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Use Trends and Geographic Variation in Neuroimaging: Nationwide Medicare Data for 1993 and 1998

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BACKGROUND AND PURPOSE: **Powerful tools, including CT and MR imaging, have revolutionized neuroimaging. These are routinely used, but the extent and variation of use has not been studied. Our purposes were to determine the use rates of MR imaging and CT (of spine, brain, or head and neck), myelography, conventional angiography, and MR angiography in diagnosing neurologic disorders; to study trends in use; and to determine regional variations in use.**

METHODS: **We used the National Part B Medicare Database for 1993 and 1998 to compare rates of use for these procedures in 10 geographic regions.**

RESULTS**: In 1993 and 1998, respectively, 13,897 and 19,431 (39.8% increase) neuroimaging procedures were performed per 100,000 Medicare beneficiaries nationwide. Use of brain or head and neck CT (30.4%) and MR imaging (43.6%), spinal CT (3.5%) and MR imaging (83.0%), myelography (56.6%), and conventional angiography (24.3%) increased in 1998 versus 1993. Increases in MR angiography were not assessed, because this procedure was not reimbursable in 1993. Regional use of brain or head and neck and spinal CT and MR studies varied considerably; ratios of highest and lowest rates were 1.38–1.56. Use of MR angiography, myelography, and conventional angiography varied three- to fourfold.**

CONCLUSION**: Use of MR and CT studies of the brain or head and neck and of the spine increased considerably in the Medicare population between 1993 and 1998. Use of conventional invasive procedures such as myelography and angiography increased strikingly, contrary to the expected decline. Regional use varied substantially.**

The costs of health care in the United States continue to escalate at an alarming pace. Researchers have described several factors, including patient sociodemographics, disease severity, provider specialty training, and the method of physician payment, that contribute to these high costs. More recently, the increasing use of newer, high-technology imaging techniques, such as CT and MR imaging, has been placed at the forefront of factors contributing to increasing health care costs. To address these issues meaningfully, the extent of use of such expensive, high-technology imaging studies must be determined. We undertook this study to ascertain the current rates of use for MR imaging, CT, myelography, and conventional angiography in the diagnosis of neurologic disorders; to determine trends in use patterns by comparing the use rates of neuroimaging procedures performed in 1993 and 1998 in the Medicare population; and to investigate geographic variation in use of these neuroimaging procedures.

Methods

We used the national Health Care Financing Administration (HCFA) Physician/Supplier Procedure Summary Master Files for 1993 and 1998. These files contain Part B Medicare billing claims filed by physicians nationally for all procedures. The billing claims are classified by codes for the type of procedure, charges, region, place of service, and specialty of the providing physician. In 1993, there were a total of 36.3 million eligible beneficiaries, of which 2.6 million (7.2%) were enrolled in a Medicare managed-care plan. In 1998, Medicare-eligible beneficiaries had increased to 38.4 million, and the percentage of the population enrolled in Medicare managed-care plans increased to 6.6 million (17.2%). Therefore, although the Medicare population increased between 1993 and 1998, the number of Medicare fee-for-service beneficiaries decreased from 33.6 million in 1993 to 31.9 million in 1998.

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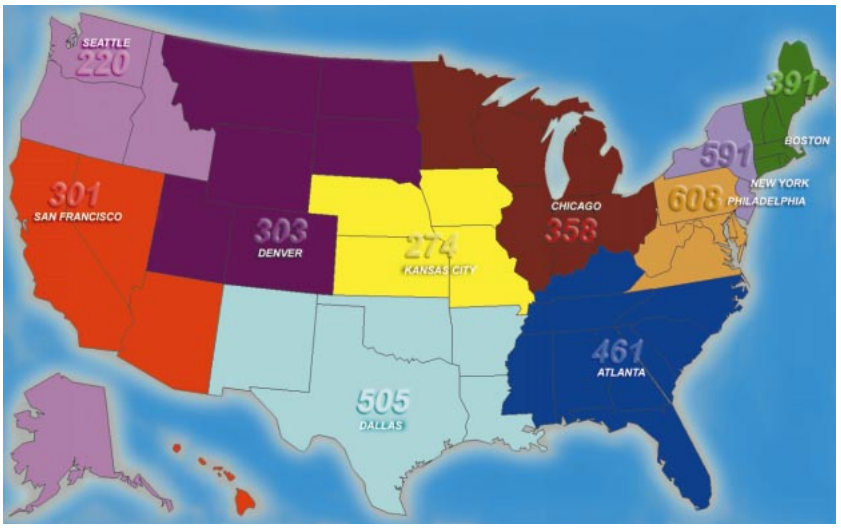

