Determinants of Diagnostic Imaging Utilization in Primary Care

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Objectives: To examine patient and physician factors affecting utilization of diagnostic imaging in primary care.

Data Sources/Study Setting: Patient-level data from a large academic group practice over the period July 1, 2007, through June 30, 2009.

Study Design: This is a retrospective cohort study of 85,277 patients cared for by 148 primary care physicians (PCPs). The dependent variable is the number of outpatient imaging exams ordered by each patient's PCP over the study period. Independent variables include 17 patient factors describing both clinical need and demographic characteristics and 7 physician factors.

Data Collection: Data were collected from the electronic medical record and associated administrative databases.

Principal Findings: Patient factors having a statistically significant effect on both the probability of any imaging and the amount of imaging were race, more than 10 medications, congestive heart failure, diabetes, hypertension, other problems, visits to the PCP, visits to specialists, and imaging exams ordered by specialists. For physician factors, experience, gender, and having another degree were statistically significant in both portions of the model.

Conclusions: Both patient and physician factors have a substantial effect on primary care outpatient diagnostic imaging utilization. Several of these significantly influence both the probability that any images will be ordered and the intensity (number) of imaging.

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For author information and disclosures, see end of text.

A central problem facing health policy makers is how to control the costs of medical services while maintaining the quality of care. Given that costs depend on utilization and unit costs, an understanding of factors driving utilization is fundamental to developing feasible and effective recommendations for cost control. Diagnostic imaging utilization is of particular interest because medical technology is often mentioned as a major driver of costs, with radiology in particular experiencing rapid growth. For example, in their 2006 report to Congress, MedPAC noted that from 1999 through 2004 growth in Medicare claims for diagnostic imaging was the highest of all physician services, at 62%.

Much of the research on utilization of health services stems from the large body of work that has demonstrated considerable variation in their use at various levels of geographic comparison.[1-3] Much of this variation in the use of medical services is not explained by differences in health status, disease-specific population health indicators, or other measures of health outcomes. This raises the question of what other factors influence utilization.

Although there is a large literature on the general topic of utilization of healthcare services, less attention has been paid to diagnostic imaging. Some studies focused on diagnostic services in general[4] or ambulatory test utilization.[5-7] Rosen, Davis, and Lesky[8] examined utilization of outpatient diagnostic imaging and found that the probability of a diagnostic imaging study being ordered was significantly affected by patient age, urgent visits, visit frequency, and physician gender. A study by Grytten and Sorensen[9] examined the use of diagnostic tests (including imaging) among Norwegian primary care physicians (PCPs); after controlling for patient age, gender, and reason for visit, the remaining variation in diagnostic test use ranged from 47% to 66%. Other studies have examined computed tomography (CT) scans and magnetic resonance imaging (MRI) only.[10-12]

The objective of this study is to examine patient and physician factors determining utilization of diagnostic imaging in primary care. Detailed patient-level data come from the physician organization associated with a large, urban academic medical center over a 2-year period. A patient-provider connectedness algorithm identifies a cohort of patients each linked to a single PCP based on outpatient visits over the previous 3 years. The analysis uses a 2-part model, which distinguishes between the probability

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Take-Away Points

- Primary care providers caring for adult patients order from 0 (63%) to 15 images per patient over 2 years, with the average being 0.72.
- Multivariable modeling of outpatient imaging utilization should take into account the observed distribution of per patient counts, which is 0 inflated and skewed to the right.
- Nine of 17 patient factors influence both the probability of any imaging and the amount of imaging performed.
- Three of 7 provider factors influence both the probability of any imaging and the amount of imaging performed.

of any imaging utilization (yes or no) and, conditional on any imaging, the amount of imaging utilization (number of exams). Multivariate regression is performed using maximum likelihood methods and zero-inflated Poisson distribution, which allows simultaneous estimation of coefficients for the 2-part model.

The study contributes to the literature by providing a deeper understanding of factors that influence the utilization of diagnostic imaging in primary care. The data used in the study are rich in detail and depth; the analysis includes 17 patient factors describing both clinical need and demographic characteristics as well as 7 physician factors, including gender, experience (years after MD degree), panel size, and having been sued for malpractice. Also, previous research on imaging utilization typically has focused solely on the amount of utilization, whereas this study applies the 2-part model in order to distinguish between the probability of any utilization and the amount of utilization, and the methodology used jointly estimates coefficients for the 2-part model.

