Published in final edited form as:

Am J Med. 2012 February ; 125(2): 155–161. doi:10.1016/j.amjmed.2011.03.031.

Repeat Abdominal Imaging Examinations in a Tertiary Care Hospital

Ivan K. Ip, MD, MPH^{a,b}, Koenraad J. Morteale, MD^{a,c}, Luciano M. Prevedello, MD^a, and Ramin Khorasani, MD, MPH^{a,c}

^aCenter for Evidence-Based Imaging, Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, Mass

^bDepartment of Internal Medicine, Dartmouth-Hitchcock Medical Center, Dartmouth Medical School, Lebanon, NH

^cDivision of Abdominal Imaging and Intervention, Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, Mass

Abstract

BACKGROUND—Reducing unnecessary repeat imaging may reduce waste and costs, and improve health care quality. We aimed to quantify repeat imaging rates in patients with abdominal imaging examinations, and identify factors associated with repeat imaging.

METHODS—We retrospectively analyzed all diagnostic abdominal computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), fluoroscopy, and radiograph reports performed at our institution between January 1, 2000 and December 31, 2009. Primary outcome measure was the rate of repeat abdominal imaging (RAI) examinations, defined as any imaging examination of the abdomen on the same patient within 0–90 days of the first (enrollment) examination. We used natural language processing tools to extract recommendations for follow-up imaging from radiology reports. Univariate and multivariate logistic regressions were fitted to determine the effect of patient age, sex, study modality, care setting, follow-up recommendations, and history of neoplasm on the primary outcome over time.

RESULTS—Over 10 years, 245,184 abdominal imaging examinations were performed (43.2% CT, 20.6% US, 16.6% radiograph, 13.9% fluoroscopy, 5.7% MRI). The RAI rate remained unchanged (41.2% to 41.7%); unadjusted RAI volume increased from 6596 to 12,218 ($P < .01$). Most repeat studies (88.2%) were not preceded by a radiologist's recommendation. Practice setting, study modality, patient age, sex, underlying health condition, and radiologist's recommendations were associated with higher rate of repeat abdominal imaging examinations.

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Requests for reprints should be addressed to Ivan K. Ip, MD, MPH, Department of Radiology, Brigham and Women's Hospital, 20 Kent Street, 2nd floor, Boston, MA 02120. iip@partners.org.

Conflict of Interest: None.

Authorship: All authors had access to the data and a role in writing the manuscript.

CONCLUSIONS—A large proportion of abdominal imaging examinations result in a repeat study. Many factors contribute to repeat imaging, including patient age, sex, underlying disease, initial study modality, practice setting, and radiologist's recommendation.

Keywords

Health policy; Imaging utilization; Repeat imaging

The use of high-cost imaging has expanded substantially over the past decade.^{1–3} While greatly contributing to patient care, the increased use of imaging also has resulted in a growth of follow-up imaging examinations. At one institution, 31% of all high-cost imaging studies performed were follow-up studies of the same modality and same body part, completed within the previous 7 months.⁴ Similarly, You et al⁵ reported redundant imaging rates of 6.7% within 30 days and 9.5% within 60 days. These rates of repeat imaging pose concerns about resource utilization and expose patients to potentially unnecessary radiation and theoretical cancer risks.⁶ Reducing rates of repeat testing has attracted attention from health care policymakers as a way to improve quality of care and reduce waste and costs. Jha et al⁷ estimated that redundant laboratory studies amounted to 8.2% of all inpatient hospital costs in 2004, with redundant radiology tests accounting for \$3.2 billion. However, relatively little information exists on the frequency and pattern of follow-up imaging across imaging modalities. Therefore, we undertook this study to quantify repeat imaging rates in patients with abdominal imaging examinations, and identify factors associated with repeat imaging. We focused on abdominal imaging examinations due to the variety of imaging modalities and organ systems involved when evaluating the abdomen. Pelvic examinations were excluded.

METHODS

Study Site and Population

Our facility consists of a 777-bed university-affiliated tertiary care hospital with 44,000 inpatient admissions, 950,000 ambulatory visits, and 54,000 adult emergency department (ED) visits accounting for nearly 500,000 imaging studies annually in 2009. Institutional review board approval was obtained for this Health Insurance Portability and Accountability Act-compliant study and patient informed consent requirements were waived. The study population included all patients aged 16 years or older who underwent any diagnostic imaging examination of the abdomen between January 1, 2000 and December 31, 2009 at our institution. Pelvic examinations that did not involve the abdomen were excluded. Patients who were employees of our health care delivery network were excluded for privacy purposes.

