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RESEARCH ARTICLE

The Relationship between Low Back Magnetic Resonance Imaging, Surgery, and Spending: Impact of Physician Self-Referral Status

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Objective. To examine the relationship between use of magnetic resonance imaging (MRI) and receipt of surgery for patients with low back pain.
Data Sources. Medicare claims for a 20 percent sample of beneficiaries from 1998 to 2005.
Study Design. We identify nonradiologist physicians who appear to begin self-referral arrangements for MRI between 1999 and 2005, as well as their patients who have a new episode of low back pain care during this time. We focus on regression models that identify the relationship between receipt of MRI and subsequent use of back surgery and health care spending. Receipt of MRI may be endogenous, so we use physician acquisition of MRI as an instrument for receipt of MRI. The models adjust for demographic and socioeconomic covariates as well as month, year, and physician fixed effects.
Data Collection/Extraction Methods. We include traditional, fee-for-service Medicare beneficiaries with a visit to an orthopedist or primary care physician for nonspecific low back pain, and no claims for low back pain in the year prior.
Principal Findings. In the first stage, acquisition of MRI equipment is a strongly correlated with patients receiving MRI scans. Among patients of orthopedists, receipt of an MRI scan increases the probability of having surgery by 34 percentage points. Among patients of primary care physicians, receiving a low back MRI is not statistically significantly associated with subsequent surgery receipt.
Conclusions. Orthopedists and primary care physicians who begin billing for the performance of MRI procedures, rather than referring patients outside of their practice for MRI, appear to change their practice patterns such that they use more MRI for their patients with low back pain. These increases in MRI use appear to lead to increases in low back surgery receipt and health care spending among patients of orthopedic surgeons, but not of primary care physicians.

Key Words. Low back pain, low back MRI, low back surgery, instrumental variables, physician self-referral

Rapid growth in medical imaging, particularly advanced and costly imaging using magnetic resonance (MR) and computed tomography equipment, has given rise to a range of questions about the value of these procedures (Iglehart 2006; Medicare Payment Advisory Commission 2009). Significant bodies of research demonstrate the ability of new imaging technologies to contribute information valuable to patient care. At the same time, there are also concerns that imaging may be overused in some contexts. Increasing use of imaging has also been associated with the potential for "treatment cascades" (Deyo 1994; Jarvik et al. 2003) in which the use of imaging leads to the use of subsequent procedures that are of low value to the patient and, but for receipt of the imaging procedure, would never have been done. While the conceptual case for imaging-driven treatment cascades is plausible, whether they are important in practice is not well understood.

One difficulty in studying treatment cascades is the ease with which unobserved characteristics of patients can bias analyses of the relationship between imaging receipt and use of subsequent treatments. Patients with more serious health conditions, who are most likely to receive treatments, may also be the most likely to get imaging procedures. If this happens, analyses that cannot adequately account for patient health would produce biased estimates.

This paper examines the relationship between receipt of magnetic resonance imaging (MRI) for back pain and the subsequent use of back surgery. This is an area that is associated with substantial costs—an estimated U.S.$80 billion in direct spine-related expenditures are incurred annually in the United States (Martin et al. 2008). It is also a classic setting for discussion of imaging treatment cascades. Imaging for low back pain without indications of serious underlying conditions has not been shown to improve clinical outcomes (Chou et al. 2009b). Since 1994, guidelines (Bigos, Bowyer, and Braen 1994) have recommended a cautious approach to the use of low back imaging because of the weak correlation between radiographic findings and clinical symptoms (Jensen et al. 1994; Jarvik and Deyo 2002) and high likelihood for acute low back pain to improve without treatment (Pengel et al. 2003). And yet rates of MRI for low back problems have increased substantially over time (Smith-Bindman, Miglioretti, and Larson 2008); one study estimated lumbar

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MRI use increased in the Medicare population by as much as 300 percent between 1994 and 2006 (Deyo et al. 2009).

Use of MRI is often associated with receipt of back surgery, in two dimensions. On one hand, patients for whom surgery is indicated often receive MRI as a precursor to surgery. On the other hand, importantly, research has shown that many people with no back pain have anatomical features in their back that appear abnormal on MRI (Jarvik and Deyo 2002). Individuals with back pain who receive MRI thus run a nontrivial risk of having a "positive" finding on MRI. The abnormality identified may not be the cause of the back pain, but the existence of the abnormal MRI finding can easily create an imperative to undertake treatments, including surgeries, to correct the abnormality. In the end, many of these surgeries, aimed at something that was not causing the pain, are ultimately unsuccessful at relieving the symptoms, but they do entail large costs as well as other risks for the patient.