CONCEPTUAL FRAMEWORK

This study examines the utilization of outpatient diagnostic imaging by PCPs caring for adult patients. We will not discuss imaging that occurs as part of disease screening programs, such as mammography and CT colonography, because the factors affecting utilization are likely to differ between imaging for screening and imaging for diagnostic purposes. Factors influencing the utilization of outpatient diagnostic imaging can be divided into 4 major classes: patient, physician, organization, and community. Because this study uses data from a single large physician organization in a single community, the focus is limited to patient and physician factors.

Patient factors affecting imaging utilization stem from clinical need as modified by demographic and socioeconomic characteristics. The physician orders imaging to address clinical uncertainty that arises about an existing medical condition or clinical event. Under ideal conditions of evidence-based practice, the mixture and amount of imaging that patients received would depend only on their existing diagnoses, disease status, and clinical events. However, the current state of medical knowledge and the consistency with which it is applied in actual practice is such that physicians' decisions about intensity and mixture of diagnostic imaging are quite variable even when faced with identical clinical scenarios. Consequently, utilization decisions also are influenced by patient factors other than clinical need as well as by physician factors.

Patient demographics such as gender and age strongly correlate with the amount and type of clinical need based on their complex relationships with many diseases and health states. However, these same demographic factors also exert social and psychological effects on the patient's likelihood to undergo diagnostic testing under various scenarios. Other patient factors such as ethnicity, level of education, and income also may affect individual patient tendencies to seek care and comply with provider recommendations.

In addition to patient factors, physician characteristics may affect a doctor's tendency to order diagnostic imaging tests. Physician training has direct effects on test-ordering behavior in primary care. Because the majority of training and experience about radiology is gained during residency, the relative intensity of imaging utilization at the training institution strongly influences subsequent decision making about imaging during practice. Previous research has found that physicians trained in high-use regions and at large academic centers tend to order diagnostic imaging more frequently than those trained in smaller centers and low-use regions.[2,5,9,13,14] Physician experience is also relevant, with empirical evidence indicating that physicians having greater experience tend to order fewer imaging tests in identical scenarios.[4,6,7,10,11,15]

Physician gender also may have an effect on use of imaging independent of experience and training, although, with the recent and substantial increase in the fraction of women trained in and practicing medicine in the United States, it may be difficult to measure, since women physicians tend to be younger and trained later. Empirical evidence about physician gender has been mixed, with studies showing both increased and decreased tendency to order imaging and other diagnostic tests between male and female doctors in primary care.[7,8,16]

Malpractice deserves special mention because the term "defensive medicine" is often used to describe the phenomenon of physicians' increased ordering of imaging and other diagnostic tests based on fear of being sued for failure to diagnose.[7,17] Being sued for malpractice is an extremely negative and unsettling event that induces a strong desire to avoid repeat occurrences.[18] Thus, if physicians have been sued for malpractice, the expectation is that they will alter future practice toward more diagnostic testing.

For purposes of the empirical analysis, the conceptual framework can be summarized as:

imaging utilization = f [patient factors (clinical need, demographic characteristics), physician factors].

METHODS

This study was conducted at Massachusetts General Hospital (MGH) and the associated Mass General Physician Organization (MGPO). The Institutional Review Board (IRB) and privacy office approved the study and deemed it to be Health Insurance Portability and Accountability Act compliant. Within the MGPO, the Primary Care Operations Improvement Group conducts analyses of the practice for internal quality assessment and improvement. In support of these efforts they have devised and validated a method for identifying a group of patients and PCPs with stable relationships to each other. The result is termed a connectedness ("loyalty") cohort. Each cohort is identified by year and comprises a list of patients who are considered to be linked to a single PCP by virtue of their outpatient visits as documented in the electronic medical record (EMR) over the 3 years ending in the "cohort" year. All patients seen in the primary care practice are initially eligible for inclusion in the cohort. Assertions about connectedness for patient-doctor pairs are calculated probabilistically from office visit history.[19-21] During the validation studies of the algorithm, cutoff probabilities were selected to produce sensitivity of 80.4%, specificity of 93.7%, and positive predictive value of 96.5%. The original goal of the method was to achieve a positive predictive value of 90% for any given provider's linked patients.[20,21]