Outcome Measures

Our primary outcome measure for each unique abdominal examination was whether or not a repeat abdominal imaging (RAI) examination was performed. We defined RAI as an imaging examination of the abdomen, performed on the same patient within 0–90 days after the initial or enrollment examination, irrespective of radiologic modality. This time period was selected to represent a broad window of time where a repeat examination could be

potentially considered relevant to the same episode of care and was based on informal consensus opinion of a multi-disciplinary group of local experts. For examinations with multiple repeat studies within 90 days of the enrollment examination, only the examination with the shortest elapsed time from the enrollment examination was counted as a repeat study for that particular enrollment examination. While we counted only the first RAI study for a particular enrollment examination, each patient may have multiple enrollment examinations. For example, if a patient underwent an ultrasound on January 1, a magnetic resonance imaging (MRI) scan on February 1, and a computed tomography (CT) scan on March 1, the MRI would be counted as a repeat examination for the enrollment study of ultrasound. In addition, the MRI also served as an enrollment study for the CT, so that the CT was counted as a repeat imaging examination because it was performed within 90 days of the MRI. A detailed example of the counting method is shown in Table 1. Secondary measures included elapsed time between enrollment and repeat examinations, as well as the number of repeat examinations performed within 90 days.

Data Collection

We queried the institution's radiology information system (IDXRad version 9; GE Healthcare, Burlington, Vt) for all diagnostic CT, MRI, ultrasound (US), fluoroscopy, and radiographs of the abdomen performed from January 1, 2000 to December 31, 2009. We tabulated examinations using their unique examination identification number (accession number) and excluded accession numbers without associated images (such as room or contrast charges). We collected several variables for each performed examination, including patient's sex, age, examination modality, date of study, and practice setting (inpatient, outpatient, ED). An additional clinical variable, the patient's recent history of neoplasm at the time each examination was performed, was obtained from the hospital billing system using International Classification of Diseases version 9 codes for neoplasm (140 to 239). Neoplasm diagnoses billed within the previous 6 months of an imaging examination were considered to be recent.

Natural Language Processing Algorithm Development and Validation

We determined whether further imaging studies were recommended by the reporting radiologist in the enrollment examination report. A natural language processing tool was developed using each digital radiology report as the input. We initially analyzed 2500 sample radiology reports containing follow-up recommendations in order to examine the commonly used phrasing patterns. A pipeline was built using General Architecture for Text Engineering⁸ as the development platform. The use of General Architecture for Text Engineering in the biomedical arena has been studied previously, with promising results.⁹ The automated application was designed to categorize each report into 1 of 3 groups on the basis of follow-up imaging recommendations: absent, present, and equivocal. Equivocal imaging recommendation was defined as advice containing phrases that may be interpreted as doubtful or ambiguous (eg, "if clinically indicated, CT may be obtained for further evaluation"). The specific recommended modality (eg, CT) was extracted when available. Nonimaging recommendations (eg, surgery, biopsy, or clinical correlation) were excluded. To validate the recommendation detection algorithm, 1000 de-identified radiology reports of diagnostic procedures performed between January 1 and January 15, 2010 were randomly

obtained using the RAND function (Microsoft Excel, Redmond, Wash). Each report was manually categorized on the basis of follow-up imaging recommendations. Findings from the automated algorithm were then compared with the manual standard.

Statistical Analysis

We descriptively analyzed the patients' demographics and the outcome measures. To validate the automated recommendation detection algorithm, the total numbers of true-positive, true-negative, false-positive, and false-negative were determined and accuracy, sensitivity, and specificity calculated. Confidence intervals were estimated using the adjusted Wald method. To examine the effect of our 7 predictors (age, sex, examination modality, date of study, practice setting, recent history of neoplasm, and radiologist's follow-up recommendation in the enrollment examination report) on RAI studies, starting with univariate analyses, we used chi-squared and *t* test methods to assess differences in likelihood of RAI. We then estimated a logistic regression model in which the dependent variable was whether or not a repeat imaging study was performed. Covariates were coded as either continuous (time in months) or categorical variables: patient age (< 20 years, 21–30 years, 31–40 years, 41–50 years, 51–60 years, 61–70 years, 71–80 years, >80 years), patient sex (male, female), practice setting (inpatient, ED, outpatient), study modality (CT, MRI, fluoroscopy, US, radiograph), recent history of neoplasm (present, absent), and radiologist recommendation (absent, present, equivocal). Statistical analyses were performed using JMP 8 (SAS Institute, Cary, NC). A 2-tailed *P*-value of <.05 was defined as statistically significant.