Two randomized controlled trials have assessed the relationship between the use of low back MRI and low back surgery or expenditures. In both trials, there was a trend toward more surgery and higher costs among patients receiving early spinal MRI (compared with those receiving standard X-rays or delayed spinal MRI), but there was insufficient power to detect a statistically significant difference (Jarvik et al. 2003; Gilbert et al. 2004).

Previous work has also shown that increased availability of MRI equipment in geographic areas is associated with higher rates of MRI and surgery among low back pain patients in the area (Baras and Baker 2009). This study, however, could not address linkages between MRI receipt and surgery use directly. Its suggestion of a link provides important motivation for this study, which attempts to directly investigate the strength of the connection.

We use a novel methodology to identify and explain the impact of receipt of low back MRI on subsequent use of procedures. Previous research has shown that nonradiologist physicians who acquire their own MRI equipment perform more MRI scans on their patients after they acquire the equipment than they did before they acquired (Hillman et al. 1990; Radecki and Steele 1990; Hillman et al. 1992; United States General Accounting Office 1994; Gazelle et al. 2007; Baker 2010). This increased use of MRI scanning appears to occur without meaningful changes in the characteristics of the patients in the doctors' practices. As such, acquisition of MRI equipment may provide a useful opportunity to study the impact of receiving an MRI scan on use of subsequent treatments. If physician acquisition of MRI leads patients with low back pain seen after acquisition to be more likely to receive MRI than patients seen before acquisition, studying the receipt of back surgery by patients before and after acquisition of the equipment can provide a potentially unbiased estimate of the impact of MRI receipt on use of low back surgery.

Data and Methods

Identification of Patient Care Episodes

This study used data from 1998 to 2005 Medicare claims records for a 20 percent random sample of traditional, fee-for-service, Medicare beneficiaries. The primary unit of analysis was an episode of care for low back pain that began with an outpatient visit to an orthopedic surgeon or a primary care physician (defined as internal medicine, general practice, or family medicine). We focused on these specialties because our analysis of the data indicated that physicians in these specialties most frequently took care of patients presenting for the first time with low back pain. We focused on episodes that began with an office visit because most discussion of treatment cascades for MRI in low back patients is associated with outpatient settings. Physician acquisition of MRI is also primarily associated with utilization of MRI in outpatients; patients hospitalized with back problems tend to be a distinct group that is more ill, and the determinants of imaging use for hospitalized patients can be quite different.

To identify episodes, claims records were first searched for instances in which a patient had an outpatient visit with a primary diagnosis of low back pain (using International Classification of Diseases Version 9 [ICD-9] codes) without having had any claims related to back pain from any doctors in the prior year. Each such instance was treated as an "index visit," indicating the beginning of a new episode of care. Although use of ICD-9 coding to identify low back pain could in principle miss visits that inadvertently do not list low back pain as the primary diagnosis, we believe this approach should produce data sufficient to support strong analyses. We identified approximately 2 percent of all office visits billed to Medicare as visits primarily for low back pain, which approximates the prevalence of office visits for low back pain (2.3 percent) in the literature (Deyo, Mirza, and Martin 2006).

There are a number of different types of low back pain. We focused on episodes for patients with nonspecific low back pain, which accounts for more than 80 percent of low back pain complaints and includes back pain associated with lumbar strains and sprains and degenerative disk disease (Jarvik and Deyo 2002). MRI and surgery for patients with nonspecific low back pain are controversial and generally not recommended (Gibson and Waddell 2005). We excluded other types of back pain, such as herniated disk and spinal stenosis, for which MRI and surgery are more likely to be accepted as beneficial.

We used claims to tally the number of low back MRI scans and low back surgeries received with 180 days of each index visit. Back surgeries were identified by the presence of a physician claim for the performance of a back surgery. Imaging procedures are typically billed in two parts: a technical component that covers the performance of the procedure itself, and a professional component that covers interpretation of the results. Medicare also allows doctors who both perform the service and do the interpretation to bill for a "global fee," which combines both the technical and professional components. We based our count of MRI procedures received on global fee claims or claims for the interpretation of an MRI scan of the lower back.

