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Rates of Advanced Spinal Imaging and Spine Surgery

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Study Design. Small area analysis.

Objectives. To determine the association between the rates of advanced spinal imaging and spine surgery across geographic areas.

Summary of Background Data. The rates of spine surgery in the United States have increased along with a concurrent rise in the use of advanced spinal imaging: CT and MRI. Spine surgery rates vary six-fold across geographic areas of the United States. Differences in patient populations and health care supply have explained only about 10% of this variation.

Methods. We used a random 5% sample of Medicare's National Claims History Part B files for 1996 and 1997 to determine procedure rates across 306 Hospital Referral Regions. We analyzed the association between spinal imaging and spine surgery using linear regression. Main outcome measures were rates of procedures and coefficients of determination (R^2).

Results. The rates of advanced spinal imaging (CT and MRI combined) varied 5.5-fold across geographic areas. Areas with higher rates of MRI had higher rates of spine surgery overall (r = 0.46) and spinal stenosis surgery specifically (r = 0.37). The rates of advanced spinal imaging accounted for 22% of the variability in overall spine surgery rates ($R^2 = 0.22$, $P < 0.001$) and 14% of the variability in lumbar stenosis surgery rates ($R^2 = 0.14$, $P < 0.001$). A simulation model showed that MRIs obtained in the patients undergoing surgery accounted for only a small part of the correlation between MRI and total spine surgery rates.

Conclusions. A significant proportion of the variation in rates of spine surgery can be explained by differences in the rates of advanced spinal imaging. The indications for advanced spinal imaging are not firmly agreed on, and the appropriateness of many of these imaging studies has been questioned. Improved consensus on the use and interpretation of advanced spinal imaging studies could have an important effect on variation in spine surgery rates. **Spine 2003;28:616–620**

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The rates of spine surgery in the United States have increased dramatically over the past 20 years.[8,21] The rates of spine surgery also vary markedly across geographic areas.[20,21] In 1996–1997, the rates of lumbar discectomy in the Medicare population varied 15-fold across hospital referral regions (HRRs) in the United States, laminectomy rates varied 7-fold, and spinal fusion rates varied 10-fold.[21] Prior studies found that only about 10% of this variation could be explained by differences in population characteristics, such as occupation and socioeconomic conditions, and health care supply variables, such as the density of neurologic and orthopedic surgeons and hospital bed supply.[20]

The marked increase in spine surgery rates over time may be related in part to the availability of advanced diagnostic imaging techniques.[9,18] Magnetic resonance imaging (MRI) can provide exquisite anatomic detail of spinal structures and can be extremely valuable in making a definitive diagnosis of many spinal disorders.[13] However, the association between anatomic irregularities in the lumbar spine found by MRI, clinical diagnoses, and outcomes are controversial.[9,11] With improving resolution of MRI, increasingly smaller irregularities can be detected, and incidental or unrelated findings may trigger further diagnostic studies or treatments.[9,19]

In this study, we examine the variation in the rates of advanced diagnostic imaging of the spine among U.S. Medicare beneficiaries in 1996 and 1997. We explore the association between rates of diagnostic imaging and spine surgery across geographic areas and evaluate the proportion of the variability in spine surgery rates that can be explained by differences in diagnostic imaging rates.

Methods

As part of the work on the Dartmouth Atlas of Musculoskeletal Health Care,[21] we used data from Medicare's National Claims History System to study beneficiaries who received diagnostic imaging and surgery of the spine. We excluded those few beneficiaries who were younger than 65 years and the small number enrolled in risk-contract managed care plans. We used data from calendar years 1996 and 1997.

Procedures were identified using Current Procedure Terminology (CPT) codes from a file of all physician claims for a 5% sample of Medicare Part B beneficiaries. CT scan of the cervical, thoracic, or lumbar spine (CPT codes 72125–72133) and MRI of the cervical, thoracic, or lumbar spine (CPT codes 72141–72158) were identified and combined to form a variable for advanced diagnostic imaging of the spine. Spine surgery procedures were identified by CPT codes, indicating any operative procedures of the spine as shown in Table 1. A complete list of CPT codes included in our definition of spine surgery has been published elsewhere.[21]