The Radiology Department at MGH provides a full range of imaging services for inpatient, emergency department, and outpatient practices. The main department is located at the MGH campus, with several ancillary outpatient sites in the Boston, Massachusetts, area. The whole department is linked via a robust electronic infrastructure with records of all imaging tests housed in a data warehouse. In total, almost 100 items of information are stored about each test, including the identity of the ordering physician, dates of order and completion, modality, body area, and setting.

Data Collection

The 2008 primary care connectedness cohort contained 87,568 patients flagged as being linked to a PCP. There were 804 patients who were linked to 26 providers with less than 100 patients in their practices. These were excluded, leaving 86,764 patients. Of these, 1483 were linked to 4 providers who had left the MGPO in late 2008 or the first or second quarters of 2009. Therefore the analytic sample includes 85,277 patients, linked to 1 of 148 PCPs. These physicians practice in 1 of 15 clinics distributed through the greater Boston area. The unit of observation for this study is the patient. The 85,277 patient medical record numbers were queried against the clinical radiology system to return all diagnostic imaging exams performed during the study interval (July 1, 2007, through June 30, 2009). The query specifically excluded interventional procedures and mammograms. **Table 1** shows the total number of outpatient diagnostic imaging exams performed on the study cohort during the study period. The dependent variable for the study was constructed by aggregating and summing (by patient) the 60,983 outpatient imaging procedures ordered by the PCP to whom the patients were linked (outpatient ordered by PCP in Table 1). The remaining diagnostic imaging procedures were performed while patients were in the emergency department (N = 34,345), were completed while patients were in the hospital (N = 29,763), or were outpatient exams ordered by specialists (N = 96,525). These other categories of imaging utilization were also aggregated by patient and summed to produce 3 patient-level imaging utilization independent variables as described below.

The EMR system was used to obtain counts of various clinical events for each patient over the study period. Hospital activity variables included visits to the emergency department (ED), inpatient hospital stays, intensive care unit (ICU) days, and inpatient observation days. Records of outpatient visits for each patient during the study period were used to sum the professional relative value units (RVUs; obtained from Centers for Medicare & Medicaid Services as of 2008) for visits to the linked PCP and to specialists.

The EMR system was used to develop an active medical problem list for each patient. The coded problems were mapped into the following broad categories: diabetes, hypertension, heart failure, coronary artery disease, renal failure, cancer, trauma, obesity, and substance abuse. For each of the major categories, a binary variable was constructed when the patient had at least 1 active problem listed falling into that category. The counts of unmapped problem codes were placed into a separate variable of other problems.

The EMR system also provided data on the number of outpatient medications each patient was taking during 2008. The queries did not count refills of the same drug and dose as new prescriptions. However, switches within a drug class and/or dose changes were counted as new prescriptions, which could result in over-counting and rendering small differences in the discrete number less meaningful than the general amount

■ **Table 1.** Outpatient Diagnostic Imaging Exams Performed on Study Cohort During Study Period

	CT	MRI	NM	PET	X-Ray	US	Total	Percent
ED	10,183	2651	489	8	18,608	2406	34,345	15.5
Inpatient	4768	1634	944	128	19,907	2382	29,763	13.4
Outpatient ordered by PCP	**10,553**	**8009**	**2288**	**398**	**27,906**	**11,784**	**60,938**	**27.5**
Outpatient ordered by specialists	16,428	13,990	3841	3311	48,748	10,207	96,525	43.6
Total	41,932	26,284	7562	3845	115,169	26,779	221,571	100
Percent	18.9	11.9	3.4	1.7	52.0	12.1	100	

CT indicates computed tomography; ED, emergency department; MRI, magnetic resonance imaging; NM, nuclear medicine; PCP, primary care physician; PET, positron emission tomography; X-Ray, radiography; US, ultrasound.

each patient was taking. Therefore, we stratified the count of outpatient medications into 4 categories.