We recorded total spending within 180 days of the index visit, including all spending from inpatient, outpatient, and physician claims. These included Medicare payments, but not beneficiary copayments and deductibles. These measures may include spending on things unrelated to back pain, but we elected to err on the side of broad inclusiveness in these measures. Because we used a differenced analysis, changes in spending associated with MRI and subsequent procedures should be detectable in changes in the means.

We coded the following measures for use as control variables in the analysis: patient age at the time of the index visit (seven categories: 65–69, 70–74, 75–79, 80–84, 85–89, 90–94, and 95+); patient sex; patient race (four categories: white, nonwhite Hispanic, black, and other); the patient's Medicaid coverage status (covered by Medicaid as a dual-eligible for any portion of the calendar year of the initial visit, or not); indicators for the presence of 30 comorbidities in the year before the index visit based on the methodology described by Elixhauser and colleagues (Quan et al. 2005); and a measure of total Medicare physician, inpatient, and outpatient spending for the patient in the 365 days before the index visit.

To ensure that utilization in the year before the index visit and for at least 180 days afterwards could be tracked, attention was restricted to index visits that took place between January 1, 1999 and June 30, 2005, where patients were at least 66 years of age at the time of the index visit (and thus had been Medicare-eligible for at least 1 entire year), and where patients had not been enrolled in a Medicare HMO in the year before the index visit or in the 180 days after it. Patients were allowed to have more than one episode of care if there was at least 1 year without any claims for low back pain after the initial 180-day period.

Classification of Episodes According to Physician MRI Acquisition Status

Our analysis uses an indicator for whether the index visit physician had acquired MRI by the time of the index visit as an instrumental variable (IV) for receipt of MRI. Each episode was coded according to whether the index visit physician was observed to acquire MRI during the study period, and, if so, whether the index visit took place before or after acquisition. Whether a physician acquired MRI was determined based on physician billing patterns for MRI technical components or global fees. Physicians can legally only bill for technical components or global fees when they use their own equipment to perform the procedure. Practically speaking, this can occur in a couple of different circumstances (Mitchell 2007). One is when physicians have purchased or leased the equipment and have the equipment in their practice. The other is when physicians have entered into legal arrangements, sometimes referred to as per-click leases, in which physicians refer patients to an outside facility for imaging but the referral triggers a one-time lease of the equipment to the physician for the performance of the referred procedure. In this latter case, the doctor would not own or lease the entire piece of equipment, but would be able to bill and be reimbursed as if he or she had done so. In both of these cases, physicians benefit financially from the performance of imaging procedures.

We thus used billing for technical components or global fees as an indicator for acquisition of MRI. This has been used successfully in previous studies (Mitchell 2007; Medicare Payment Advisory Commission 2009; Baker 2010). All claims submitted by each index physician (not just those for his or her low back patients) between 1998 and 2005 were examined for cases in which the physician billed for a technical component or global fee for an MRI procedure. For physicians who were observed to bill for a technical component or global fee, the date of the first such billed procedure was noted. Because the analysis emphasizes pre–post comparisons, only acquiring physicians who provided at least one episode of care for a back-pain patient before and after the date of their first billed MRI procedure (1,271 orthopedists and 1,033 primary care physicians) were included in the final study sample. We considered requiring multiple technical component or global fee bills before considering a doctor to have acquired MRI and found that this produced generally similar results.

We also distinguished episodes of low back care where the index visit doctor falls into a group that we term "traditional users" of MRI. This group was intended to capture physicians who use MRI in conventional ways and who should thus provide a means of understanding the underlying trends in MRI use over the study time period. This group of doctors was designed to contain a group that would not have incentives to use MRI associated with acquisition. Specifically, these physicians provided at least two episodes of care in the study period, were never observed to bill for an MRI technical component or global fee, self-refer an MRI procedure, or refer an MRI procedure to another physician in their same specialty. This group also excluded physicians who were ever observed to refer for MRI to independent diagnostic and testing facilities, where relevant incentives can be difficult to identify. While it is difficult in claims data to identify every possible arrangement that might create nonmedical incentives for using MRI, we believe these exclusions should be defined as a "traditional user" group that excluded doctors with the vast majority of common and direct nonmedical incentives for ordering MRI. Included in this group were 7,717 orthopedists and 84,809 primary care physicians.