Hospital referral regions represent health care markets for

Table 1. Codes Used to Identify Procedures

Category	CPT Code	Description	% of Spine Procedures
Lumbar stenosis surgery	63047	Laminectomy, facetectomy and foraminotomy, 1 segment; lumbar	29
	63017	Laminectomy without facetectomy/foraminotomy/diskectomy, >2 segments; lumbar	2
	63005	Laminectomy without facetectomy/foraminotomy/diskectomy, 1/2 segments; lumbar	2
Other common procedures	63030	Laminotomy w/partial facetectomy/foraminotomy/herniated diskectomy, 1 interspace; lumbar	14
	22612	Arthrodesis, posterior/posterolateral, single level; lumbar	9
	22842	Posterior segment instrumentation; 3–6 vertebral segments	6
	22554	Arthrodesis, anterior interbody, w/diskectomy; cervical below C2	5
	63075	Diskectomy, anterior; cervical, 1 interspace	4
	63042	Laminotomy w/partial facetectomy/foraminotomy/herniated diskectomy, re-exploration; lumbar	4
	22845	Anterior instrumentation; 2–3 vertebral segments	3
	63045	Laminectomy, facetectomy and foraminotomy, 1 segment; cervical	2
	63081	Vertebral corpectomy, anterior; cervical, 1 segment	1
	22851	Intervertebral biomechanical device(s) to vertebral defect/interspace	1
	22630	Arthrodesis, posterior interbody w/laminectomy/diskectomy, single interspace; lumbar	1
Uncommon procedures, <1% each	CPT codes: 20250, 20251, 22100, 22101, 22102, 22110, 22112, 22114, 22210, 22212, 22214, 22220, 22222, 22224, 22325, 22326, 22327, 22556, 22558, 22590, 22595, 22600, 22610, 22800, 22802, 22804, 22808, 22810, 22812, 22830, 22840, 22841, 22843, 22844, 22846, 22847, 22849, 22850, 22852, 22855, 22899, 63001, 63003, 63012, 63015, 63016, 63020, 63040, 63046, 63055, 63056, 63064, 63077, 63085, 63087, 63090, 63170, 63180, 63185, 63191, 63194, 63195, 63196, 63197, 63199, 63200, 63250, 63251, 63252, 63265, 63266, 63267, 63270, 63271, 63272, 63275, 63276, 63277, 63280, 63281, 63282, 63285, 63286, 63287, 63290, 63300, 63301, 63302, 63303, 63304, 63305		16

CPT = Current Procedure Terminology.

tertiary medical care. Zip code regions were assigned to local hospitals based on where the plurality of residents was hospitalized. These regions were further aggregated into HRRs based on where most of the residents received major cardiovascular and neurosurgical procedures. A complete description of the methods for defining HRRs has been published elsewhere.[21]

Denominator data for Medicare enrollees was obtained from the Medicare Denominator file. The 1996 and 1997 Medicare enrollee population included those alive and age 65–99 years on June 30, 1996 and June 30, 1997, respectively, and were summed to give person-years. Rates were calculated by dividing procedure rates in each of 306 HRRs by the appropriate denominator population for that geographic area.[21] All rates were adjusted for age, sex, and race, using the indirect method with the 1996–1997 national Medicare population as the standard.[21]

Data Analysis. We used simple linear regression to assess the association between the rates of CT and MRI in different geographic regions and between advanced diagnostic imaging (CT plus MRI) and spine surgery. In the latter analysis, the dependent variable was spine surgery, the independent variable was the rate of advanced diagnostic imaging, and the unit of analysis was the HRR. The primary outcome measure was the coefficient of determination (R^2) derived from this regression. Calculations were done using Stata Software (Stata Statistical Software, release 6.0, 1999; published by Stata Corp., College Station, TX).

A certain amount of correlation between rates of advanced imaging of the spine and spine surgery would be expected to arise from the use of advanced imaging in planning the details of the surgical procedure. Because essentially every patient undergoing spine surgery will have an MRI or CT scan performed before surgery, there will necessarily be more imaging studies performed in areas with higher rates of spine surgery as part of this surgical planning. To assess the magnitude of this "autocorrelation," we created a simulation to account for this factor.[16]

We calculated the correlation between rates of advanced spinal imaging and spine surgery that would result if all patients receiving spine surgery received an imaging study and the rest of the images were randomly distributed across the HRRs. We calculated a hypothetical imaging rate for each HRR that was equal to the rate of spine surgery in that HRR plus a randomly assigned MRI rate chosen from a distribution with the same mean and standard deviation as the observed data. We correlated the simulated imaging rate with the spine surgery rate for each HRR to find the degree of "autocorrelation." The simulation was repeated 200 times, and the distribution of correlation coefficients from the simulation was compared with the actual observed correlation. The probability that the observed correlation occurred from the simulated distribution merely by chance was calculated with a Z-statistic, assuming a normal distribution of the simulated correlation coefficients, and more conservatively, with no distribution assumptions, using the Tchebycheff inequality.[6]