FIG 1. Map of the United States depicts the 10 HCFA regions. The use rate of MR angiography per 100,000 Medicare beneficiaries is shown in each region.

TABLE 1: CPT-4 codes

Procedure	CPT-4 Code
CT, brain or head and neck	70450, 70460, 70470, 70480–70482, 70486–70492
CT, spine	72125–72133
MR imaging, spine	72141, 72142, 72146–72149, 72156–72158
MR imaging, brain or head and neck	70540, 70551–70553
MR angiography, head and neck	70541
Myelography	62284
Angiography, cerebral	75660, 75662, 75665, 75671, 75676, 75680, 75685

For the purpose of this study, we determined the number and type of neuroimaging studies performed by analyzing the Current Procedural Terminology (CPT-4) codes contained in the billing claims filed by physicians (1, 2). We reviewed all CPT-4 codes that represented CT and MR imaging of the brain, head and neck, and spine (Table 1). Claims were grouped into the following categories: 1) CT of the brain or head and neck (12 codes), 2) CT of the spine (nine codes), 3) MR imaging of the brain or head and neck (five codes), and 4) MR imaging of the spine (nine codes). We also reviewed CPT-4 codes for MR angiography (one code) and the supervision and interpretation components of conventional angiography (seven codes). For each category, we determined the total number of procedures performed in 1993 and 1998.

We used the HCFA region codes for the geographic analysis. Ten region codes are named for the city in which the HCFA regional office is located, as follows: Boston, New York, Philadelphia, Atlanta, Chicago, Dallas, Kansas City (Missouri), Denver, San Francisco, and Seattle. These 10 regions include all 50 states and the territories of the United States. The Figure shows the states in each of these regions. One additional code, ''Traveler's Railroad,'' which identifies Medicare recipients by miscellaneous categories (eg, railroad workers) rather than by geographic location, was excluded from the analysis of geographic data.

Use rates per 100,000 beneficiaries were calculated for the total and regional beneficiary populations for each year by dividing the procedure frequency in each record by the total and regional beneficiary counts for the appropriate year and multiplying by 100,000. Because our study represents a complete count of the Medicare fee-for-service population, it may be argued that any difference in rates represents a true difference between populations. One also could consider Medicare beneficiaries as a subpopulation and compute traditional variability statistics. To determine whether regional variation was the result of chance factors, we calculated 99% confidence intervals for the rates.

SAS version 6.12 for Windows was used to combine the datasets for each year, and tables were constructed by using PROC TABULATE to sum frequencies and calculate percentages for the categories of interest (3).

Results

In 1993, 13,897 neuroimaging procedures per 100,000 beneficiaries were performed in the Medicare population nationwide. In 1998, 19,431 neuroimaging procedures per 100,000 beneficiaries were performed nationwide in Medicare patients. This change represents a 39.8% increase in the use rate of all neuroimaging procedures in the Medicare population in 1998 compared with 1993 (Table 2).

CT Use

The use rate of brain or head and neck CT per 100,000 Medicare beneficiaries was 8192 procedures in 1993 compared with 10,679 procedures in 1998; this change represented an increase of 30.4%. The use rate per 100,000 of spine CT was 1094 procedures in 1993 compared with 1132 procedures in 1998; this change represented a modest increase of only 3.5%.

