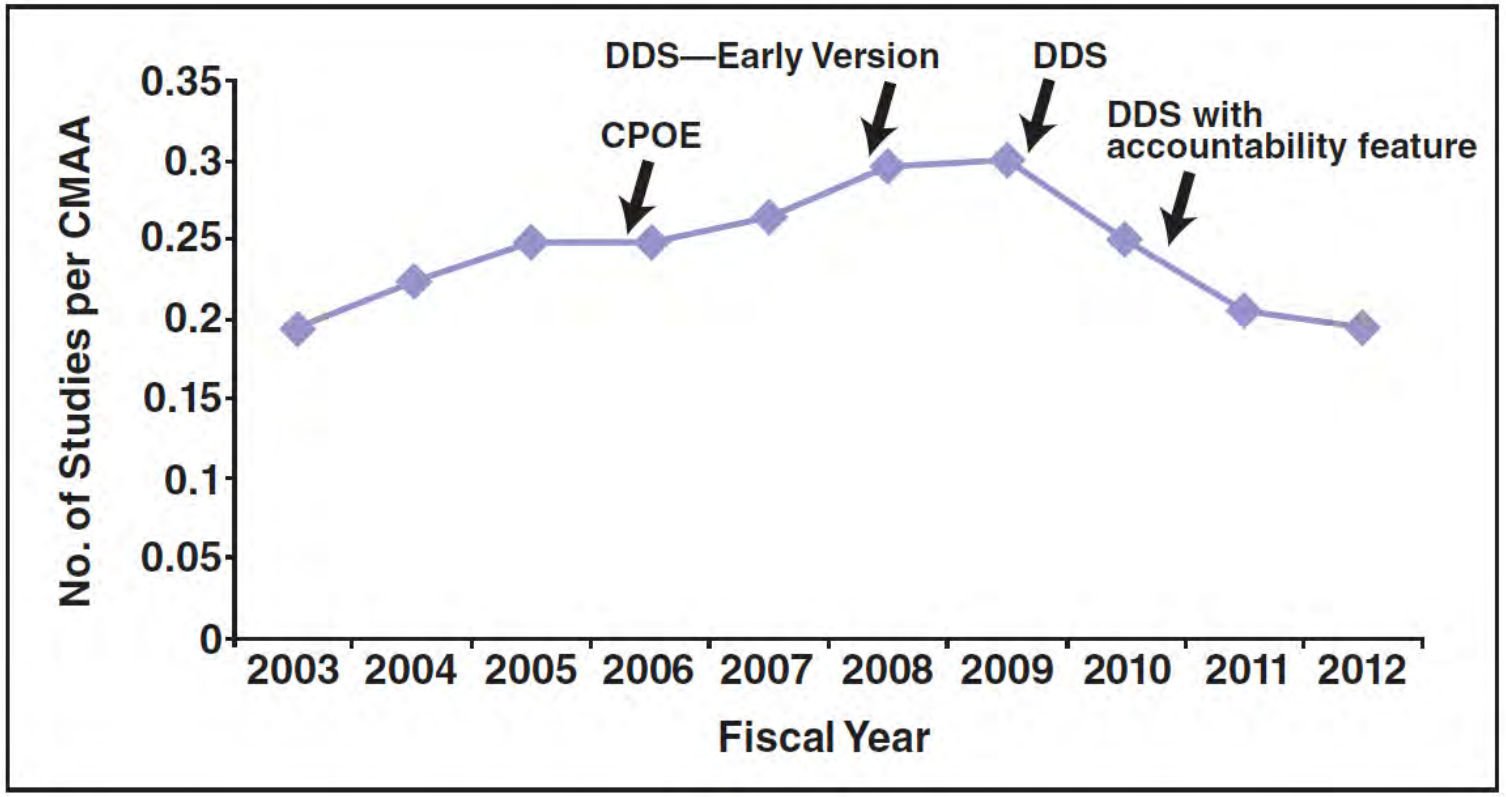


Nuc Med



US

Sample HIT Initiatives to Reduce Inpatient Imaging Overuse and CT Utilization Per Case-mix-adjusted Admission (CMAA)