■ Results

The rates of spinal CT varied 7.5-fold; 3.2 per 1000 Medicare enrollees to 23.7 per 1000 enrollees. The rates of spinal MRI varied 7.1-fold; 8.2 per 1000 enrollees to 58.6 per 1000 enrollees. Figure 1 shows the very small but statistically significant positive correlation between the rates of CT and MRI across HRRs ($R^2 = 0.13$; $P = 0.03$). Although the association is weak, it does not show the negative correlation that would be expected from a substitution effect if CT and MRI were substituted for each other based on local availability.

The rates of spine surgery varied 6-fold: 1.45 per 1000 Medicare enrollees to 8.56 per 1000 Medicare enrollees.

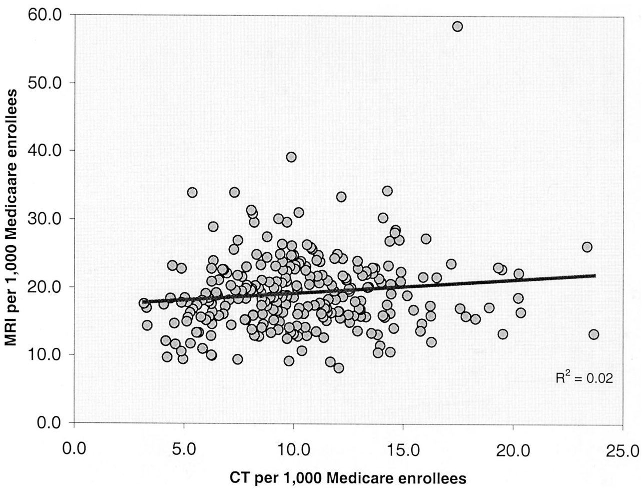

Figure 1. The association between rates of spinal CT and spinal MRI (1996–1997). Each dot represents one of 306 HRRs, and the best fit least squares regression line is shown ($R^2 = 0.02$).

The ratio of the rates of advanced spinal imaging to spine surgery averaged 8.6 persons imaged per surgery and ranged from a low of 3.8 to a high of 21.9. Figure 2 shows the distribution of rates of CT/MRI and of spine surgery across geographic areas in the United States.

Figure 3 shows the association between rates of advanced diagnostic imaging and spine surgery. Areas with higher imaging rates had higher surgery rates. The variation in imaging rates explained about 22% of the variation in spine surgery rates ($R^2 = 0.22$; $P < 0.001$). Eliminating two outlier regions did not change these results. Limiting the spine surgery procedures to just lumbar spinal stenosis procedures yielded similar results. The variation in imaging rates explained about 14% of the variation in lumbar stenosis surgery rates ($R^2 = 0.14$; $P < 0.001$).

The simulation revealed a small average correlation coefficient of 0.16 with a standard deviation of the simulated coefficients of 0.05. The probability that the observed correlation of 0.46 occurred by chance from this distribution was extremely low ($P < 0.01$) assuming a normal distribution and $P < 0.03$ with no distribution assumptions. Only a small part of the association between imaging and surgery rates was the result of "autocorrelation." Whereas imaging rates explained 22% of the total spine surgery rates, based on the simulation "autocorrelation" would explain only 2.6% of the variation in surgery rates.

Discussion

We found a moderate correlation between the use of advanced diagnostic imaging and the rates of spine surgery across geographic areas of the United States. These findings are consistent with prior work by Verrilli and Welch who found an extremely strong correlation between changes in the rates of CT/MRI of the spine and spine surgery among U.S. Medicare beneficiaries over time.[19] A correlation of imaging and spine surgery over time, however, could be the result of secular trends, a general increase in procedure rates over time. Geographic comparisons are much less prone to such general trends. Areas that have high rates of one procedure often demonstrate low rates of other procedures, a phenomenon sometimes referred to as the surgical signature.[21] Therefore, our findings of a geographic correlation adds considerable strength to a direct association between rates of spinal imaging and spine surgery.