RESULTS

Descriptive Statistics

Between January 2000 and December 2009, 245,184 eligible abdominal imaging examinations were performed (43.2% CT, 20.6% US, 16.6% radiographs, 13.9% fluoroscopy, 5.7% MRI). Figure 1 shows the distribution of imaging modalities over time. More than two fifths (41.6%) of examinations had an RAI performed within 90 days (Figure 2). The number of RAIs increased during the 10 years, with the unadjusted volume increasing from 6596 to 12,218, although no change in the relative frequency of repeat examinations was observed (41.2% in 2000 to 41.7% in 2009; slope 0.007% per year; *P* = .87). Among those studies with repeat imaging, the mean elapsed time between enrollment examination and RAI examination was 15.4 days (95% confidence interval [CI], 15.2–15.5 days, range 0–90 days, median 4 days) and the mean number of RAI examinations was 2.8 (95% CI, 2.78–2.82, range 1–41, median 2). Sixty percent of RAI examinations (61,145 of 101,901) were performed with the same imaging modality as the enrollment examination. The rates of RAI varied significantly across care settings (*P* <.0001). Inpatient units and the ED had the highest rates of RAI (60.7% and 40.9%, respectively), with 26.2% RAI for outpatients (Table 2).

Natural Language Processing Validation

The automated detection of the presence/absence of follow-up imaging recommendations had a sensitivity of 94.5% (95% CI, 90.3%–97.0%), specificity of 99.3% (95% CI, 98.3%–99.7%), and accuracy of 98.3% (95% CI, 97.3%–99.0%).

Among reports that contained further imaging recommendations, the classification of equivocality had a sensitivity of 89.7% (95% CI, 75.9%–96.5%), specificity of 98.1% (95% CI, 94.4%–99.6%), and accuracy of 96.5% (95% CI, 92.8%–98.4%).

Radiologist's Recommendations

Approximately 14.2% (34,751/245,184) of diagnostic abdominal reports contained a recommendation (including 4.8% equivocal ones) for additional abdominal imaging studies, ranging from 11.8% in 2000 to 14.4% in 2009 (slope = 0.096% per year; $P = .389$). The rate of follow-up recommendations in the enrollment examination reports differed significantly across care settings, ranging from 16.3% in the outpatient to 13.9% in the ED to 11.6% in the inpatient services ($P < .0001$). Only 28,860 (11.8%) of abdominal examinations performed were preceded by a recommendation.

Regression Analysis

Univariate analysis (Table 2) reveals that imaging modality ($P < .001$), patient sex ($P < .001$), practice setting ($P < .001$), patient's age ($P < .001$), and history of cancer ($P < .001$) were associated with the outcome of RAI.

The logistic regression converged without any errors. The R^2 was 0.10 and P -value was $< .01$. Table 3 demonstrates results after adjusting for confounders. Examinations performed on older patients had a higher repeat rate than patients < 20 years old. Radiograph examinations had the highest rates of RAI examinations (odds ratio = 2.50), followed by US (odds ratio = 1.35). Studies performed in the inpatient and ED settings were more likely to result in repeat imaging (odds ratios 3.51 and 2.13, respectively). Patients with recent history of neoplasm were 46% more likely to have RAI examination than patients without cancer.

After adjusting for confounders, considerable differences remained in RAI rates, depending on whether a follow-up recommendation was made by the radiologist when interpreting the enrollment examination. Studies that contained further imaging recommendation by radiologists were 24% more likely to be followed-up than those that did not contain any recommendation ($P < .001$).

DISCUSSION

In 1986, Mold and Stein¹⁰ described the too-common “cascade effect” in the clinical care of patients, where an initiating abnormal test result may trigger a chain of diagnostic events. Repeat imaging studies, sometimes, represent part of this cascade. In our study, we found that RAI was common practice, occurring in approximately 40% of all abdominal studies, with significant variation across care setting, usually with the same imaging modality. This repeat rate remained unchanged over a decade, with a mean number of 2.8 RAI studies per patient.