The MGH registrars' database was used to obtain relevant information pertaining to the 148 PCPs in the study, including gender, birth year, medical school graduation year, and medical school state (or country for foreign medical graduates). All were licensed in the state of Massachusetts, and the publicly available website for the Massachusetts Board of Medicine was queried to determine whether or not each physician had been sued for medical malpractice in the past 10 years.

Variables

Table 2 presents descriptive statistics for the variables used in the analysis, with frequency and percent shown for categorical variables and mean and standard deviation shown for numeric variables. The dependent variable is the per patient number of outpatient imaging tests ordered by the patient's PCP over the study period. The value of this variable ranged from zero (for 53,617 = 62.9% of the patients) to 15, with a mean of 0.715 and a standard deviation of 1.26.

The independent variables fall into 2 categories—patient factors (measured on a per patient basis) and physician factors (measured on a per physician basis, then linked to loyal patients of the given physician). Patient factors expected to influence outpatient imaging utilization include demographic characteristics (age, race, and gender), indicators of clinical problems (number of medications, medical problems, hospital readmission within 30 days), utilization of other medical services (PCP visits, specialist visits, ED visits, observation days, inpatient stays, inpatient length of stay [LOS], and inpatient ICU), and other imaging utilization (outpatient imaging ordered by specialists, ED imaging, and inpatient imaging). Physician factors expected to influence utilization include gender, experience (years since graduating medical school), foreign medical graduate status, having an additional degree, having been sued for malpractice, size of panel, and size of clinic.

Statistical Analysis

For the regression analysis, a zero-inflated Poisson (log-link) model was estimated using PROC GENMOD (SAS Version 9.3, SAS Institute Inc, Cary, North Carolina) with all independent variables included in both the zero-model and count portions of the regression.[22-24] This method is appropriate for a 2-level utilization model, which jointly estimates the effect of each independent variable on the probability of any imaging utilization (the zero-model portion) and on the amount of imaging utilization (count portion). The significance of each of the independent variables was determined from the type 3 table of Wald χ^2 statistics. To quantify the direction and size of the independent variable effects, explicit reference levels for the categorical variables were specified (using the PARAMETER = REFERENCE option).

RESULTS

Factors Affecting Probability of Any Imaging

Table 3 presents the regression results; the zero-model coefficients are listed in the middle column. The coefficients were transformed by exponentiation for clarity and can be interpreted similarly to odds ratios in logistic regression. Thus, a value of 1.1 would indicate a 10% higher probability of any imaging being ordered by the patient's linked PCP compared with reference for categorical predictors or a unit increase for quantitative ones. Conversely, a coefficient of 0.9 would indicate a 10% lower probability of any imaging being ordered by the patient's linked PCP.

Patient factors that had a statistically significant effect on the probability of any imaging included race, more than 10 medications, cancer, congestive heart failure, diabetes, hypertension, trauma, other problems, visits to the linked PCP, visits to specialists, imaging exams ordered by specialists, and imaging exams ordered during observation days in the hospital. The effect on the probability of any imaging was positive for race, trauma, other problems, visits to the linked PCP, visits to specialists, imaging exams ordered by specialists, and

Table 2. Descriptive Statistics

Variable		Frequency/Mean	Percent/Standard Deviation
Outpatient imaging tests ordered by PCP		.715	1.26
Patient factors (n = 85,277)			
Age	Years	53.7	15.9
Race	Black	4278	5.0%
	Hispanic	5924	6.9%
	Other	6643	7.8%
	White	68,432	80.2%
Gender	Female	49,568	58.1%
	Male	35,709	41.9%
Medications	None	4475	5.2%
	1-5	45,536	53.4%
	6-10	23,390	27.4%
	>10	11,876	13.9%
Problem	Coronary artery disease	3940	4.6%
	Cancer	9925	11.6%
	Congestive heart failure	867	1.0%
	Renal failure	1096	1.3%
	Diabetes	9485	11.1%
	Obesity	8855	10.4%
	Hypertension	25,219	29.6%
	Substance abuse	770	0.9%
	Trauma	1804	2.1%
Other problems	Count	7.75	6.94
PCP visits	Summed RVU	4.95	4.83
Specialist visits	Summed RVU	5.69	7.73
ED visits	Count	.33	1.04
Observation days	Count	.13	.54
Inpatient stays	Count	.20	.67
Readmit <31 days	Count	.02	.21
Inpatient LOS	Days	.92	4.70
Inpatient ICU	Days	.05	.76
Specialist imaging	Exam count	1.13	2.36
ED imaging	Exam count	.40	1.56
Inpatient imaging	Exam count	.35	2.41
Physician factors (n = 148)			
Gender	Female	76	51.4%
	Male	72	48.6%
Experience	Years	13.3	4.82
FMG	Yes	8	5.4%
	No	139	93.9%
Extra degree	Yes	14	9.5%
	No	134	90.5%
Malpractice	Yes	7	4.7%
	No	140	94.6%
Panel size	<500	37	25.0%
	500-749	36	24.3%
	750-999	36	24.3%
	≥1000	39	26.4%
Clinic size	Active physicians	13.3	4.82