MR Imaging Use

The use rate per 100,000 of brain or head and neck MR imaging was 2976 procedures in 1998 compared with 2072 procedures in 1993, an increase of 43.6%. The use rate per 100,000 of spine MR imaging increased 83.0% during the interval, from 1598 procedures in 1993 to 2924 procedures in 1998.

TABLE 2: Use rates of neuroimaging procedures per 100,000 fee-for-service Medicare beneficiaries

Procedure	1993	1998	Increase (%)
CT, brain or head and neck	8192	10,679	30.4
MR imaging, brain or head and neck	2072	2976	43.6
CT, spine	1094	1132	3.5
MR imaging, spine	1598	2924	83.0
Myelography	265	415	56.6
Angiography	676	840	24.3
MR angiography	NA	465	NA
Total	13,897	19,431	39.8

Note.—NA indicates not applicable.

Myelography and Angiography Use

The use rate per 100,000 Medicare population of myelography was 265 in 1993 compared with 415 procedures in 1998; this change represented an increase of 56.6%. The use rate per 100,000 population of conventional angiography increased by 24.3%, from 676 procedures in 1993 to 840 procedures in 1998.

Geographic Variation in Use

Geographic variation in the use of neuroimaging procedures is shown in Table 3. The national average rate of use of CT of the brain or head and neck in 1998 was 10,679 studies per 100,000 Medicare beneficiaries; the rate ranged from a high of 11,953 in Atlanta to a low of 7903 in Seattle. The national average use rate of CT of the spine in 1998 was 1132 studies per 100,000, ranging from a high of 1360 in Dallas to a low of 874 in San Francisco.

Regional variation in MR studies of the brain or head and neck and spine also was considerable. The national average use rate of MR imaging of the brain or head and neck in 1998 was 2976 studies per 100,000 Medicare beneficiaries; the use rate ranged from a high of 3317 in San Francisco to a low of 2273 in Seattle. The national average use rate of MR imaging of the spine was 2924 studies in 1998 per 100,000 population; the rate ranged from a high of 3349 in Atlanta to a low of 2501 in Kansas City.

The regional variation in use of MR angiography, myelography, and conventional angiography was much greater. The national average use of MR angiography in 1998 was 465 studies per 100,000, ranging from a high of 608 in Philadelphia to a low of 220 in Seattle. This difference represents an almost threefold variation. The national average use for myelography in 1998 per 100,000 was 415, ranging from a high of 591 in San Francisco to a low of 147 in New York. This difference represents a fourfold variation. The national average use of conventional angiography in 1998 per 100,000 was 840; the rate ranged from a high of 1183 in Dallas to a low of 291 in Boston—again, a fourfold variation.

Does the geographic variation in our study represent real differences in rates of use, or is it merely random variation? This type of question arises frequently within the field of statistical quality control. ''Shewart 3σ'' control limits—3 SD confidence bands—often are used in this field to describe the range of chance variation (3). The 3σ confidence intervals for the rates we reported are very small. The 3σ confidence intervals for highest and lowest regions for each procedure listed in Table 4 did not overlap; this finding indicated that the differences were real rather than chance variations.

Discussion

Diagnostic workup of patients with neurologic disorders has been revolutionized during the past 2 decades, with vast advances in technology. CT, MR imaging, and MR angiography have been rapidly assimilated into routine clinical practice. The literature is replete with descriptions of continual technologic improvements leading to faster imaging times, improved resolution, and new applications for diagnosis as well as treatment. Despite these developments, little is known about the use patterns of these high-technology, noninvasive diagnostic procedures or about their effect on the use of more conventional procedures such as myelography and angiography.

Our data reveal a sharp increase (39.8%) in the use of imaging procedures for the diagnosis of neurologic disorders in the Medicare population nationwide between 1993 and 1998. Review of the literature reveals that the vast majority of the neuroimaging studies is performed by radiologists (4–6) and therefore are not self-referred.