Our 41% RAI rate is within the wide range of prevalence previously reported. Lee et al⁴ reported a 31% overall repeat testing, and You et al⁵ reported redundant imaging rates of 6.7%–9.5%. The large prevalence range observed may be due to several factors. First, there are variations in how authors define repeat imaging. We considered repeat testing to include any imaging modality, whereas Lee et al⁴ focused on same modality repeats. Our study also defined repeat imaging as studies performed within 3 months, whereas others have used different cutoffs. Hence, You et al⁵ reported much smaller repeat rates in 7, 30, and 60 days. In addition, the You study was performed in a Canadian setting, with marked differences in the health care delivery model, style of practice, and access to high-cost imaging modalities compared with the setting for our study.¹¹

Our study identified several factors associated with increased rate of RAI, including practice setting, enrollment study modality, patient age, sex, and underlying health conditions, as well as radiologist's recommendations. Not surprisingly, studies performed in the inpatient and ED settings were more likely to result in repeat imaging, due to both the acuity of patient's conditions and the availability of imaging studies. Patients who obtained a radiograph or ultrasound initially were more likely to undergo follow-up studies, often a CT or MRI. While the choice of initial study modality often varies with institutional differences, the high frequency of follow-up CT or MRI observed in our study may indicate that in certain clinical situations, bypassing a radiograph or ultrasound in lieu of a CT or MRI as an initial study may be a reasonable management strategy to avoid repeat testing and potential delays in diagnosis. As oncologists often use imaging studies to follow patients for possible recurrence or re-staging following treatment, patients with history of cancer were significantly more likely to undergo repeat imaging. Our findings also showed that male patients were more likely than females to have repeat studies. Although the exact explanation of this observation is unclear, sex-biased decisions for further testing have been previously reported.¹² Patient's age also was found to be a significant factor for repeat imaging; older patients were more likely to undergo follow-up studies. This also is likely secondary to multiple factors, including patients' comorbid conditions, higher incidence of incidental findings with age,^{13,14} and ordering physician's higher clinical suspicion for disease for older patients.

In our 10-year study, 14.1% of abdominal imaging reports contained a radiologist's follow-up recommendation. We found that follow-up recommendations by radiologists were associated with only a small but statistically significant increased likelihood of RAI. Most (88.2%) repeat studies occur in the absence of radiologist follow-up recommendation. Other patient-specific factors, including age and underlying disease processes, are associated with a higher likelihood for repeat imaging.

Our study has several limitations. First, it was performed at a single academic medical center and, therefore, the generalizability of our findings to other settings is unclear. Tertiary teaching hospitals often care for patients with higher acuity who require more frequent surveillance of their disease. Second, in order to extract a radiologist's recommendation from the digital report, we developed an automated algorithm to categorize each report on the basis of recommendation. While we believe this is a valid algorithm, as demonstrated in a small sample, we could be under- or overestimating the recommendation frequency by a

small percentage. Third, because this is a retrospective study, we could not account for telephone or “curbside” recommendations made by the radiologists (either the reporting radiologist or a radiologist providing a second opinion on the same examination) to ordering clinicians, which would result in underestimation of rates of follow-up recommendation. Also, we may be underestimating repeat testing as we were unable to capture examinations performed at other institutions. Furthermore, our study is limited by our reliance on data available to us, which provide an incomplete picture of factors that may influence a clinician’s decision to pursue additional imaging, including patient’s severity of disease and indication for the study. The association we observed between radiologists’ follow-up recommendation and repeat testing does not prove causation. The imaging findings alone may have required repeat testing with or without the radiologist’s explicit recommendation. Finally, it is beyond the scope of this study to evaluate the clinical “appropriateness” of repeat testing or of the radiologist’s recommendation for further imaging.

In conclusion, the high repeat rates of abdominal imaging examinations in our institution, nearly 40%, remain unchanged over a decade. Many factors contribute to repeat imaging, including patient’s age, sex, underlying disease, and initial study modality, as well as practice setting and radiologist’s recommendation. The great majority of RAI occurs in the absence of radiologists’ follow-up recommendations. Given the frequency and volume of repeat testing and its potential impact on quality of care and costs, future studies should evaluate strategies to improve the appropriateness of repeat testing and follow-up imaging recommendations.

Acknowledgments

Funding: This study was funded in part by Grant 1UC4EB012952-01 from the National Institute of Biomedical Imaging and Bioengineering.

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CLINICAL SIGNIFICANCE

- The volume of repeat abdominal imaging examinations has grown by 85% over a decade.
- Practice setting, study modality, patient's age, sex, underlying health condition, and radiologist's recommendations are associated with an increased rate of repeat imaging.
- Most imaging examinations (88.2%) are performed without a radiologist's recommendation; such recommendations occur in 14% of cases and are associated with a small but significant increase in repeat testing.

Figure 1.

Trend of abdominal imaging studies by modality. CT = computed tomography; Fluoro = fluoroscopy; MRI = magnetic resonance imaging; US = ultrasound.

Figure 2.
Frequency of abdominal imaging examinations with repeat imaging.