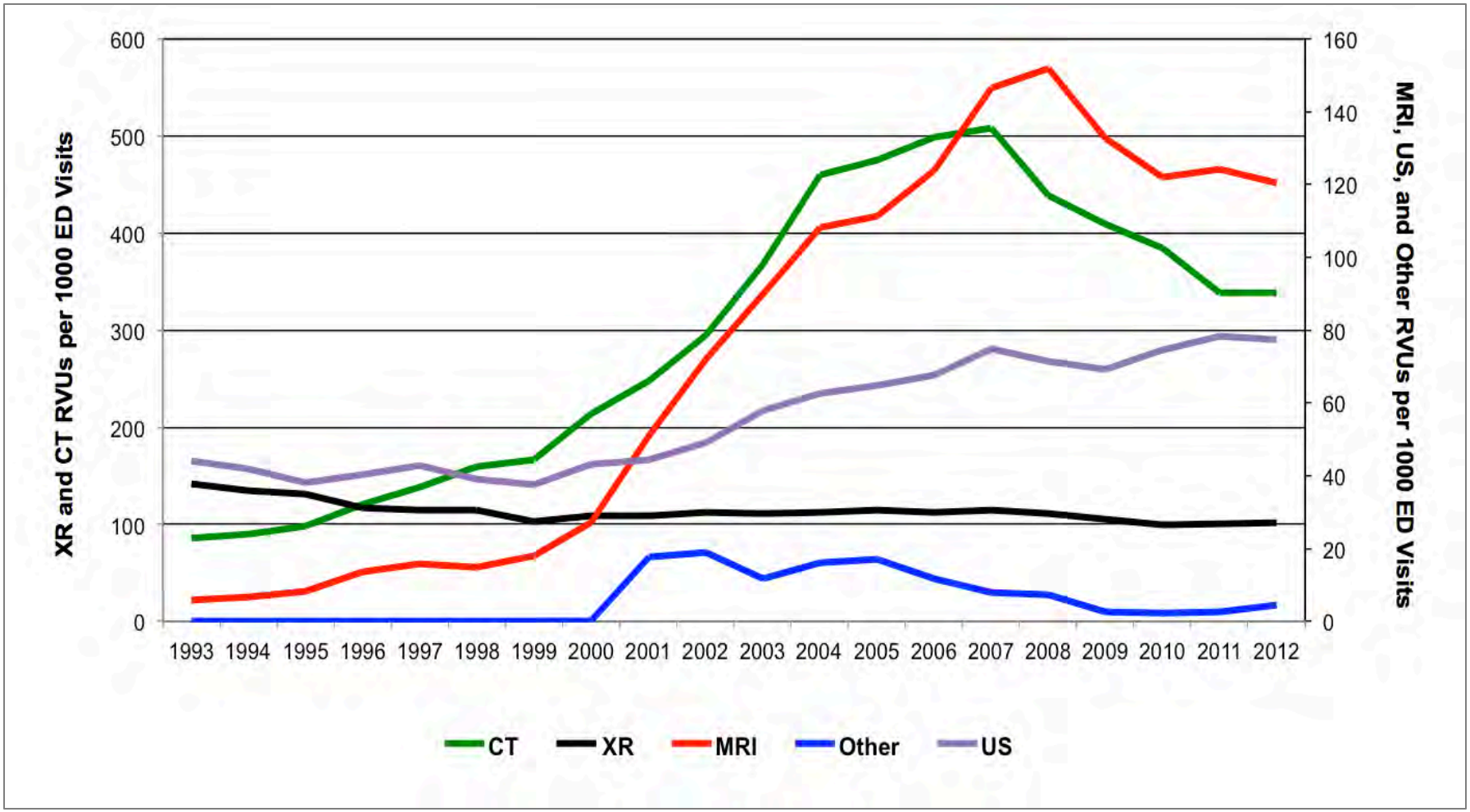


Emergency Department Imaging

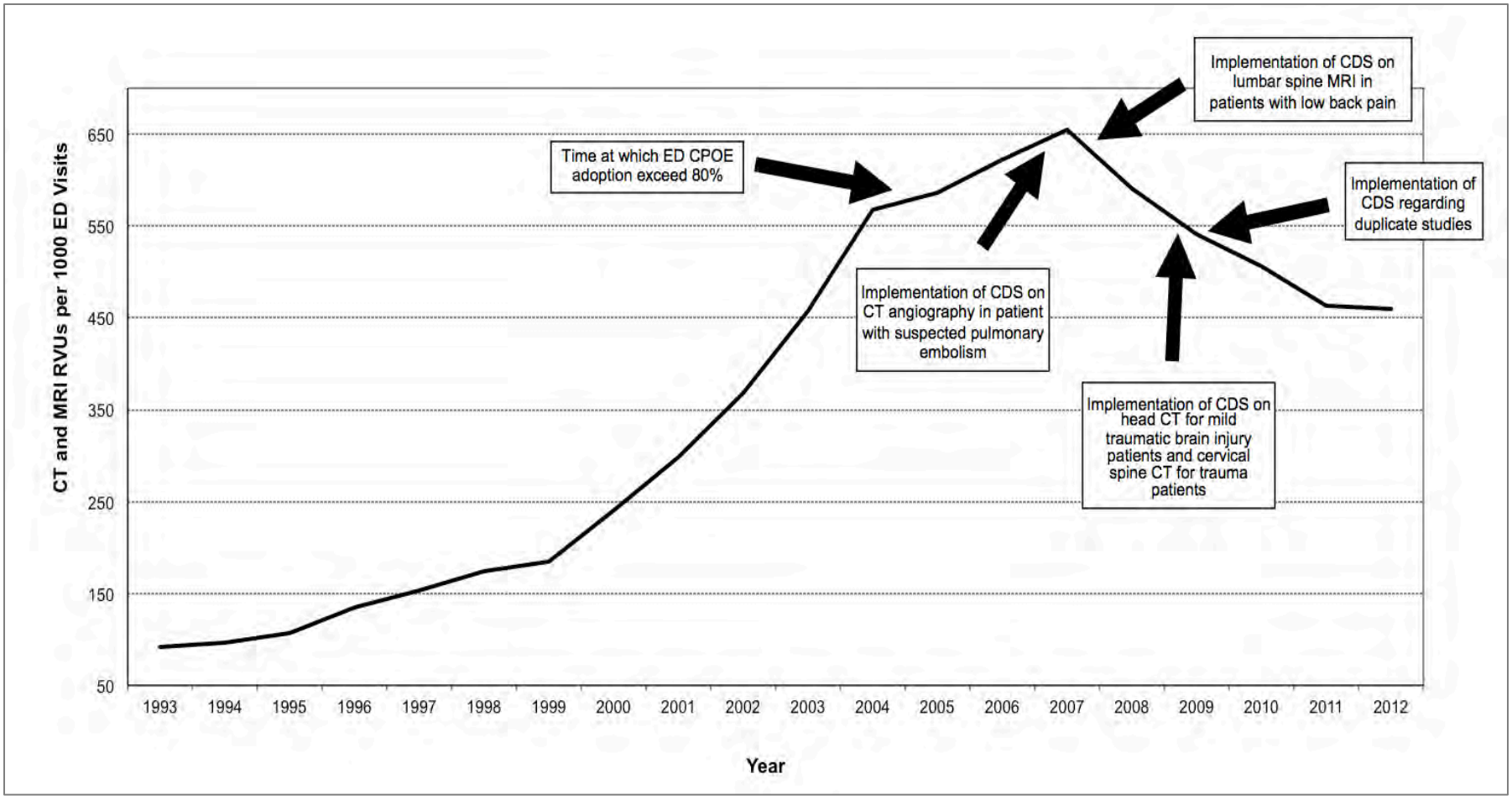
After 15 years (1993-2007) of increasing ED imaging use, we observed 25% reduction in overall imaging, 33% reduction in CT, and 21% reduction in MRI per 1000 ED visits between 2007-2012

Reference:
Raja AS, *et al*. Radiology Utilization in the Emergency Department: Trends of the last Two Decades. American Journal of Roentgenology, 2014. In Press.

Trends in ED Imaging RVUs by Study Modality from 1993 to 2012



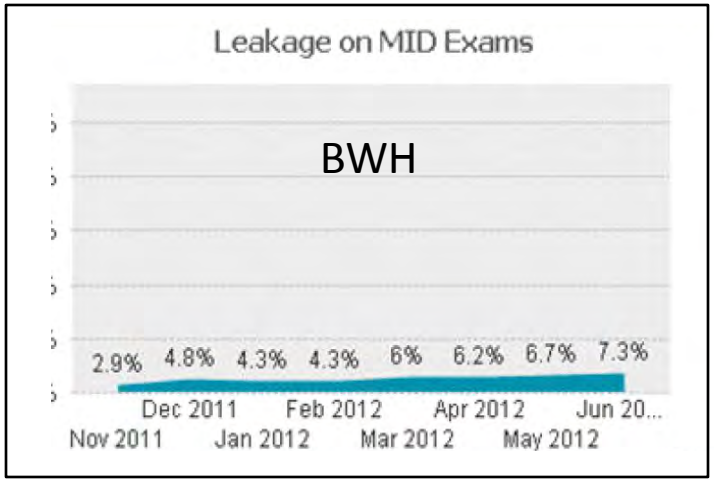
Timing of Illustrative Institutional Initiatives to Reduce Inappropriate High Cost Imaging (CT and MRI) in the ED