There are perhaps many reasons for such a substantial increase in the CT and MR imaging studies of the brain, head, and neck, as well as MR imaging of the spine. First, a marked growth nationwide in the number of CT and MR systems exists, although 1993 and 1998 data cannot be compared directly because no national database records the number of scanners. Second, both CT and MR systems have been upgraded substantially and have had faster imaging capabilities since 1993. For example, helical CT units with faster scanning and expanded clinical applications have been assimilated into clinical practice. Similarly, MR technology has undergone notable improvement, with more

TABLE 3: 1998 use rates of neuroimaging procedures per 100,000 fee-for-service Medicare beneficiaries in the 10 HCFA regions

Region	CT, Brain or Head and Neck	MR Imaging, Brain or Head and Neck	CT, Spine	MR Imaging, Spine	Myelography	Angiography	MR Angiography	Total
Boston	9826	2573	988	2571	207	291	391	16,848
New York	9992	2697	1065	2423	147	350	591	17,266
Philadelphia	11,572	3166	956	2915	253	731	608	20,200
Atlanta	11,953	3282	1262	3349	664	1155	461	22,127
Chicago	10,581	2560	1073	2440	305	916	458	18,334
Dallas	10,438	3216	1360	3322	560	1183	505	20,585
Kansas City	9538	2539	1278	2501	331	895	274	17,357
Denver	7920	2707	969	3072	253	648	303	15,873
San Francisco	8845	3317	874	3058	591	597	301	17,584
Seattle	7903	2273	991	3039	414	443	220	15,284
All regions (nationwide)	10,679	2976	1132	2924	415	840	465	19,432

Note.—Raw totals may differ slightly from sum of components because of rounding of components.

powerful gradients, that allow perfusion and diffusion imaging for patients with suspected stroke, among other new applications. MR spectroscopy has provided an entirely new dimension in the arena of biologic imaging. It could be argued that such advances have provided new, useful information, but they have not led to additional examinations. There has been a tremendous surge in open-magnet imagers, which facilitate the MR examination of patients who are claustrophobic or large. Third, knowledge about the expanded capabilities of CT and MR systems in the study of neurologic disorders has progressively diffused throughout the medical community. Fourth, the increasing longevity of the Medicare population may have contributed to the increased use of imaging studies. In the acute-care setting after therapeutic interventions, patients in neurointensive care units now are monitored more frequently and aggressively with CT and MR imaging. Fifth, patient expectations may have caused the use of imaging procedures to escalate.

Growth of spine MR imaging was rapid (83.0%) compared with a relatively slow growth in spinal CT (3.5%). This finding is not surprising, because the vast majority of spinal imaging examinations in the Medicare population are performed to assess back pain, and MR provides more comprehensive information about disk disease and degenerative changes than does CT. On the other hand, MR imaging of the spine did not appear to be a substitute for myelography, because the use rate of myelography increased by 56.6%. The increase in the use of myelography is puzzling because anecdotal claims by several neuroradiologists, including those in our own practice, indicate a substantial decrease in the use of myelography. Perhaps the code for myelography is being used in error or for some other procedure; this possibility needs further investigation.

Our data also reveal an increase in the use rate of conventional angiography, an invasive procedure, despite the availability of noninvasive MR angiography. The data for the use of MR angiography in 1993 are not available, because it was not a reimbursable procedure then. Nonetheless, it appears that MR angiography has been added to the patient's diagnostic workup, without supplanting conventional angiography. Several reasons for this may be possible. One is that, for successful substitution to occur, rigorous technology assessment must establish the newer technique as the criterion standard; this assessment has not yet occurred. Second, all physicians, particularly neurologists and neurosurgeons, who are primary patient care decision-makers must be appropriately educated. Third, during the learning phase for a new technique such as MR angiography, questionable observations may need clarification, which may require the use of an older tested technique. Our database includes only summary sets and does not allow us to track individual patients to study duplicative procedures.