ED indicates emergency department; FMG, foreign medical graduate status; ICU, intensive care unit; LOS, length of stay; PCP, primary care physician; RVU, relative value unit.
Frequency and percent are shown for categorical variables and mean and standard deviation for numeric variables.

■ **Table 3.** Results: Multivariate Regression (Zero-Inflated Poisson Model)

		Probability of Imaging	Intensity of Imaging
Patient Factors			
Age	Years	1.0000	1.0096[a]
Gender	Male [ref]	—	
	Female	1.0185	1.0608[a]
Race	White [ref]	—	
	Black	1.1859[a]	1.0870[a]
	Hispanic	1.0635	1.167[a]
	Other	1.1114[a]	0.9983
Medications	None [ref]	—	
	1-5	1.0397	1.0190
	6-10	0.9650	1.0620
	>10	0.8305[a]	1.0944[a]
Problem	Coronary artery disease	0.9737	0.9601
	Cancer	0.8808[a]	1.0251
	Congestive heart failure	0.7387[a]	0.9177[a]
	Renal failure	1.0870	0.8568[a]
	Diabetes	0.6835[a]	0.9249[a]
	Obesity	0.9713	1.0441[a]
	Substance abuse	1.0369	0.9303
	Hypertension	0.7862[a]	0.9086[a]
	Trauma	1.2730[a]	1.0447
Other problems	Count	1.0004[a]	1.0060[a]
PCP visits	Summed RVU	1.0054[a]	1.0327[a]
Specialist visits	Summed RVU	1.0003[a]	1.0072[a]
ED visits	Count	0.9987	0.9955
Observation days	Days	1.0135[a]	0.9957
Inpatient stays	Count	0.9947	1.0197
Readmit <31 days		0.9930	1.0117
Inpatient LOS	Days	1.0000	0.9890[a]
Inpatient ICU	Days	1.0000	0.9871[a]
Specialist imaging	Exam count	1.0008[a]	1.0132[a]
ED imaging	Exam count	1.0003	0.9938
Inpatient imaging	Exam count	1.0000	1.0185[a]
Physician factors			
Gender	Male [ref]	—	—
	Female	1.0644[a]	1.1139[a]
Experience	Years	1.0002[a]	0.9941[a]
FMG	Yes	1.1713[a]	0.9576
Extra degree	Yes	1.2808[a]	1.1832[a]
Malpractice	Yes	1.1122	0.9724
Panel size	<500 [ref]	—	—
	500-749	1.0836	1.0907[a]
	750-999	1.0593	1.1549[a]
	≥1000	1.0676	1.0602[a]
Clinic size	Active physicians	1.0006	1.0090[a]

ED indicates emergency department; FMG, foreign medical graduate status; ICU, intensive care unit; LOS, length of stay; PCP, primary care physician; RVU, relative value unit.
[a]Statistically significant at confidence level of <.05. Results are expressed as incident rate ratios by exponentiation of the model coefficients.

imaging exams ordered during observation days in the hospital. For example, the probability of any imaging utilization was approximately 0.5% higher for each additional visit to the linked PCP. For more than 10 medications, cancer, congestive heart failure, diabetes, and hypertension, the effect on the probability of any imaging was negative. For example, patients taking more than 10 medications had a probability of any imaging utilization that was approximately 17% less than for patients taking no medications. Although this may seem counterintuitive, the results for more than 10 medications, cancer, congestive heart failure, diabetes, and hypertension may reflect the fact that patients with serious medical problems are more likely to have their imaging exams ordered by specialists than by their respective PCPs.