The rates of imaging appear to represent a true increased propensity for diagnostic evaluation; areas with higher rates of CT scan also had higher rates of MRI rather than exhibiting a substitution effect of one type of imaging for the other. This finding is also consistent with prior work, which found that MRI was often obtained in addition to, as opposed to instead of, other imaging methods.[1]

For patients with low back pain, a precise anatomic diagnosis is often impossible, which leads to various imprecise diagnoses.[10] Advanced diagnostic imaging is an important part of the workup for some spinal disorders, including infections, tumors, or disorders associated with leg pain and neurologic compromise such as herniated discs and spinal stenosis that may benefit from surgery. Unfortunately, these imaging tests are quite nonspecific. Herniated discs are frequently found in asymptomatic adults: studies have revealed herniated lumbar discs in 21–76% of asymptomatic individuals without any history of low back problems.[2,5,14,17]

The ability for advanced imaging to detect asymptomatic anatomic irregularities creates the potential for overestimation of prevalence of surgically amenable disease in the lumbar spine and a clinical cascade: increasing use of diagnostic imaging detects more abnormalities, which in turn begets increasing efforts to treat disease.[9,19] This cascade may be particularly problematic in spine surgery because the key factor for a successful outcome is said to be proper patient selection,[12] and higher population-based rates of elective spine surgery have been associated with inferior outcomes.[15]

An alternative explanation for our findings is that the higher rates of surgery may be responsible for the higher imaging rates. Areas with higher rates of spine surgery will have more postsurgical patients. Although our simulation model showed that MRIs obtained as part of surgical planning played only a small role in the observed correlation, a greater tendency to perform MRIs in patients who had previously been operated on could account for the observed association. If this hypothesis were true, such downstream consequences would have important implications for anyone trying to understand the true costs of spine surgery.

Some readers may not find a moderate correlation with an R^2 of 0.22 very compelling. It is worth noting, however, that imaging rates alone explained more than twice as much of variation in spine surgery rates as com-