TABLE 4: 99% confidence intervals for HCFA regions with the highest and lowest use rates per 100,000 fee-for-service Medicare beneficiaries for each neuroimaging category

Procedure	Region with Highest Rate	Highest Rate*	Region with Lowest Rate	Lowest Rate*	Ratio of Highest and Lowest Rates
CT, brain or head and neck	Atlanta	11,953 ± 37	Seattle	7903 ± 80	1.51
CT, spine	Dallas	1360 ± 19	San Francisco	874 ± 16	1.56
MR imaging, brain or head and neck	San Francisco	3317 ± 32	Seattle	2273 ± 44	1.46
MR imaging, spine	Atlanta	3349 ± 21	New York	2423 ± 24	1.38
MR angiography	Philadelphia	608 ± 13	Seattle	220 ± 14	2.76
Myelography	Atlanta	664 ± 9	New York	147 ± 6	4.52
Angiography	Dallas	1183 ± 18	Boston	291 ± 12	4.07

* Data are the regional use rates ± 99% confidence interval.

Thus, we could not determine the percentage of patients who underwent both MR angiography and conventional angiography. Fourth, and perhaps the most important factor, may be the publication of the North American Symptomatic Carotid Endarterectomy Trial (NASCET) and the European Carotid Surgery Trial in 1991, which demonstrated the benefit of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis (70–99% stenosis). NASCET reported a stenosis-dependent effect for the degree of carotid stenosis, as defined at arteriography, and the degree of risk reduction after carotid endarterectomy (7, 8). The results of the Asymptomatic Carotid Atherosclerosis Study also lead to a substantial increase in the number of carotid endarterectomy procedures (9). The increase in conventional angiography may have paralleled the increase in carotid endarterectomy. Noninvasive tests, such as MR angiography and duplex sonography, now are increasingly used to measure carotid stenosis, but the debate about the criterion standard in imaging of carotid stenosis continues (8).

Although geographic variation in the use of a variety of healthcare services has been widely documented, these studies have largely focused on the use of medical and surgical procedures, hospital costs, and resource consumption (10–18). Farrow et al (19) reported marked variation in the use of breast-conserving surgery for localized breast cancer; this variation was not explained by demographic factors. Nattinger et al (20) described similar variations in breast-conserving surgical procedures that were not explained by differences in hospital characteristics.

Several investigators (11, 21) have reported geographic variations in population-based rates of invasive cardiac procedures, including coronary angiography, coronary artery bypass grafting, and percutaneous coronary interventions. Lucas et al (22) reported substantial variation in the use of echocardiography in the Medicare population. They proposed that the geographic variation seen in their study reflects a lack of consensus about how and in whom echocardiography should be used. In northern New England, Wennberg et al (23) reported a geographic 3.5-fold variation in the population-based rate of imaging stress tests and a fourfold variation in the rate of nonimaging stress tests.

Research regarding geographic variation in the use of diagnostic neuroimaging procedures is scare. Our study revealed considerable geographic variations in use. The overall rate of neuroimaging procedures in the Medicare population was the highest in the Atlanta region, where it was 1.5 times higher than the rate in the Seattle region, which ranked the lowest nationally. The Dallas and Philadelphia regions ranked second and third.

Our data show that geographic variation in the rates of use of MR imaging of the brain or head and neck and of the spine was considerable; the high rate–to–low rate ratios were 1.46 and 1.38, respectively. The regional variation in the use of CT of the brain or head and neck and of the spine was more pronounced; the high rate–to–low rate ratios were 1.51 and 1.56, respectively. The San Francisco region ranked the highest in MR imaging of the brain or head and neck, but it was near the lower end for CT studies of the brain or head and neck. On the other hand, the Atlanta and Philadelphia regions had high use of both MR imaging and CT of brain or head and neck but low use of MR angiography and myelography. The San Francisco, Seattle, and Denver regions had high use of spinal MR imaging but ranked low for the use of spinal CT. On the other hand, the Atlanta and Dallas regions had high use of both MR imaging and CT of the spine. No consistent pattern in the use of imaging procedures was observed, unlike the pattern of trends described in the literature for hospitalization. Ashton et al (24) showed that regions with high rates of admission for one condition tended to have high rates for other conditions, and areas with low overall rates tended to have low rates for each of the eight categories of disease.