The physician factors having a statistically significant effect on the probability of any imaging utilization included years of experience, gender, foreign medical graduate status, and possession of another graduate degree in addition to the MD. All of these factors had a positive effect on the probability of any imaging. For example, patients of PCPs who were female had a probability of any imaging utilization that was approximately 6% higher than comparable patients of PCPs who were male.

Factors Affecting Intensity of Imaging

The coefficients from the count (intensity) of imaging utilization portion of the model measure the effect of a given factor on the number of imaging exams ordered over the study period by the patient's linked PCP. These are shown in the far right column of Table 3 and have been transformed (by exponentiation) to incident rate ratios. Analogous to the probability of any imaging, for a given factor, a value of 1.1 would indicate 10% greater number of images ordered by the PCP, whereas a value of 0.9 would indicate 10% fewer images. The patient factors having a statistically significant and positive effect on the intensity of imaging utilization included age, gender, race, more than 10 medications, obesity, other problems, visits to the linked PCP, visits to specialists, imaging exams ordered by specialists, and imaging exams ordered while in the hospital. For example, patients who were female had approximately 6% more imaging exams ordered by their PCPs than comparable patients who were male. Factors that had a statistically significant and negative effect on the amount of imaging utilization included congestive heart failure, renal failure, diabetes, hypertension, days as inpatient, and days in ICU. Patients with congestive heart failure, for example, had approximately 8% fewer imaging exams ordered by their respective PCPs than those without this medical condition.

In terms of provider factors, gender, having another degree, panel size, and clinic size had a statistically significant and positive effect on the amount of imaging utilization. Patients of PCPs who were female, for example, had approximately 11% more imaging exams ordered than comparable patients of PCPs who were male. Provider years of experience, on the other hand, had a negative effect, such that patients of PCPs with an additional year of experience had approximately 1% fewer imaging exams ordered.

Factors Affecting Both Probability and Intensity of Imaging

Of the variables included in Table 3, some factors significantly affected the probability of any imaging and not intensity of imaging ordered by the linked PCP, some affected intensity and not probability, and some affected both probability and intensity. The **Figure** presents results for factors that are statistically significant in both portions of the model. Due to the difference in scale, Panel A shows the results for the categorical variables and Panel B for the numeric variables.