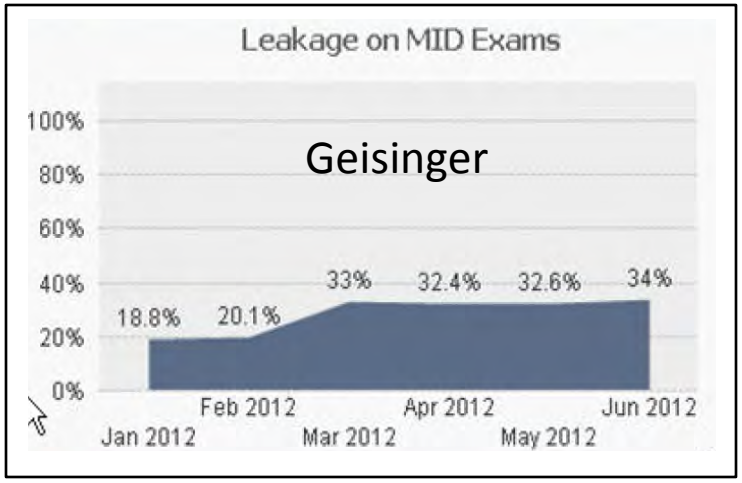


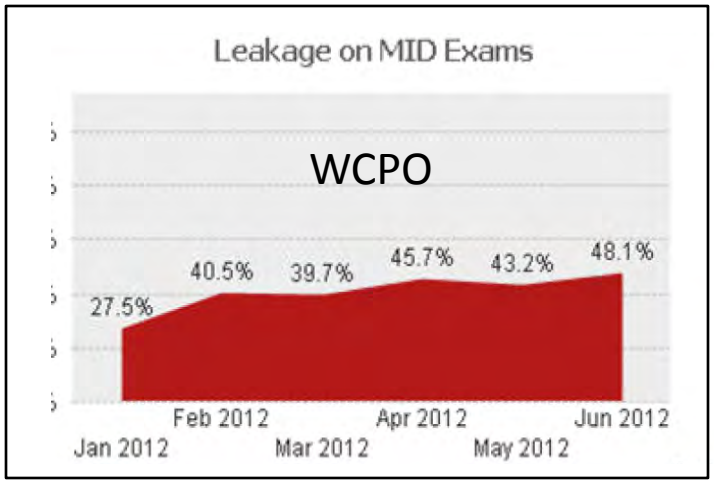
Tightly integrating imaging CDS to enterprise-wide scheduling of high cost imaging to improve access for ordering providers' practice enables substantial reduction in 'leakage', thus optimizing providers' exposure to the healthcare delivery system's standard of care

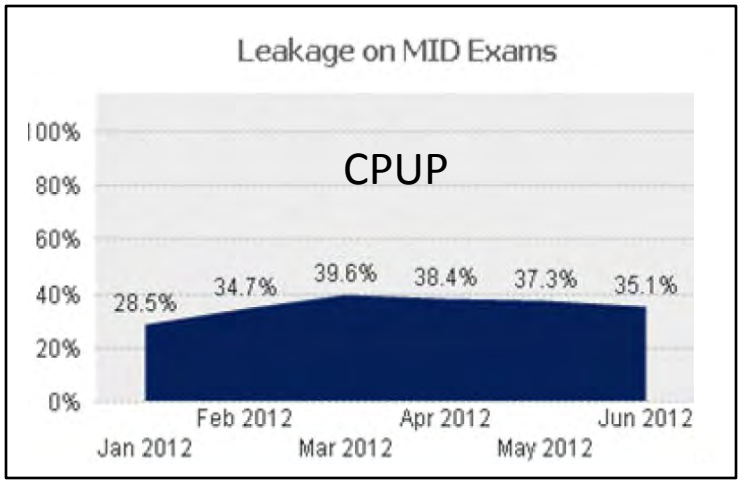
Reference:
Medicare Imaging Demonstration. DHHS/CMS 95-W-00279/1. Preliminary Interim Report, Year-1.

‘Leakage’ Data for MID exams by Institution
Based on All CMS MID Imaging Claims Paid (*provided by CMS as part of MID)*









Reference:
Medicare Imaging Demonstration. DHHS/CMS 95-W-00279/1. Preliminary Interim Report, Year-1.

About Center for Evidence-Based Imaging (CEBI)

Goals of the Program

The Center for Evidence-Based Imaging (CEBI) is dedicated to achieving measurable improvements in the quality, safety and efficiency of care delivery, using innovative information technology solutions and change management strategies. Technology innovations span all processes of care relevant to imaging at Brigham and Women's Hospital (BWH), Brigham and Women's Faulkner Hospital (BWFH) and Dana Farber Cancer Institute (DFCI). Change management strategies address people, process, and technology issues to enable performance improvement. Extensive dashboard and data analytics tools enable continuous measurement and monitoring of key performance indicators to sustain gains, empower leaders and managers, and motivate further improvements.

Program History

Founded by Steven E. Seltzer, MD and Ramin Khorasani, MD in the fall of 2002, CEBI is a unique multi-disciplinary translational research center with diversified funding sources including research grants from the National Institutes of Health (NIH), the Centers for Medicare & Medicaid Services (CMS), the Agency for Health Care Research and Quality (AHRQ), and private foundations, as well as a multi-million dollar philanthropic endowment. A fully-funded endowed *Distinguished Chair for Medical Imaging IT* was established in 2013 to support the Director of CEBI with Ramin Khorasani, MD as its first incumbent.

CEBI's educational programs in healthcare informatics support fellowship, residency and medical student training The fellowship programs include (i) a two year National Library of Medicine funded fellowship (one fellow per year) culminating in a Master of Science degree in Medical Informatics at Harvard University, and (ii) a two year Evidence-Based Imaging fellowship (1-2 fellows per year) which incorporates the summer program in clinical effectiveness at the Harvard School of Public Health as a required component of the fellowship program. This 7-week intensive educational program provides training in a range of topics including bio-statistics, experimental design, epidemiology, decision analysis, health policy, ethics, etc. Academic credits obtained during the clinical effectiveness course qualify for 1/3 of credits required to obtain a Master of Public Health degree at Harvard. The tuition for this course work is covered by CEBI. CEBI Faculty offer mentorship to residents interested in doing research in informatics, quality and patient safety. The 2 year evidence-based imaging fellowship is also available to BWH radiology residents as part of the new '3+2' curriculum. The medical student training program in quality, patient safety and informatics will be available to Harvard medical students in 2015 (1-2 students per year).