Our analysis focused on episodes where the index visit doctor was in the group of acquiring doctors or in the traditional user group. There were some doctors who fell into neither of the two groups. These doctors were those who did not ever bill themselves for a technical component or global fee, but did do things like refer for MRI to another doctor in the same specialty, which could be an indication of a shared equipment arrangement where the financial incentives are not clear, or refer to independent imaging facilities where the financial incentives associated with utilization can be quite murky. A total of 2,887 orthopedists and 7,747 primary care physicians fell into this category, and we excluded episodes with these doctors.

Our analysis also excluded episodes with MRI-acquiring physicians who started less than 180 days before the initial billing date, because these episodes may well have been in progress at the time the physician began billing for MRI.

Our final study sample consisted of 740,467 patient episodes of low back pain. There were 78,914 episodes of care associated with 8,988 orthopedists, and 661,553 episodes associated with 85,842 primary care physicians.

Statistical Strategy

Our approach to identifying the effect of MRI receipt on subsequent procedure use was to compare surgery rates and spending in patients seen before physicians acquire MRI to rates of use in patients seen after. If acquisition induces a shift upwards in MRI use, and this is not associated with changes in patient characteristics, it will create an opportunity to learn about the relationship between MRI use and surgery use and spending, mitigating the endogeneity biases that can complicate comparisons of surgery use and spending in patients who do and do not receive MRI.

We adopted an IVs framework to implement the analysis (Greene 2003). We used physician acquisition of MRI equipment as the instrument for identifying receipt of MRI. The validity of this instrument depends on two things: first, it must be associated with use of MRI. This appeared satisfying in our data. As we will show, physicians who acquire MRI become more likely to order MRI scans for their patients. Patients who see physicians after they have acquired MRI are thus more likely to receive MRI procedures than patients who see the same physicians before they have acquired. Second, acquisition of MRI by a physician should not be associated with other characteristics of the physician or his or her patients who also influence the use of surgery. Because we had panel data, we included physician fixed effects in the model, which eliminates the potential for bias from underlying characteristics of physicians, such as their preferences about the use of imaging or surgery. Finally, we will show that time trends in the utilization of MRI by acquiring doctors in the period before MRI acquisition are quite similar to time trends for nonacquiring doctors, and that there is a discrete jump up in the utilization of MRI at the time of acquisition, suggesting that differential time trends possibly related to underlying characteristics of doctors or patients are not likely at work.

We implemented the IV estimator using two-stage least squares. In the first stage, we estimate patient-level regressions of the form

$$\begin{aligned} MRI_{i,j,t} = &\beta_0 + \beta_1 \times ACQUIRED_{j,t} + \beta_2 \times X_{i,t} \\ &+ \beta_3 PHYS_j + \beta_4 \times TIME_t + \varepsilon_{i,j,t} \end{aligned} \quad (1)$$

where MRI is an indicator of receipt of low back MRI within 180 days of the index visit by patient i, treated by physician j, at time t. ACQUIRED is a dummy variable indicating whether physician j had acquired MRI by time t or not. X is a vector of patient characteristics, PHYS is a vector of physician fixed effects, TIME is a set of controls for year and month, and ε is an error term.

The models included as controls (X) patient age, sex, race, Medicaid status, prior year Medicare spending, and a set of 30 dummies for the Elixhauser comorbidities. The models also included physician fixed effects, which absorb all underlying characteristics of physicians that are fixed over time. In particular, this absorbs fixed differences in MRI use rates between physicians who acquire equipment and traditional users. The TIME controls control for generalized time trends. In this framework, the coefficient on the

ACQUIRED variable identifies the change in MRI use rates associated with acquisition, based on within physician pre–post differences in MRI use rates, relative to time trends in use rates by patients of the traditional physician group.

The second-stage model estimated the effects of MRI receipt on surgery utilization and spending, using patient-level regressions of the form

$$\begin{aligned} Y_{i,j,t} =& \beta_0 + \beta_1 \times MRIHAT_{j,t} + \beta_2 \times X_{i,t} \\ &+ \beta_3 \times PHYS_j + \beta_4 \times TIME_t + \varepsilon_{i,j,t} \end{aligned} \quad (2)$$

where Y is a utilization or spending measure and MRIHAT is predicted MRI utilization from the first-stage model. Other variables in equation (2) were identical to those in equation (1).