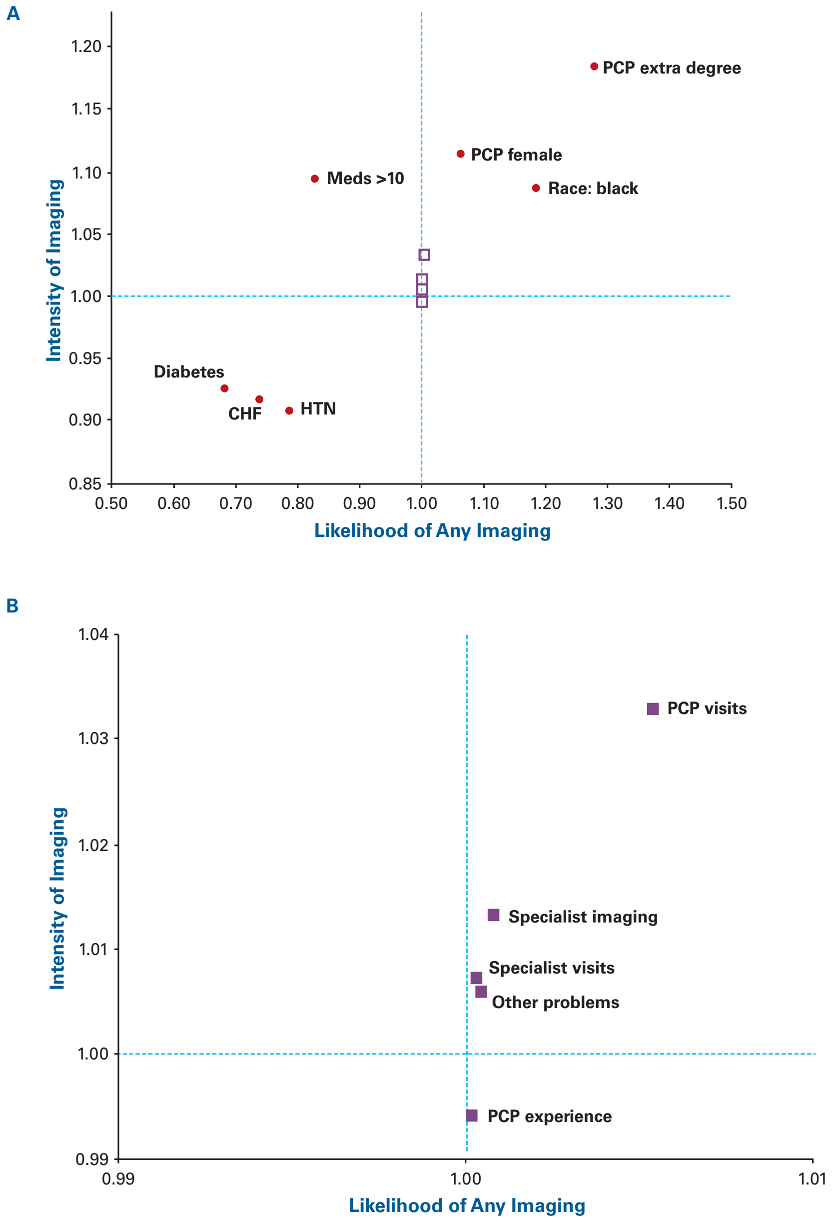
Patient factors that were statistically significant in both portions of the model include race (black), more than 10 medications, congestive heart failure, diabetes, hypertension, other problems, visits to the linked PCP, visits to specialists, and imaging exams ordered by specialists. With the exception of more than 10 medications, these patient factors have effects in the same direction on both probability of any imaging and intensity of imaging. For patients taking more than 10 medications, however, the probability of any imaging is less than for patients taking no medications while the intensity of imaging is higher than for patients taking no medications.

For physician factors, experience, gender, and having an extra degree were statistically significant in both portions of the model. Gender and having an extra degree had a positive effect on both probability of any imaging and intensity of imaging, while physician experience had a very small positive effect on the probability of any imaging but a negative effect on imaging intensity.

DISCUSSION

This study examined patient and physician factors affecting utilization of outpatient diagnostic imaging ordered by PCPs caring for a stable cohort of patients. The data came from a practice associated with a large, urban academic medical center over a 2-year period. Variables related to a patient's clinical need tended to be significantly associated with imaging utilization, as would be expected. For example, the amount of visits to the linked PCP strongly influenced both the probability of any imaging and the amount of imaging. This positive relationship was also true for visits to specialists and outpatient imaging ordered by specialists.

■ **Figure.** Factors Significantly Affecting Both Probability of Any Imaging and Intensity of Imaging



(A) Categorical Variables. (B) Numeric Variables.
CHF indicates congestive heart failure; HTN, hypertension; PCP, primary care physician.

Among the demographic patient factors, age and gender had a statistically significant and positive effect only on the amount of imaging ordered by the patient's PCP. Race, on the other hand, affected both the probability of any imaging and the amount of imaging. Specifically, black patients had a probability of any imaging utilization ordered by their PCPs that was approximately 19% higher than for comparable whites, and black patients had approximately 9% more imaging exams ordered by their PCPs than comparable patients who were white. We can only speculate about the etiology of this apparent ethnic disparity. Perhaps the PCPs elected to order imaging tests themselves rather than refer black patients having comparable problems on to specialists.

Physician factors contributed significantly and substantially to imaging utilization. Physician years of experience, gender, foreign medical graduate status, and having another degree had a positive effect on the probability of any imaging. Physician years of experience had a negative effect, while gender, having another degree, panel size, and clinic size had a positive effect on the amount of imaging. One notable factor that did not reach statistical significance for either probability or intensity of imaging was our physician-level, binary malpractice variable.