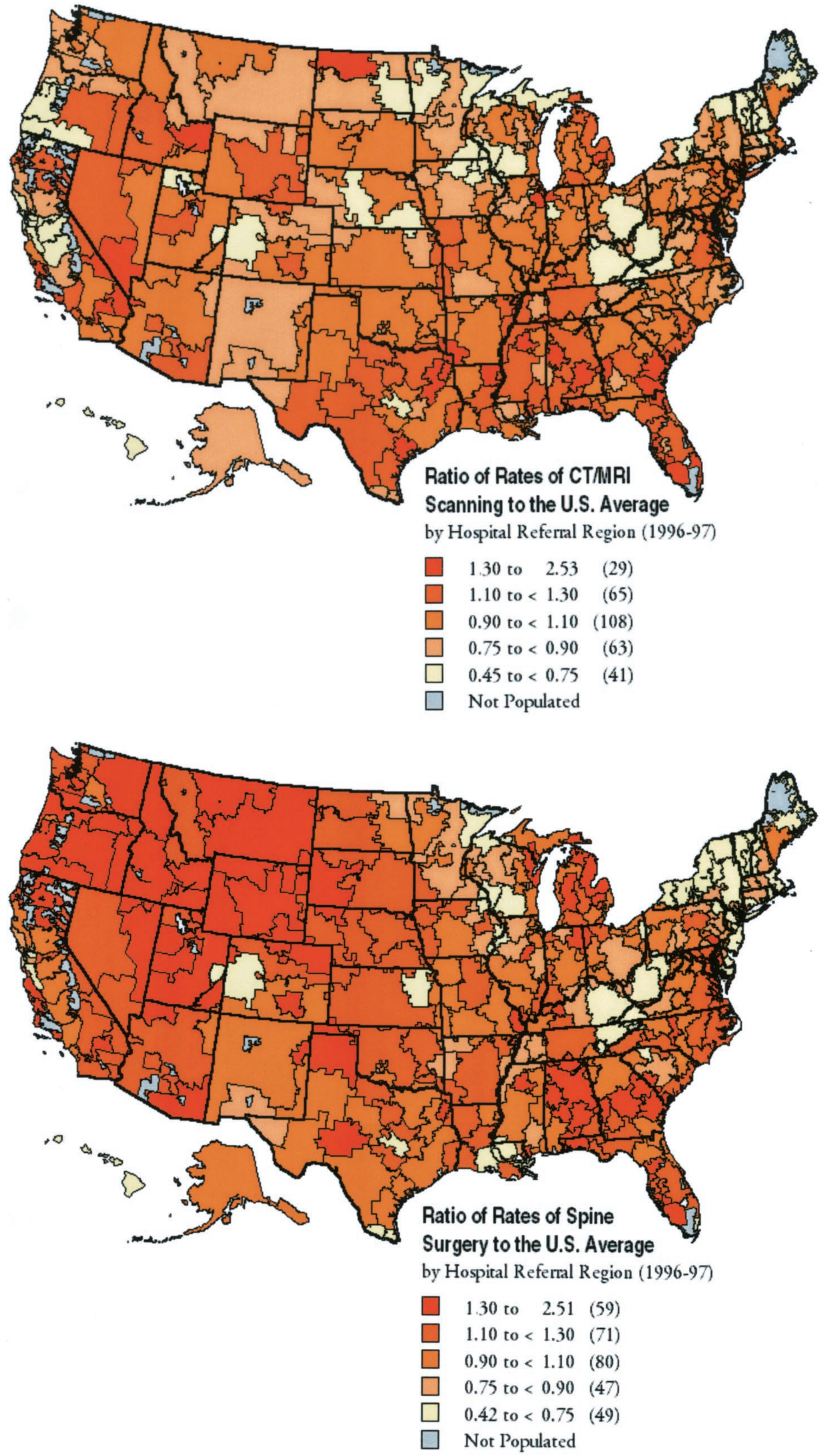

Figure 2. Rates of CT/MRI (upper map) and spine surgery (lower map) across geographic areas. © Trustees of Dartmouth College 2000. (Reprinted with permission from Weinstein J, Birkmeyer J, eds. The Dartmouth Atlas of Musculoskeletal Health Care. Chicago, IL: American Hospital Press, 2000:2–58.)

binations of population characteristics and health care supply variables have explained in prior studies.[20] We expect that there are several other variables at work to explain as complex a phenomenon as the rate of spine surgery within a community. The net effect of these other variables is evident in the variability of the ratio of imaging rates to spine surgery rates. Understanding the causes of this variability represents fertile ground for future work.

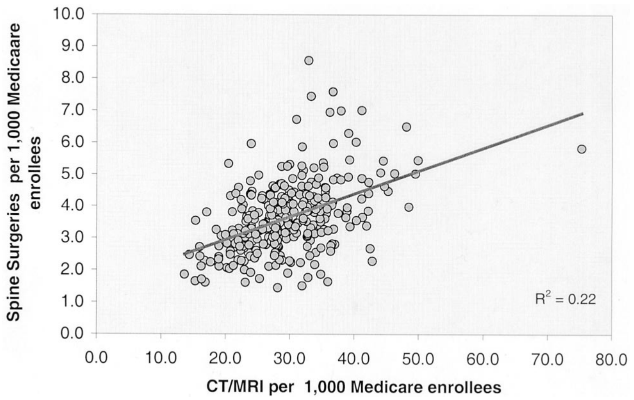

Figure 3. The association between rates of advanced spinal imaging (CT and MRI) and spine surgery (1996–1997). Each dot represents one of 306 HRRs, and the best fit least squares regression line is shown ($R^2 = 0.22$). © Trustees of Dartmouth College 2000. (Reprinted with permission from Weinstein J, Birkmeyer J, eds. The Dartmouth Atlas of Musculoskeletal Health Care. Chicago, IL: American Hospital Press, 2000:2–58.)

The administrative data used in this study do not contain detailed clinical information. As a result, it is impossible to assess the clinical appropriateness of the imaging or surgical decision-making or to determine the "right rate" for these procedures. The high variability, however, argues strongly that at least some of the rates are far from optimal. Without detailed clinical data, we are unable to directly assess the clinical validity of the CPT codes used. However, we used reimbursable procedure codes that are subject to Medicare audits rather than diagnosis codes; they therefore should accurately reflect the care given.

Many authors have warned of the hazards of obtaining advanced imaging tests in patients who do not meet strict clinical criteria.[2,4,9,10,14] Despite these warnings, there remains substantial variability in clinicians' thresholds for obtaining advanced spinal imaging.[7] In one study, only 25% of advanced spinal images met the authors' lax criteria for appropriateness.[3] Our current findings suggest that improved consensus on the use and interpretation of advanced spinal imaging could have an important effect on variation in spine surgery rates.

■ Key Points

- There is marked geographic variation in rates of spine surgery, and differences in patient populations and health care supply have explained only about 10% of this variation.
- Areas with higher rates of advanced spinal imaging (MRI and CT) had higher rates of spine surgery, with imaging rates accounting for 22% of the variability in spine surgery rates.
- MRIs obtained in the patients undergoing surgery accounted for only a small part of the correlation between MRI and spine surgery rates.
- Improved consensus on the use and interpretation of advanced spinal imaging studies could have an important effect on variation in spine surgery rates.

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