We estimated both the first and the second stages using OLS estimation. The dependent variable in the first stage was a dichotomous indicator for receipt of MRI and, in the second stage, one of the dependent variables was a dichotomous indicator for receipt of surgery. Despite the dichotomous variables, use of OLS (linear probability) models produced results that were consistent, although they were inefficient. Because our models involved large numbers of fixed effects, this model also offered computational advantages—approaches involving conditional logistic regressions, for example, are computationally prohibitive.

All analyses were performed using *Stata* 11.1 (College Station, TX, USA). This work was approved by the Stanford University School of Medicine Institutional Review Board.

RESULTS

Table 1 summarizes selected characteristics of our study sample. Overall, patients of physicians who were traditional MRI users and patients of physicians who acquired MRI were similar in age and gender, but patients of self-referring physicians were less likely to be Black or have dual Medicaid enrollment (column 1). Patients of acquiring physicians, before and after they began to bill for MRI, had similar demographic characteristics, percent Medicaid enrollment, and prior year health spending (column 2). We compared prevalence of Elixhauser comorbidities among patient groups (see Appendix SA2); there were few statistically significant differences, suggesting that patients in the traditional and MRI acquirer groups, and patients of physicians before and after MRI acquisition, had similar disease burden.

Table 1: Summary of Patient Characteristics and Low Back Magnetic Resonance Imaging (MRI) Utilization

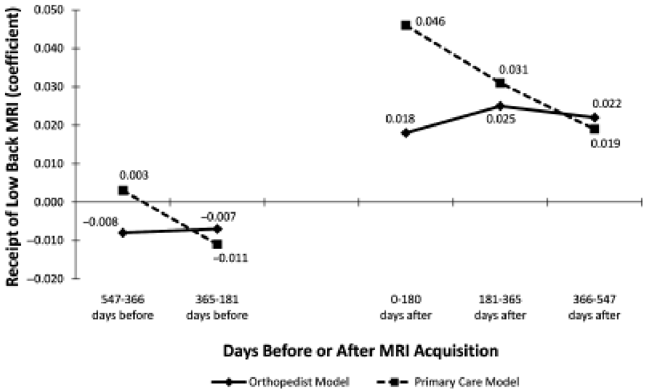
	(1) Physician Self-Referral Status			*(2) Among Self-Referring Physicians*		
	Traditional MRI Users	*Will or Has Acquired MRI*	*p-Value*	*Before MRI Acquisition*	*After MRI Acquisition*	*p-Value*
Orthopedist episodes ($n = 78{,}914$)	70,400	8,514		3,485	5,029	
Orthopedic surgeons (n)	7,717	1,271				
Patient characteristics						
Female (%)	64.4	65.3	0.118	64.5	65.8	0.228
Black (%)	4.6	4.3	0.119	4.4	4.2	0.743
Mean age (years)	76.5	76.4	0.077	76.5	76.3	0.098
With dual Medicaid coverage (%)	8.4	7.0	<0.001	7.3	6.7	0.355
Mean prior year total Medicare spending (U.S.$)	5,093	4,883	0.052	4,726	4,992	0.163
Receives low back MRI within 180 days (%)	19.5	25.0	<0.001	21.8	27.2	<0.001
Primary care episodes ($n = 661{,}553$)	655,393	6,160		2,559	3,601	
Primary care physicians (n)	84,809	1,033				
Patient characteristics						
Female (%)	64.9	65.7	0.183	66.1	65.4	0.542
Black (%)	5.9	3.8	<0.001	3.9	3.7	0.748
Mean age (years)	76.5	76.5	0.523	76.6	76.5	0.588
With dual Medicaid coverage (%)	15.4	11.7	<0.001	12.1	11.5	0.487
Mean prior year total Medicare spending (U.S.$)	4,131	4,332	0.077	4,054	4,529	0.048
Receives low back MRI within 180 days (%)	10.5	14.5	<0.001	11.2	16.7	<0.001

Table 1 also shows unadjusted sample averages of the MRI use measures studied. Within 180 days of the index visit, patients of primary care physicians had lower rates of MRI use than patients of orthopedic surgeons; patients of traditional MRI users had lower rates of MRI use than patients of physicians who began billing for MRI (10.5 versus 14.5 percent for primary care episodes, 19.5 versus 25.0 percent for orthopedist episodes). We control for these differences in utilization of MRI by including physician fixed effects in the models.