Table 1

Example of Enrollment Examination and Repeat Abdominal Imaging Counting for Patient X

Abdominal Study Performed	Date Performed	Counting
Ultrasound	1/2/2009	–Examination #1 for patient X
Radiograph	2/4/2009	–Examination #2 for patient X –Repeat abdominal imaging study for examination #1
Ultrasound	5/20/2009	–Examination #3 for patient X
CT	10/10/2009	–Examination #4 for patient X
MRI	12/31/2009	–Examination #5 for patient X –Repeat abdominal imaging study for examination #4

CT = computed tomography; MRI = magnetic resonance imaging.

Table 2

Summary of Observations Stratified by Outcome and Results from Univariate Regression Analysis

Variable	Number of Observations (%)		Univariate Regression	
	Examinations with Repeat Imaging	Examinations without Repeat Imaging	Chi-Squared	P-Value
Time (by years)			1.13	.288
2000	6596 (41.2%)	9400 (58.8%)		
2001	7232 (41.4%)	10,254 (58.6%)		
2002	8204 (41.5%)	11,542 (58.5%)		
2003	9823 (42.4%)	13,334 (57.6%)		
2004	10,106 (41.6%)	14,208 (58.4%)		
2005	10,903 (41.2%)	15,559 (58.8%)		
2006	11,432 (41.6%)	16,057 (58.4%)		
2007	12,292 (41.8%)	17,110 (58.2%)		
2008	13,095 (41.1%)	18,735 (58.9%)		
2009	12,218 (41.7%)	17,084 (58.3%)		
Recommendation on enrollment study			0.47	.792
With recommendations	14,406 (41.5%)	20,345 (58.5%)		
Without recommendations	87,495 (41.6%)	122,938 (58.4%)		
Practice setting			24,453.74	<.001*
Inpatient	55,092 (60.7%)	35,716 (39.3%)		
Outpatient	29,161 (26.2%)	82,101 (73.8%)		
Emergency	17,648 (40.9%)	25,466 (59.1%)		
Patient sex			953.56	<.001*
Female	47,925 (38.5%)	76,452 (61.5%)		
Male	53,976 (44.7%)	66,831 (55.3%)		
Enrollment study modality			13,375.99	<.001*
CT	36,443 (34.4%)	69,441 (65.6%)		
MRI	4444 (31.8%)	9567 (68.2%)		
Fluoroscopy	13,510 (39.6%)	20,620 (60.4%)		
US	20,371 (40.4%)	30,056 (59.6%)		
Radiograph	27,122 (66.6%)	13,599 (33.4%)		
Patient's age group			1811.72	<.001*
<21 years	1132 (31.0%)	2518 (69.0%)		
21–30 years	7583 (33.4%)	15,098 (66.6%)		
31–40 years	11,814 (37.0%)	20,138 (63.0%)		
41–50 years	15,636 (39.5%)	23,913 (60.5%)		
51–60 years	20,780 (42.7%)	27,837 (57.3%)		
61–70 years	20,708 (45.0%)	25,337 (55.0%)		
71–80 years	16,639 (46.3%)	19,287 (53.7%)		
>80 years	7609 (43.4%)	9155 (54.6%)		
Recent history of neoplasm			2072.27	<.001*

Variable	Number of Observations (%)		Univariate Regression	
	Examinations with Repeat Imaging	Examinations without Repeat Imaging	Chi-Squared	P-Value
Absent	53,474 (37.7%)	88,388 (62.3%)		
Present	48,427 (46.9%)	54,895 (53.1%)		

CT = computed tomography; MRI = magnetic resonance imaging; US = ultrasound.

* Denotes statistical significance.

Table 3

Predictors of Repeat Abdominal Imaging Studies within 90 Days, from Multivariate Regression Analysis

Variable	Odds Ratio	P-Value
Time (by year)	1.03 per 10 years	.066
Recommendation on enrollment study (reference = none)		
Certain	1.24	<.001*
Equivocal	1.21	<.001*
Practice setting (reference = outpatient)		
Inpatient	3.51	<.001*
Emergency	2.13	<.001*
Patient sex (reference = female)		
Male	1.15	<.001*
Enrollment study modality (reference = CT)		
MRI	1.09	<.001*
Fluoroscopy	1.40	.423
US	1.35	.004*
Radiograph	2.50	<.001*
Patient's age group (reference = <20 years)		
21–30 years	1.22	<.001*
31–40 years	1.43	.474
41–50 years	1.54	<.001*
51–60 years	1.63	<.001*
61–70 years	1.65	<.001*
71–80 years	1.61	<.001*
>80 years	1.40	.580
Recent history of neoplasm (reference = absent)		
Present	1.46	<.001*

CT = computed tomography; MRI = magnetic resonance imaging; US = ultrasound.

* Denotes statistical significance.