CEBI's translational research program and its educational mission are enhanced by close collaboration and co-location with the clinical operations team supporting quality improvement (QI) and medical imaging information technology programs at BWH.

Accomplishments

Various multi-year initiatives have resulted in profound changes in care delivery at BWH. Three are highlighted below.

1. Clinical Decision Support

Expanding on the concepts of a clinical decision support (CDS) system to reduce medication errors at BWH and a rudimentary imaging CDS pilot initiated for inpatients in 1993[1], a web-enabled CDS program was designed and launched in 1998[2] (US patent 6,029,138; held by BWH and licensed to Medicalis Corporation in 2000). By embedding CDS in physician workflow, we aimed to reduce inappropriate use of imaging through real-time evidence-based decision support at the point of care. By creating CDS-enabled consequences for ignoring evidence presented in CDS, we devised physician-led CDS-enabled targeted interventions to enable, measure and assess adherence to evidence-based practice, improve quality, and reduce unnecessary imaging and waste. We named the initiative *radiology medical management program*[3] to emphasize the goal of effectively managing imaging needs of patient populations. Highlighting the impact of our interventions to reduce unnecessary imaging, we were able to negotiate with our local payers (Blue Cross/Blue Shield, Tuft's, Harvard Pilgrim) to avoid onerous payer pre-authorization programs for providers who used our radiology medical management program beginning 2005. The integration of an enterprise scheduling module into the workflow of the ordering provider's practice ensures that the imaging capacity created by the elimination of inappropriate testing as the result of CDS improves access for appropriate imaging services. The value delivered to the patient and the ordering physician through this convenient, web-enabled, integrated workflow also reduces leakage (i.e. reduces the number of imaging studies referred to radiology providers outside BWH, BWFH and DFCI). A series of peer reviewed publications highlight the impact of this initiative. For example, we have observed a 12% sustained reduction in ambulatory high cost imaging per 1000 member months for a commercial payer population (2005-2009)[3], a 21% reduction in use of CT per severity of disease adjusted inpatient admission (2009-2012)[4], a 33% reduction in use of CT per 1000 ED visits (2007-2012)[5] and a 5%[6]-7.5%[7] reduction is repeat CT scans. Results of our condition-specific interventions include a 12.3% reduction in use of MRI for ambulatory patients with low back pain[8], a 20% reduction in use of chest CT pulmonary angiography (CTPA) for suspected pulmonary embolism in the ED,[9] and a 12% reduction in use of CTPA for inpatients[10]. We have shown that CDS can be used to unambiguously measure, monitor and enhance provider adherence to evidence[11] and national quality measures[12]. We have described best practices for imaging CDS[13] and demonstrated that properly deployed, providers rarely enter erroneous clinical data to avoid onerous CDS interactions (to 'game the CDS system')[14]. We have also shown that the educational effect of CDS, even if based on high quality evidence, is unlikely to optimize practice or to reduce unwarranted variation among providers[12,15]. CDS-enabled consequences for ignoring high quality evidence embedded in CDS will likely be needed to enhance the educational effect of CDS[8,13]. In parallel, the leakage rate for high cost imaging at BWH has plummeted to <1%, compared to 13-25% leakage at other academic institutions, based on analysis of CMS claims data from the recently completed Medicare Imaging Demonstration. The pioneering work on imaging CDS at CEBI and BWH has helped influence public policy.

2. **Multi-Disciplinary PACS**

   Beginning in 2003 and in collaboration with EMC Corporation and General Electric, the CEBI team defined, designed and implemented the first multi-disciplinary picturing archiving and communication system (PACS) program to combine imaging from multiple –ologies (including radiology, cardiology, obstetrics and gynecology, intra-operative imaging, etc.) into a single PACS. Diagnostic image quality, web-enabled image distribution was integrated into the electronic health record (EHR) to enable access to all imaging data at the point of care. This initiative enabled elimination of x-ray film and associated costs including printers and re-organization of support staff employed in the radiology film library by the end of 2005.

3. **Communication of Critical Test Results**

   Optimizing closed loop communication of critical test results is a national patient safety goal. A four-year quality improvement initiative lead by the CEBI team beginning in 2006 demonstrated substantial improvements in closed loop communication of critical results. Several private foundation grants from CRICO-Risk Management Foundation as well as AHRQ, funded the design, implementation and evaluation of a public domain software application, Alert Notification of Critical Results (ANCR), to automate creation, notification, escalation, and audit of critical alerts[16,17]. Between 8% to 9% of radiology reports at BWH contain a critical result. Some 50,000 critical results are generated annually in radiology, cardiology, and pathology using ANCR and >98% are acknowledged by providers within the required parameters of the BWH policy for communication of critical results[18].

Future Goals

Imaging CDS will remain a major focus of our future work. We have helped design a new integration model between imaging CDS and EHRs and thus will maintain our existing imaging CDS program, integrated with Epic, for deployment in June 2015. We aim to expand our multi-disciplinary, multi-center collaborations in CDS, which currently include Weill-Cornell School of Medicine and Geisinger Health System, to create a broader learning consortium. Such collaborations will enhance our ability to define and refine best practices for CDS, accelerate the creation of needed evidence, and compete for federal and other sources of extramural funding.

We will expand our capabilities with ANCR and decision support for radiologists to ensure timely and appropriate follow up of evidence-based recommendations made by radiologists.

We will also refine, implement and measure the impact of a more formal Radiology Consult Service (RCS)[19,20] to assess the value of diagnostic radiologist's contribution to patient care beyond the traditional role of primary interpretation of imaging studies. In each workflow described below, the goal is to convey and document the professional opinion of the radiologist consultant in a formal consult note which will be stored in the EHR, similar to other clinical consultants. We will assess the

value of RCS on various aspects of patient care. The RCS program has several components, with some examples described in more detail below.