For the first stage of the IV analysis, in which we estimated the impact of physician MRI acquisition on patient receipt of MRI (equation [1]), the estimated coefficients were the following: orthopedist model coefficient = 0.025, $p = .014$; primary care model coefficient = 0.035, $p = <.001$. In other words, receipt of MRI was strongly correlated with physician acquisition of MRI. Among patients of orthopedists, for every 100 episodes, the number of patients receiving any MRI goes up by 2.5 after acquisition, controlling for a wide range of patient characteristics, physician fixed effects, and general time trends in MRI use. Evaluated around the mean (20), this is an increase of about 13 percent. Results for primary care doctors indicated a somewhat larger response, with an increase of about 32 percent when evaluated around the sample mean (11). These results have instrument F-statistics greater than 10, as recommended for the first-stage IV regressions (Staiger and Stock 1997).

An important question about the validity of using MRI acquisition as an instrument for MRI use is whether the increases in MRI use for acquiring doctors could be simply an artifact of underlying faster growth in MRI use among acquiring physicians. Figure 1 provides evidence that help evaluate this question. Here, we augmented equation (1) to interact the acquisition measure with dummies for calendar halves before and after acquisition. This allowed us to trace out the pattern of MRI use by patients of acquiring doctors over time, relative to time trends in use by patients of traditional users. The figures plotted are differences in utilization between acquiring doctors and traditional MRI doctors by calendar half. Because these models include fixed effects for doctors, baseline differences in MRI use between traditional and acquiring doctors are also removed, so that by construction the difference in the first period considered (three calendar halves before acquisition) is set to zero. Before acquisition, there is no evidence that doctors that will go on to acquire MRI are trending upwards in their MRI use at a faster rate than their traditional MRI colleagues (the "before acquisition" plot is stable or trending down). At the point at which physicians acquire MRI, there is a distinct jump up in their MRI use, approximately a 2–4 percentage point increase. For orthopedists, this increased rate of use persists, but for patients of primary care

Figure 1: Plot of Linear Regression Coefficients for MRI Receipt, before and after Physician Acquisition of MRI



Note. Estimates based on regressions that control for patient demographics, Medicaid status, prior year health spending, comorbidities, and year, month, and physician fixed effects. Note that the 6 months preacquisition were dropped due to uncertainty in timing of acquisition and because those episodes might have been in progress at the time of acquisition.

doctors, the difference between the acquirer and traditional user rate narrows noticeably over time. We believe these results strengthen the validity of equipment acquisition as an instrument for MRI receipt, with which we can identify the effect of MRI use on subsequent treatment use and spending.

Tables 2 and 3 present results from the second stage of the IV analysis (equation [2]) for orthopedist and primary care models, respectively. These models show the relationship between 180-day MRI use and 180-day surgery and low back spending. We have only included the primary independent variable of interest, MRI receipt (see Appendix SA2 for full set of coefficients). For each outcome of interest, we also show coefficients from a standard OLS regression model that does not instrument for MRI use.

Among patients of primary care doctors (Table 3), receipt of MRI was associated with an increased probability of receiving surgery of 9.8 percentage points. However, in the IV estimation, the coefficient fell substantially and became insignificant. One interpretation of this is that patients most likely to receive surgery are also likely to have an MRI done. The IV approach should correct for this. Once we used IV estimation, for patients of primary care doctors, there was no evidence of a causal effect of MRI receipt on surgery.

For patients of orthopedists (Table 2), however, there was evidence of an effect. In the IV model, receiving an MRI procedure was associated with a

Table 2: Regression Estimates and Standard Errors for the Association between Orthopedists' Magnetic Resonance Imaging (MRI) Acquisition Status and Patients' Low Back MRI Use, Surgery Use, and Spending

Dependent Variables	*Model*	*Key Independent Variable Low Back MRI Receipt*
Low back surgery receipt	OLS	0.082 (0.001)*
	IV	0.341 (0.139)**
Total low back spending	OLS	1,941 (24)*
	IV	4,161 (2,130)$^{+}$
Total physician payments	OLS	868 (6)*
	IV	1,964 (570)*
MRI physician payments	OLS	347 (2)*
	IV	1,159 (267)*
Procedures physician payments	OLS	308 (5)*
	IV	901 (401)**
Outpatient facility spending	OLS	210 (3)*
	IV	– 350 (300)
Inpatient spending	OLS	863 (20)*
	IV	2,547 (1,789)

Notes. Model includes 78,914 patient episodes. Standard errors in parentheses.

Estimates based on standard OLS or two-stage instrumental variables (IV) regressions that control for patient demographics, Medicaid status, prior year health spending, Elixhauser comorbidities, and year, month, and physician fixed effects. Regressions include physicians who bill for MRI (acquirers) and traditional MRI users.