Limitations

One limitation of the study is that it did not examine imaging utilization that occurs as part of disease-screening programs. While important for population health and public policy, fundamental differences exist between imaging for screening and imaging for diagnostic purposes. For example, given agreement on the appropriate level of screening, policy makers are primarily concerned with under-utilization of imaging for screening, whereas the extent and nature of over-utilization tend to be the key issues for diagnostic imaging. Another limitation is that the dependent variable, outpatient imaging utilization, was quantified by number of imaging exams. However, some imaging exams cost considerably more than others. Thus, if cost were the only focus of the analysis, summed RVUs for the imaging exams would be a preferable outcome measure.

The patient population examined was specifically selected by evidence of a stable relationship with a PCP. New patients or those with irregular attendance might have more imaging due to lack of PCP familiarity with their clinical situation. All physicians in the practice are salaried employees. Consequently, providers in this setting may be subject to less influence from other incentives affecting utilization than would be the case in a private practice that owns or leases imaging equipment and thus profits from technical component reimbursements.[25] Therefore, our results may not generalize to other primary care practice settings.

As mentioned in the introductory material, physician training after medical school (residency and/or fellowship) likely has influence on test ordering behavior (in this case imaging). We did not have consistent and reliable data about place, type, and timing of residency/fellowship training for the PCPs studied. Therefore, we cannot make any assertions about these effects or their interaction with the other physician-level variables studied.

In terms of imaging utilization management, the outpatient multispecialty group used in the study is arguably a "best practice" setting, having used EMRs since 1995 and a computerized outpatient radiology order entry (ROE) system since 2004. In addition, starting in 2005 a decision support (DS) component was added to the system that is triggered with all orders for CT, MRI, and nuclear medicine studies. A retrospective study in the same setting over 7 years ending in 2009 found that, after correction for overall practice activity, there were substantial reductions in imaging utilization growth rates, especially for CT scans, which were attributed to the ROE-DS system.[26] Although the aforementioned ROE-DS system does render and record "appropriateness scores" for high-cost outpatient studies, these were not analyzed or used as control variables in the current study. We plan to extend this research in several directions including correlation of appropriateness with variations in utilization by provider, specialty, and over time.

Policy Implications

The key policy concern related to diagnostic imaging stems from substantial and rapidly rising costs. However, any attempts to control imaging utilization growth in general or to target "high users" for special attention must be informed by proper modeling of the factors driving imaging utilization. In discussing policy implications, it is important to emphasize that the focus of this study is not what is often called physician profiling, with the accompanying debate over appropriate risk adjustment.[27] Rather, this study examines all factors thought to influence utilization. These findings thus should be useful in decisions about what factors to include in risk adjustment.

A major implication of the study is that physician factors have a substantial effect on outpatient diagnostic imaging utilization, even after controlling for a host of patient factors. This contrasts with the presumed outcome under ideal conditions of evidence-based practice, in which imaging utilization would depend only on a patient's medical condition, with a certain level of randomness due to clinical uncertainty. Caution is warranted, though, due to the lack of a "gold standard" against which to measure "appropriate" utilization.[28]

An important next step in understanding utilization of medical services will be to examine physician factors and how they combine with patient need variables to influence utilization. An interesting question is why a physician's years of experience has a small positive effect on the probability of any imaging, but a negative effect on the amount of imaging ordered. Another question is why, as a physician's panel size increases, the amount of imaging ordered per patient also increases (but not the probability of any imaging). One possibility is that this stems from time pressure on the physician. For instance, an initial visit to a PCP for headache that occurs at the end of a busy day in clinic might be more likely to include an imaging test than otherwise. Again, however, judgments about under- or over-utilization are only valid given an established standard of comparison.

For this data set, outpatient imaging ordered by a patient's PCP accounted for 27.5% of all diagnostic imaging, with 43.6% of all imaging exams being ordered by specialists (Table 1). An important topic for future research thus will be the consideration of imaging utilization by specialists and the relationship between imaging exams ordered by PCPs and those ordered by specialists for similar patients. It may be, for example, that some PCPs who order fewer imaging exams themselves also refer more often to specialists; such a pattern of behavior could ultimately be more costly overall than PCPs who order more imaging exams but refer to specialists less often. As mentioned above, we are seeking to combine these sorts of population-level imaging utilization studies and variation analyses with normative assertions about the appropriateness of the examinations being enumerated.

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