1. **Pre-imaging consultation**
    a. An RCS web-enabled portal is in pilot phase in several primary care practices to support the deployment of patient-centered medical home initiative at BWH. Using a smart-phone or a web browser, referring providers can request a consult from subspecialty trained faculty radiologist assigned to RCS each day. Early results are encouraging and highlight the need for ease of access to radiologist consultants to devise the most optimal workup for patients. Use of this tool is voluntary for our referring provider community.
    b. RCS consultation is required when providers deviate from evidence-based recommendations presented as part of CDS during order entry for targeted clinical scenarios. This workflow enables and enforces a 'peer-to-peer' consultation between providers to help reduce unnecessary use of imaging as part of our radiology medical management program. We have witnessed an increase in adherence to evidence and a significant and sustainable reduction in use of high cost imaging when 'peer-to-peer' consultation is implement to support CDS implementation[3,8].
    c. RCS at the time of planning high cost imaging studies (so called protocolling) before imaging is performed could substantially reduce unnecessary imaging or change the requested imaging workup in our preliminary studies. A radiologist centric view of the data in the EHR at the time of protocolling is critical in providing optimal clinical information for the radiology consultant.[21]

2. **Consultation during image acquisition**
    a. Targeted RCS during image acquisition may help tailor the imaging protocol to answer specific clinical questions, shorten image acquisition, reduce patient discomfort and unnecessary follow up imaging. Such interventions may be most optimally piloted for targeted diagnostic MRI procedures.

3. **Post-imaging consultation**
    a. Re-interpretations of imaging studies performed and reported elsewhere, may reduce unnecessary/repeat imaging[22].
    b. RCS as part of a multi-disciplinary disease-focused clinic may help devise the most optimum care management strategy with the radiologist consultant subspecialist an active

member of the consultation team[23]. Similar strategies maybe deployed in the ambulatory, ED or inpatient settings.

c. Patient-focused RCS. RCS clinics may be of substantial value to patients seeking an expert opinion on a variety of imaging related clinical issues. An example maybe RCS for patients with dense breasts identified at screening, particularly in light of 'dense breast' legislation that has become law in many states, including recently in Massachusetts.

We believe that RCS will become an indispensible tool in the era of population health and disease management, particularly if we can unambiguously demonstrate the value of diagnostic radiologist as a consultant, beyond the well-established role of primary interpretation of imaging procedures, in healthcare delivery.

Program Personnel

Faculty:

- Ramin Khorasani, MD, MPH. Associate Professor of Radiology.
  Dr. Khorasani is the first incumbent of the *Distinguished Chair of Medical Informatics* at BWH established in 2013, and CEBI's Director and founder. He also serves as Vice Chair for Quality, Safety, and IT in Radiology.
- Kathy Andriole, PhD. Associate Professor of Radiology.
  Dr. Andriole brings a wealth of experience in imaging informatics to CEBI. She leads CEBI's educational programs in imaging informatics.
- Ivan Ip, MD, MPH. Instructor in Radiology.
  Dr. Ip joined the CEBI faculty in July 2012 with a clinical appointment in primary care and general internal medicine at BWH. He is an internist with a focus on health policy, health services research, biostatistics and epidemiology. His expertise is in health IT, with special focus on CDS, natural language processing, and 'big data' are uniquely suited to the mission of CEBI.
- Ronilda Lacson, MD, PhD. Assistant Professor of Radiology.
  An internist, Dr. Lacson's major focus is in machine learning, natural language processing, ontologies, and IT tools for optimizing hand-offs, such as communication of critical results and transitions of care.
- Ali Raja, MD, MBA, MPH. Assistant Professor of Emergency Medicine and Radiology.
  Dr. Raja's major focus is use of health IT tools, specifically CDS, to improve quality, safety and efficiency in emergency medicine. He also serves as Vice Chair in Emergency Medicine at BWH.
- Louise Schneider, MD. Assistant Professor of Medicine.
  A practicing primary care physician, Dr. Schneider brings more than 15 years of experience in design and implementation of health IT solutions, specifically using CDS, to enable evidence-based

practice to improve quality and reduce waste. She also serves as the Medical Director of the Fish Center for Women's Health at BWH.

- Vlad Valtchinov, PhD. Instructor in Radiology.
  Dr. Valtchinov's major focus is in artificial intelligence, imaging and genomics informatics, and design and implementation of 'big data' strategies and analytics to accelerate evidence discovery and delivery at the point of care.

CEBI 2014 faculty, fellows, and staff

Active Projects

1. **Imaging CDS**

   Multiple prospective trials are currently underway to refine best practices for imaging CDS and optimize the use of imaging, including:

   - A randomized controlled trial to assess the synergistic impact of practice pattern variation reporting (in addition to CDS) on adherence to evidence.
   - Design and establishment of a public domain national/international repository of transparently scored (identifying the strength of each unique piece of evidence) library of health IT consumable evidence to accelerate the adoption and implementation of evidence-base imaging CDS in support of its broad national implementation in 2017 to enable providers to meet the requirements of the Protecting Access To Medicare Act of 2014 (Public Law No: 113-93),
   - Design and implementation of imaging CDS integrated with Epic (version 2014) for June 1, 2015 implementation at BWH. We will assess the impact on practice pre- and post-implementation.
   - Assess impact of Medicare Imaging Demonstration interventions.

2. **Communication and timely follow up of critical test results**
    - Assess impact of ANCR on patient safety.
    - Implement and assess impact of ANCR on timely and appropriate follow up of imaging recommendations.

3. **Radiology Consultation Services (RCS)**

    Design, implement and assess value of various RCS components on quality, safety, efficiency of care.

4. **Reduce unwarranted variation in radiology reports to improve the quality of radiology reporting**

    Develop and implement various quality improvement initiatives using technology tools such as structured reporting templates, targeted computer-aided diagnosis tools and decision support for radiologists. Reduce unwarranted variation in radiology reporting to improve quality of radiology reports.

5. **Reduce unwarranted variation in technical radiology protocols across BWH radiology network**

    Optimize radiation exposure in CT.

Collaborations and Cooperative Relationships

Selected highlights are described below

At Brigham and Women's Hospital:

- CEBI leads the radiology medical management program to reduce inappropriate use of imaging in collaboration with Brigham and Women's Physician Organization leadership (Mike Healey, MD, Associate Medical Director, and Jessica Dudley, MD, Medical Director).
- CEBI co-designed and implemented a meaningful use program for radiology in collaboration with Brigham and Women's Physician Organization leadership (Mike Healey, MD).
- CEBI designs, implements and assesses the impact of targeted interventions in improving quality, and reducing waste in emergency medicine in collaboration with emergency medicine leadership (Ali Raja, MD, Vice Chair; Jay Schuur, MD, Vice Chair; Ron Walls, MD, Chairman).
- CEBI evaluates national trends in care of patients with non-traumatic knee pain in collaboration with the Department of Orthopedic Surgery (Elizabeth Matzkin, MD) and primary care (Mike Healey, MD).

At Dana Farber Cancer Institute:

CEBI is working to assess the impact of QI initiatives including use of CDS on reducing unnecessary thoracic imaging in bone marrow transplant patients with fever/neutropenia in collaboration with Eric Jacobsen, MD, Clinical Director, Adult lymphoma program.