$^{+}$Significant at 10%.

**Significant at 5%.

*Significant at 1%.

large increase in the probability of receiving surgery. Among patients who come to receive MRI after their doctor acquires MRI, the probability of surgery within 6 months of the index visit was estimated to go up by 34 percentage points. The increase in the size of the coefficient between the standard OLS regression (0.082) and IV models (0.341) for orthopedist episodes is striking, but it may be attributable to the fact that the IV results pick out the impact in the group of patients whose MRI use changes due to acquisition, while the results from the standard OLS regression reflect the average relationship between MRI and surgery use across all patients (and possibly including the reverse-causal effects that can occur when a decision for surgery leads to the performance of an MRI as a preparatory step).

We performed additional analyses to assess whether the relationship between MRI and surgery use was sensitive to changes in the definition of our IV. We narrowed the definition of MRI acquisition by including those

Table 3: Regression Estimates and Standard Errors for the Association Between Primary Care Physicians' Magnetic Resonance Imaging (MRI) Acquisition Status and Patients' Low Back MRI Use, Surgery Use, and Spending

Dependent Variables	*Model*	*Key Independent Variable Low Back MRI Receipt*
Low back surgery receipt	OLS	0.098 (0.001)*
	IV	0.056 (0.071)
Total low back spending	OLS	2,055 (8)*
	IV	1,179 (1,992)
Total physician payments	OLS	813 (2)*
	IV	970 (266)*
MRI physician payments	OLS	292 (1)*
	IV	704 (102)*
Procedures physician payments	OLS	269 (2)*
	IV	244 (185)
Outpatient facility spending	OLS	262 (1)*
	IV	− 200 (177)
Inpatient spending	OLS	980 (7)*
	IV	409 (1,035)

Notes. Model includes 661,553 patient episodes. Standard errors in parentheses.

Estimates based on standard OLS or two-stage instrumental variables (IV) regressions that control for patient demographics, Medicaid status, prior year health spending, Elixhauser comorbidities, and year, month, and physician fixed effects. Regressions include physicians who bill for MRI (acquirers) and traditional MRI users.

*Significant at 1%.

physicians who billed for MRI at least 3, 5, or 10 times during the study period. We found that our indicator for physician self-referral was quite robust. The coefficients for the IV and OLS analyses (Table 4) did not drastically change when we narrowed our definition of MRI acquisition. We suspect that the most impact on MRI ordering patterns likely came from physicians having any self-referral claims rather than having more self-referral claims.

Regarding spending, results suggest that an incremental MRI was associated with higher physician spending. For orthopedist patients, receiving MRI was associated with an increase in total 1-year spending of U.S.$4,161, substantially more than the cost of the MRI scan alone and consistent with the significant increase in surgery use (Table 2). For primary care patients, the IV estimate of the effect of MRI on spending was positive but not statistically significant (Table 3). We also estimated similar models, breaking total spending down into categories. An incremental MRI procedure was associated with higher spending on physician claims for MRI of U.S.$1,159 for orthopedists and U.S.$704 for primary care physicians. One important implication of this

Table 4: Sensitivity Analysis of Physician Self-Referral Indicator (Magnetic Resonance Imaging [MRI] Acquisition Status)

	Dependent Variable: Low Back Surgery Receipt			
	Orthopedist		*Primary Care*	
Definition of Physician MRI Acquisition	*OLS*	*IV*	*OLS*	*IV*
≥ 1 claim, global or technical fee for MRI	0.082	0.341	0.098	0.056
	(0.001)*	(0.139)**	(0.000)*	(0.071)
≥ 3 claims	0.082	0.374	0.098	0.039
	(0.001)*	(0.161)**	(0.001)*	(0.065)
≥ 5 claims	0.082	0.343	0.098	0.056
	(0.001)*	(0.177)$^{+}$	(0.000)*	(0.060)
≥ 10 claims	0.082	0.318	0.098	0.039
	(0.001)*	(0.170)$^{+}$	(0.000)*	(0.082)

Notes. Standard errors in parentheses.