The geographic variation in the use of MR angiography was striking; the ratio of highest use to lowest use was 2.76. The Philadelphia and New York regions had the highest rate of MR angiography use. Even more striking was the fourfold variation in the use of the traditional invasive proce-

dures, namely myelography and conventional angiography. The Atlanta and Dallas regions ranked the highest in catheter angiography use, while the Atlanta, San Francisco, and Dallas regions had the three highest rates in the use of myelography.

Broad geographic variation may reflect the ease of availability of the newer imaging techniques, although this possibility would not explain the great variation in the use of conventional angiography and myelography. Variation may be influenced by the concentration of teaching hospitals in large metropolitan areas. It also may indicate uncertainty about the best diagnostic study for a given clinical indication, and therefore, it may be influenced by the biases of the physician who orders the diagnostic test. Freeborn et al (25) performed a controlled intervention, using clinical practice guidelines and feedback to reduce variability in primary-care physician use of procedures for imaging of the lumbar spine. Automated radiology-use data were used to compare changes in use rates and variability in intervention and control physician groups over the course of the study. Even when physicians were provided with practice guidelines and feedback about their practice patterns, the practice patterns were not influenced.

Ashton et al (24) reported significant geographic variations in the rates of hospitalization for groups of patients with chronic medical conditions in the Veterans Administration health-care system. This study was characterized by a lack of any influence of self-serving financial incentives, because Veterans Administration physicians are salaried and do not gain financially if they hospitalize more patients. Ashton et al argued that such variations likely reflect regional differences in physicians' practice patterns. The use of diagnostic imaging procedures for a suspected medical condition also may be influenced by the referring physicians' practice patterns. Features of the practice setting and patient expectations and behavior also may be contributing factors. For example, investigators in a multicenter study used data from National Low Back Pain study in an attempt to relate patient characteristics to the use of particular diagnostic imaging examination in patients with persistent low back pain. Nonclinical factors, such as higher annual household income, disability compensation, and male sex were associated with increased use of MR imaging compared with conventional radiography and CT myelography (26).

Our study has several limitations. First, the Medicare database provides complete nationwide information for fewer than 25% of all patients in the United States. The younger population, as well as managed-care Medicare patients, are excluded. This database does provide complete coverage for fee-for-service Medicare beneficiaries; however, this is a substantial segment of the population who have health care to a greater extent. It provides an accurate representation of trends and regional variation in use within this group, and these findings likely can be extrapolated to the population at large. Second, the datasets used were summary datasets with no information on the diagnoses underlying the claims. Therefore, it was impossible to compare changes or regional variation in use for different diagnostic groups. Third, we had no demographic information or comorbidity information for the patients. We could not adjust for demographic or case-mix variation among regions. We also could not assess whether differences in the mean age of the Medicare population in the various HCFA regions could explain the large variation in use of neuroimaging. Fourth, although the literature indicates that healthcare use is related to the resources available, these datasets do not contain information about the number of CT and MR imaging facilities available. In fact, we know of no national database that contains this information.

Conclusion

Our study revealed a considerable increase in the use of MR and CT studies of the brain or head and neck and spine in the Medicare population between 1993 and 1998. Contrary to the expected decline in the use of conventional invasive procedures such as myelography and angiography, our data reveal a parallel increase in their use. A substantial (more than fourfold) regional variation in the use of neuroimaging procedures existed.

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