At Partners Healthcare System:

CEBI leads the effort to integrate the Alert Notification of Critical Results (ANCR) application with Patient Reported Outcome Measures (PROMs) so that ANCR can help optimize closed loop communication of critical values generated by PROMs (e.g., patient reported suicide risk) with the responsible care provider in collaboration with Neil Wagle, MD, MBA, Medical Director, Patient Reported Outcome Measurement.

At Harvard:

CEBI is working to assess geographic variations in use of imaging in the United States to identify potential targets for performance improvement initiatives in collaboration with Atul Gwande, MD, Director, Ariadne labs.

Beyond Harvard:

CEBI leads efforts to explore strategies for the capture of patient reported data to enhance existing data from the EHR to enable measurement, monitoring and performance improvement in Cancer, in collaboration with Joe Jacobsen, MD, Chief Quality Officer, and Jonathan Darer, MD, Chief Innovation Officer, Geisinger Health System, Danville, PA.CEBI is working to develop, implement and assess interventions to improve the appropriate use of imaging to promote evidence-based practice in collaboration with Keith Hentel, MD, Vice Chair, Radiology, Weill-Cornell School of Medicine, NY, NY; Jonathan Darer, MD, Chief Innovation Officer, Geisinger Health System, Danville, PA.

CEBI is exploring methods to optimize the communication of critical test results using ANCR in collaboration with Keith Hentel, MD, Vice Chair, Radiology, Weill-Cornell School of Medicine, New York, NY.

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Goals of the Program

Medical Imaging Information Technology (MIIT) division is responsible for i) leadership, implementation, training and support of all clinical imaging IT applications, ii) leadership, coordination and execution of quality and patient safety programs, change management, and performance improvement initiatives, and iii) dashboard and data analytics tools which enable continuous measurement and monitoring of key performance indicators to sustain gains, empower hospital and departmental leaders, managers, and individual providers, and motivate further improvements.

MIIT leadership and managers coordinate activities, participate and contribute to all relevant hospital and health system committees, functional teams and leadership structures. Wherever relevant, MIIT capabilities are extended beyond the radiology department to support related activities in other departments (e.g. multi-disciplinary PACS support for other –ologies such as non-invasive cardiology and cardiac catheterization laboratory, obstetrics and gynecology, anesthesia; critical test result communication for cardiology and pathology) or across the entire enterprise (e.g., computerized order entry, decision support and enterprise scheduling for radiology, cardiology, GI endoscopy, etc). In this fashion, MIIT is an important resource for performance improvement for the health system with diverse sources of funding. Co-located with the Center for Evidence-Based Imaging, MIIT clinical operational solutions also support innovations and translational research at BWH, BWFH and DFCI.

Program History

Under the leadership of Steven Seltzer, MD, Health Information technology (HIT) activities were initially centralized in 1998 to support multi-disciplinary PACS implementation with Ramin Khorasani, MD as director. Given synergies between IT and performance improvement, quality and safety initiatives, MIIT division was formed in 2006 to consolidate clinical IT, quality, safety, and change management programs.

Radiology Vice Chair for quality, safety and medical imaging, IT serves as Medical Director of MIIT (Ramin Khorasani, MD, MPH) with administrative leadership (Maria Damiano, RT, MBA) and reporting structures to both radiology and hospital leadership. Two radiology quality and patient safety officers (Anik Sahni, MD, Jennifer Siegelman, MD, MPH) spend 20% effort each at MIIT, reporting to the Medical Director. The support team has expanded from 6 FTEs in 2001 and now includes 31 FTEs (including professionals specializing in IT, quality improvement, process redesign, and project management).

Clinical Imaging IT Applications

A range of multi-vendor software applications is supported using an integration and interoperability platform. Select applications are described briefly.

System integration and interoperability is fundamental in enabling the execution of a multi-vendor, best of breed, medical imaging workflow. A workflow engineering team, led by Dick Hanson, uses an interoperability and integration platform (Intelligo, Medicalis Corporation, San Francisco, CA) to design, execute and maintain all needed integration. This in-house expertise, combining deep workflow knowledge and commercially available software, is a major factor in creating the desired imaging health IT workflow in our health system. More than 30 software applications are integrated using Intelligo with thousands of messages travelling through the infrastructure every hour. The imaging health IT architecture planning, design and implementation, including business continuance and disaster recovery, is led by Michael Clyne.

Computerized Provider Order Entry (CPOE): CPOE (Medicalis Corporation, San Francisco, CA) is integrated into the electronic health record. More than 700,000 imaging requests are entered each year in CPOE using structured iterative menus in all care settings (inpatient, outpatient, ED). Approximately half of all imaging requests are entered directly by licensed providers, with the remaining requests entered by non-licensed proxy staff (e.g. office staff). Orders entered by proxy staff generate an electronic notification to licensed providers requiring licensed providers to electronically sign orders from tethered or mobile devices before imaging can be performed. Compliance with hospital order signature policy by licensed providers before imaging is performed is nearly100%.

Clinical Decision Support (CDS):

CDS is integrated into CPOE. Evidence from diverse sources, including professional society guidelines, peer reviewed publications, or local best practices, are available in CDS (Medicalis Corporation, San Francisco, CA). CDS can be configured for each unique piece of evidence to target improvements by institution, care setting, provider specialty, practice, or individual providers. CDS is the core IT tool for the radiology management program described below.

Enterprise Scheduling:

Web-enabled and integrated into CPOE, enterprise scheduling module (Medicalis Corporation, San Francisco, CA) enables on-line bookings in providers' offices without the need to contact radiology central scheduling. Ease of scheduling has been a major factor in reducing leakage at BWH for high cost imaging (estimated to be < 1-2% based on claims data for Medicare patients analyzed as part of the Medicare Imaging Demonstration).

Protocolling, Patient Tracking, Radiologist-technologist Communication, Technologist Workflow, Requisition Viewer:

Web-enabled modules (Medicalis Corporation, San Francisco, CA) enable automation using tethered or mobile devices. Workflows previously managed through traditional Radiology Information Systems (RIS), are now features of web-enabled workflow modules to complement gaps in electronic health records,

rendering RIS solutions obsolete, complementing PACS capabilities, and helping optimize workflow in radiology to improve efficiency, quality and patient safety.