Regression estimates and standard errors for the association between patient's low back MRI use and surgery use, using physician self-referral status as an instrument for patient MRI receipt. Orthopedist model includes 78,914 patient episodes. Primary care model includes 661,553 patient episodes. Number of MRI claims billed by physicians is over the 1999–2005 study period. Estimates based on standard OLS or two-stage instrumental variables (IV) regressions that control for patient demographics, Medicaid status, prior year health spending, Elixhauser comorbidities, and year, month, and physician fixed effects. Regressions include physicians who bill for MRI (acquirers) and traditional MRI users.

$^{+}$Significant at 10%.

**Significant at 5%.

*Significant at 1%.

finding is that the costs of doing these incremental MRIs was much higher than just the cost of the MRI itself (roughly U.S.$500), and it could appropriately be taken to include the costs of the additional procedures done as a result of the MRI. The IV results also suggest that there were increases in spending for other services that accompanied the MRI procedure, which is consistent with the observed increases in surgery rates. There was some evidence for reductions in spending in outpatient settings (such as emergency departments and hospital clinics) and increased hospital spending, although estimates in these two categories taken alone were not significant.

Discussion

Orthopedists and primary care physicians who begin to bill for the performance of MRI procedures, rather than referring patients outside of their practice for MRI, appear to change their practice patterns such that they use more MRI for their patients with low back pain. These increases in MRI use appear to lead to increases in low back surgery receipt among patients of orthopedic surgeons, but not of primary care physicians. In addition, for both orthopedists and primary care doctors, increases in MRI receipt are associated with higher levels of physician spending, at levels beyond what would be predicted by the receipt of the procedure alone. For orthopedists, there is further statistically significant evidence of increases in total spending. In these estimates for low back pain patients, these additional costs are up to several times the cost of the MRI itself.

There are several important limitations. Our analysis examined low back care among a subset of Medicare patients, orthopedic surgeons, and primary care physicians. With our patient and significant physician self-referrer exclusion criteria, we examined about 25 percent of all nonspecific low back pain visits seen by orthopedic surgeons and primary care physicians from 1999 to 2005 (2.8 million). The effect of these low back MRI procedures on our study population may be different from the effects of other MRI procedures done in other patients (with different demographics and disease type) under other circumstances (different physician specialty, health plan). Treatments for low back pain, and the use of imaging more generally, may also be changing over time. Other factors influencing the use of imaging and treatments for back pain may also change these relationships over time. Nonetheless, we believe the existence of the relationships we measured should encourage clinicians and policy makers to pay attention to linkages between imaging and treatment use and more generally to the possibility that cascade effects in medicine can occur, and when appropriate, respond accordingly.

This study did not directly evaluate patient outcomes. It is possible that additional use of MRI and the resulting incremental procedure use and spending was associated with improved outcomes in some patients. However, there is reason to be concerned that it may not always have been. The focus of our study was care of patients with nonspecific low back pain, for which MRI and surgery are quite controversial. Guidelines in many cases recommend against their use (Chou et al. 2007, 2009a, b).

We did not directly evaluate reasons for differences in the measured effect of MRI use on surgery in patients of primary care physicians and orthopedists. One possible source of a difference is the fact that orthopedists are typically able to perform back surgeries themselves, while primary care physicians would refer their patients to a surgeon. This may make the linkage between additional MRI and a decision for surgery tighter for a self-referring orthopedist than a self-referring primary care physician, with the involvement of additional steps and an additional physician who would make the decision about whether to proceed to surgery. Another possibility is unobserved differences in the characteristics of patients with the same ICD-9 codes seeing orthopedists and primary care physicians. While there is no evidence to suggest that these kinds of differences exist, if those patients with unobservable characteristics that would lead to a closer relationship between imaging and surgery were more likely to see orthopedists than primary care doctors, it could lead us to observe this pattern in our results.

As policy makers increasingly struggle with rising health care costs, it is important that they continue to pay attention to rapidly advancing technologies and relationships between them. Developing approaches that can encourage the use of imaging in appropriate ways may ultimately impact utilization of a range of costly services like low back surgery. Approaches like bundled payments and the development of broader organizations, using the proposed accountable care organization or other models, could provide mechanisms for improving the efficiency of care (Medicare Payment Advisory Commission 2010). More specifically, continued attention to self-referral issues seems important. Recent changes in Medicare payments may have reduced the incentives for acquisition of in-office MRI going forward, but these results are an indication of the fact that self-referral can have important impacts on physician practice (Levin et al. 2009). These impacts may be felt with other types of imaging, or in other areas of medicine as new technologies are developed and diffused.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.
Appendix SA2: Full Model Details.