Picture Archiving and Communication System (PACS):

A single integrated PACS supports clinical services at BWH, BWFH and DFCI. The core PACS (Centricity v 4.0.3, GE, Chicago, IL) also serves as the enterprise archive for imaging studies at BWH, BWFH and DFCI (including radiology, cardiology, Ob-Gyn, intra operative imaging, etc). The system architecture allows for robust business continuance and disaster recovery. More than 450 TB of usable 'long term' storage (ATMOS, EMC Corporation, Hopkinton, MA) is replicated at 2 distinct locations with near real time access (typically within 30 seconds for all stored imaging dating back to 1998). Ninety TB of short term storage (CLARiiON, EMC Corporation, Hopkinton, MA) enables immediate access to 18 months of imaging data. More than 7.5 million imaging studies are stored in PACS, growing in excess of 5 TB (after lossless compression) monthly. More than 250 PACS workstations, including more than 130 Radiology Clinical Workstations, host the PACS application to enable paperless workflow. 'Mini-PACS' implementations in ultrasound (Syngodynamics, Siemens Corporation, Malvern, PA) and Nuclear Medicine (Hermes Corporation, Stockholm, Sweden) complement the core PACS for enhanced visualization tools.

Enterprise Image Distribution and Viewing:

Centricity Web-enabled and tablet applications, integrated into the electronic health record, enable more than 400 concurrent users to access diagnostic quality imaging data anytime, anywhere. Each month, 4,000-5,000 unique users view some 200,000 imaging studies on 25,000 - 30,000 unique patients on-line (not including images viewed on PACS workstations). Film production at BWH was stopped in 2006.

Advanced Visualization Tools:

The advanced post processing initiative (APPI) enabled integration of multiple visualization tools in Centricity with payment to vendors dependent on frequency of use of advanced visualization tools. We have integrated multiple visualization tools from various vendors into PACS to enable near seamless workflow. These tools allow enhanced visualization and image analysis by radiologists at the Radiologist Clinical Workstation (RCW) and include tools to aid in the interpretation of complex cardiac studies, virtual colonoscopy, multi-parametric MRI of the prostate, breast MRI, breast tomography studies, and multi-planar reconstructions, among others.

iConsult:

Internally developed application provides a radiologist-centric abstract of the electronic medical record in the context of imaging viewed in PACS at the Radiologist Clinical Workstation without the need for multiple logins. iConsult also prompts radiologists and support to enter or capture needed information to aid radiologist in becoming meaningful users of health IT.

Alert Notification of Critical Results (ANCR):

ANCR development was funded by multiple CRICO-Risk Management Foundation grants from 2010-2014 and was internally developed to improve patient safety. ANCR is integrated into radiologist and referring provider workflow to automate alert generation, notification, acknowledgement, escalation, monitoring, and auditing to enhance timely closed loop communication of critical results.

Report Generation:

Speech recognition software (Powerscribe 360 v 2.0, Nuance, Burlington, MA) is integrated in radiologist workflow and is accessible through all Radiology Clinical Workstations. Two structured reporting applications, developed internally, serve report generation needs in ultrasound and non-invasive cardiac imaging. We no longer provide transcriptionist services. An internally developed paging portal notifies attending radiologists (if radiologists report signature performance does not meet departmental requirements) when preliminary reports generated by trainees are available for final signature.

Electronic Teaching File:

RSNA Teaching File solution has been integrated into the Radiologist Clinical Workstation (enhanced PACS workflow) using internally developed integration layer.

Peer Review:

Internally developed software is integrated into the Radiology Clinical Workstation and enables ad-hoc peer review process for each clinical section as well as randomly selected peer review workflow and reporting to meet ACR accreditation requirements.

Referring Physician Portal:

For referring providers who are not part of our health system, a web-enabled software module (Medicalis Corporation, San Francisco, CA) enables secure, HIPAA compliant solution to order, schedule imaging studies, and review resulting reports and images on-line.

Automated Coding:

An automated coding application (OptumInsight, Inc., Eden Prairie, MN) is integrated into the billing workflow and enhances consistency of coding and coder productivity for CPT and ICD-9 coding for technical and professional billing.

Tele-radiology:

A suite of software applications provides integrated workflow including remote site order entry, order and image transmission to the tele-radiology core where radiologists use a single worklist to view and report imaging studies from tele-radiology clients. Reports are then distributed electronically to remote practices.

Image Importing:

CD-importing capabilities (Life-Image, Newton, MA) enable imaging to be imported to Centricity PACS for viewing by all providers. Importing is distributed outside radiology department as well as provided within the radiology image service center.

Quality, Patient Safety and Performance Improvement

A broad range of quality, patient safety, and performance improvement programs are in place. Below is a brief summary of select initiatives. Key Performance Indicators (KPIs) available on the quality dashboard and analytics are measured, monitored by relevant stakeholders, and help drive performance improvement initiatives.

Radiology Medical Management Program:

The program is led by an executive committee including Ramin Khorasani, MD, MPH (co-chair; Vice Chair Radiology), Mike Healy, MD (co-chair; Associate Medical Director, Brigham and Women's Physician Organization [BWPO]), Louise Schneider, MD (Primary Care) and Ali Raja, MD, MPH, MBA (Vice Chair Emergency Medicine), and with participation of members from all specialties. The goal of the program is to enable evidence-based practice, reduce inappropriate use of imaging, improve quality, and reduce waste. This physician-led, CDS-enabled program has resulted in profound changes in our practice: substantial reductions in intensity of imaging per patient as well as in disease-focused interventions, well beyond the national trends in imaging utilizations. These results are broadly published in peer-reviewed literature and summarized in the section on the Center for Evidence-Based Imaging. Because of this program and in agreement with select payers, BWPO providers bypass intrusive payer-based pre-authorization programs for the three large local payers (BC/BS, Tufts, and Harvard Pilgrim) that account for nearly half of all high cost imaging in our practice.

Access:

By integrating enterprise scheduling into CPOE/CDS, we provide on-line access for scheduling radiology. Thus, cancellation of an inappropriate imaging request in response to the radiology medical management program improves access for appropriate imaging for all referring providers without the need to call a central scheduling office. Outpatient high cost imaging leakage (BWH providers referring patients to non-BWH imaging providers) is remarkably low (<2-3%) compared to a 15-30% range typical of academic

medical centers (based on Medicare data analysis captured as part of Medicare Imaging Demonstration). Such minimal leakage rates not only improve health system financial performance, but more importantly, ensure that our referring providers and patients are exposed to current state of evidence embedded in CDS. In addition to leakage, we monitor outpatient appointment access with time to third available appointment. Current performance is in the one to two day range for MRI, and same day access for CT. Emergency departmental and inpatient MRI access 80th percentile targets are five and 24 hours, respectively from order placement to exam complete.

Timeliness of Diagnostic Reporting:

A Performance Improvement Incentive Program (PIIP) was designed in conjunction with 'pay for quality' health systems payer contracts. Each radiologist can qualify for semi-annual performance based variable compensation by meeting a monthly 80th percentile signature time of less than six hours and by meeting sectional daily unread exam measure (<4%). These incentives focused on ensuring timely interpretation and reporting of all diagnostic procedures irrespective of care setting (above measure apply to inpatients, outpatients, and ED patients equally). Current 80th percentile department-wide performance (all patients; 7x24x365) is one and a half hours for signature time and 12 hours from exam completion (time when image acquisition is complete) to final report.

Closed Loop Communication of Critical Test Results:

Overall, 8-9% of all radiology reports contain a critical result based on our health system policy. Of the more than 40,000 alerts generated each year, >98% are acknowledged within the requirements of our institutional policy. Of all alerts, 1% represent level 1 or red alerts (potentially life threatening), 31% are level 2 or orange alerts (could harm the patient within a few days), and 68% are level 3 or yellow alerts (could harm patient in months or years).

Reducing Unnecessary Radiation Exposure:

We have undertaken multiple interventions focused on CT initially, including: (i) Pre-imaging interventions include use of CDS-enabled radiology medical management program (data available in multiple peer-reviewed publications) to reduce unnecessary use of CT. For example, we have reduced use of chest CT in the evaluation of pulmonary embolism by 20% in the ED and by 12% for inpatients, and seen a 12% reduction in use of head CT in the evaluation of minor head trauma in the ED. We have also reduced redundant use of CT by 7.5% (imaging same body part within 90 days); (ii) Interventions 'during' imaging include optimizing imaging protocols and reducing scanner to scanner variation in imaging protocols; and (iii) Post-imaging interventions including extraction of radiation exposure data from the DICOM-header. We have also created an analytics tool and a process to use exposure event 'outlier' analysis to identify targets (imaging protocols and/or unique scanners) for improvements. This work is the led by one of our

radiology quality and patient safety officers in concert with medical director of CT and organ system-based section heads.

Improve Quality of Radiology Reports:

Improving timeliness of radiology reporting and efforts to optimize communication of critical results have already been described. Several additional improvement initiatives led by one of our radiology quality and patient safety officers are underway. We took the opportunity during a recent upgrade to our speech recognition application upgrade to review more than 11,000 structured report templates that had accumulated in our previous version of the speech recognition application. The review process resulted in selection of 641 department-wide templates which were then migrated to the new version of the application. We will continue twice-yearly review of templates to ensure the documents meet our departmental reporting requirements. We have also begun design and implementation of decision support tools for radiologists to reduce unwarranted variation in follow up recommendations and to improve the quality of interpretation.

Meaningful Use (MU):

Working collaboratively with BWH MU team, an internally developed application (iConsult) was created and embedded in the Radiologist Clinical Workstation to extract clinical information necessary for meeting MU requirements in order to identify patients with missing data for MU. Processes were then created to capture the needed data using forms at radiology front desks with later entry of data into the certified EHR by MU trained non-MD staff. Radiologists have been trained to enter relevant clinical information if needed (such as problem lists or allergy information) into EHR to help meet MU goals. More than 95% of all eligible BWPO radiologists were certified as meaningful users for stage 1 and qualified for the incentive payments from CMS. We have modified our program so that similar portion of radiologists should be able to qualify for stage 2 MU, which we expect to complete and report to CMS in the fall of 2014.

Contrast Agent Safety:

Led by Srini Mukundan, MD, PhD, the contrast agent safety committee oversees all aspects of contrast administration at BWH, with a description of activities elsewhere in this document.

Peer Review:

Internally developed software integrated into the Radiologist Clinical Workstation enables both random and ad-hoc quality assurance programs. Random peer review (a requirement for ACR accreditation) results are not unexpected. Of the more than 4000 reports peer reviewed last quarter, 99% were scored as 1 (agree with original interpretation) or 2 (minimal disagreement not clinically relevant). Twenty five of 4000 reports were scored as 3 (disagreement likely to be clinically significant) and 9 reports were scored as 4 (clinically

significant disagreements). The same infrastructure is used to submit ad-hoc peer review cases in each section to promote systems learning and future error prevention.

Performance Measurement:

Dashboard and Analytics Key Performance Indicators (KPIs) are continuously defined, measured, monitored, and shared with relevant stakeholders to sustain gains, empower hospital and departmental leaders, managers, and individual providers, and motivate further improvements. A very small subset are presented in the hospital's balanced Score Card dashboard, including financial performance, closed loop communication, and high cost imaging capacity utilization. The Radiology departmental quality dashboard displays more than 100 metrics in quality, safety, efficiency, financial performance, education (e.g. portion of case volume interpreted with a trainee), and research (e.g. radiologist's academic productivity). Each quarter, select KPIs are the focus of presentation in the dashboard. The balance score card and the quality dashboard are presentation tools (users do not have the ability to drill down and create new targeted reports to analyse data further). Analytics tools enable a more robust analysis and drill down of target data to help identify performance gaps, to motivate and support further improvements. More than 15 imaging performance analytics or IPAs have already been created to address specific analytic needs of leaders, managers, and performance improvement teams.

Data transactions from all clinical operational IT systems are extracted continuously and stored in a radiology data warehouse that is then used to create various performance measures to populate quality dashboard or IPAs. The performance measurement team is led by Matt Raffol and Dick Hanson and relies on the expertise and contribution of six to eight people with various responsibilities in MIIT.

Future Plans

The planned implementation of Epic on May 30, 2015 at Brigham and Women's Hospital, Brigham and Women's Faulkner Hospital, and Dana Farber Cancer Institute has created resource challenges for the MIIT team, delaying other important previously planned initiatives. With extensive support and leadership from Drs Betsy Nabel (CEO, Brigham and Women's Hospital), Steven Seltzer, and the clinical and administrative leadership of the Brigham and Women's Hospital, all the imaging health IT innovations currently in use will be maintained and, in fact, enhanced by integration into Epic for the go-live on May 30, 2015. MIIT resources have been working in concert with the Partners eCare team, Epic, and Medicalis to create the most sophisticated user experience possible. Indeed, we are now in the test phase of the integration, and all design concepts have been successfully implemented. Thus, in addition to workflow innovations within the radiology department, the CDS-enabled radiology medical management program and enterprise scheduling modules will be available through Epic for all of our users. This progress is critical for meeting the requirements for imaging CDS on January 1, 2017 (as part of Protecting Access to Medicare Act of 2014) while maintaining the full fidelity of our physician-led, CDS-enabled radiology medical management program to improve quality and reduce waste.