Changes in the Use and Costs of Diagnostic Imaging Among Medicare Beneficiaries With Cancer, 1999-2006

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Context Emerging technologies, changing diagnostic and treatment patterns, and changes in Medicare reimbursement are contributing to increasing use of imaging in cancer. Imaging is the fastest growing expense for Medicare but has not been examined among beneficiaries with cancer.

Objective To examine changes in the use of imaging and how those changes contribute to the overall cost of cancer care.

Design, Setting, and Patients Analysis of a nationally representative 5% sample of claims from the US Centers for Medicare & Medicaid Services from 1999 through 2008. Patients were Medicare beneficiaries with incident breast cancer, colorectal cancer, leukemia, lung cancer, non-Hodgkin lymphoma, or prostate cancer.

Main Outcome Measures Use and cost of imaging by modality, year, and cancer type.

Results There were 100 954 incident cases of breast cancer, colorectal cancer, leukemia, lung cancer, non-Hodgkin lymphoma, and prostate cancer from 1999 through 2006. Significant mean annual increases in imaging use occurred among all cancer types for positron emission tomography (35.9%-53.6%), bone density studies (6.3%-20.0%), echocardiograms (5.0%-7.8%), magnetic resonance imaging (4.4%-11.5%), and ultrasound (0.7%-7.4%). Conventional radiograph rates decreased or stayed the same. As of 2006, beneficiaries with lung cancer and beneficiaries with lymphoma incurred the largest overall imaging costs, exceeding a mean of $3000 per beneficiary within 2 years of diagnosis. By 2005, one-third of beneficiaries with breast cancer underwent bone scans and half of beneficiaries with lung cancer or lymphoma underwent positron emission tomography scans. Mean 2-year imaging costs per beneficiary increased at a rate greater than the increase in mean total costs per beneficiary for all cancer types.

Conclusion Imaging costs among Medicare beneficiaries with cancer increased from 1999 through 2006, outpacing the rate of increase in total costs among Medicare beneficiaries with cancer.

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In 2008 in the United States, cancer claimed more than half a million lives and cost $228.1 billion, including $93.2 billion in direct medical costs.[1,2] Cancer-related expenditures are expected to grow faster than any other area of health care.[3] As the number of people in the United States affected by cancer increases, per-patient costs for cancer treatment have increased markedly. Most emerging cancer chemotherapeutic agents cost more than $5000 per month of treatment.[4]

Most patients with cancer are enrolled in Medicare, and the policies of Medicare not only directly affect the health expenditures of Medicare beneficiaries, but also indirectly influence the coverage policies of private insurers and Medicaid programs.[5,6] In 2003, the Medicare Prescription Drug, Improvement, and Modernization Act (MMA) reduced reimbursement for cancer chemotherapy. The MMA was enacted in response to substantial disparities between costs and reimbursement rates for cancer drugs, after investigations by the US Department of Health and Human Services and other government entities.[7-9] Although the reductions in reimbursement sparked concerns about access to care, overall access to specialty care,[10] and specifically to cancer treatment, was not adversely affected in subsequent years.[11]

A possible explanation for unchanged access in the presence of reduced reimbursement for chemotherapy is substitution of other types of medical services.[11,12] For example, costs for diagnostic imaging are among the fastest growing Medicare expenses.[10] The types and costs of imaging, including costly new imaging modalities, among Medicare beneficiaries with cancer have not been examined previously. Therefore, we studied changes in the use and costs of imaging and examined how those changes have influenced the cost of cancer care.

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METHODS

We obtained administrative claims data for a national 5% sample of Medicare beneficiaries for 1997 through 2008 from the Centers for Medicare & Medicaid Services (CMS). The data include inpatient, outpatient, carrier, skilled nursing facility, home health, hospice, and durable medical equipment claims and the corresponding denominator files. Medicare inpatient files contain institutional facility claims covered under Medicare Part A, and outpatient files contain claims by institutional outpatient providers (eg, hospital outpatient departments, ambulatory surgery centers). The carrier files contain provider claims for services covered under Medicare Part B, and durable medical equipment claims include medical equipment purchased for use in a patient's home or an institution serving as a home. The denominator files contain beneficiary identifiers, sex, race/ethnicity, birth dates, dates of death, zip codes, and information about program eligibility and enrollment. The institutional review board of the Duke University Health System approved this study.

Study Population

The study population included Medicare beneficiaries living in the United States for whom a diagnosis of breast cancer, colorectal cancer, leukemia, lung cancer, non-Hodgkin lymphoma, or prostate cancer was listed on an inpatient, outpatient, or carrier claim between 1999 and 2006 (eTable 1, available at http://www.jama.com). We chose these cancers because of their high prevalence among elderly patients and the routine use of imaging in their diagnosis and staging. We used the 2007 and 2008 claims data for ascertainment of follow-up resource use and costs only. We defined the date of disease onset as the date of the earliest observed cancer claim. For a case to be considered a new-onset or incident case, we required beneficiaries to be eligible for fee-for-service Medicare for at least 2 years before the date of disease onset and to have no claims for any type of cancer during that time. In addition, we required that beneficiaries have at least 1 additional claim for the same cancer type within 60 days of the first claim. We limited the sample to beneficiaries aged 67 years or older to minimize the risk of misclassifying prevalent cases as incident. Inclusion in the analysis was conditional on survival for at least 60 days from the date of disease onset.

Diagnostic Imaging

We measured the number of imaging procedures undergone by each Medicare beneficiary by counting the number of diagnostic imaging claims in the 2-year period after disease onset. We organized claims for imaging into 8 categories: bone density studies, computed tomography (CT), echocardiography, magnetic resonance imaging (MRI), nuclear medicine, positron emission tomography (PET), radiography, and ultrasound (eTable 2). To avoid double counting, we included only global and professional claims (ie, those containing Healthcare Common Procedure Coding System [HCPCS] modifier code 26). We counted CT scans that were concurrent with PET scans as PET scans.

To obtain 2-year diagnostic imaging costs, we summed line-item Medicare reimbursement amounts from all outpatient and carrier claims with a *Current Procedural Terminology* (*CPT*) code or HCPCS code for an imaging procedure (eTable 2). Before the implementation of the Medicare Outpatient Prospective Payment System (OPPS) in August 2000, line-item payment amounts were not available for outpatient facility claims. To estimate line-item payment amounts before this date, we obtained the average nonzero payment for each line-item imaging claim paid in 2000 under the OPPS system (August through December 2000). We then matched these values by *CPT* or HCPCS code to pre-OPPS 1999 and 2000 line-item claims, adjusting for inflation as needed. Eleven codes were not present in the post-OPPS data, representing 0.3% of imaging claims in the pre-OPPS period. We set the payment amounts for these claims to zero.

To place diagnostic imaging costs in the context of total Medicare spending, we obtained 2-year costs to Medicare for each beneficiary by summing the Medicare reimbursement amounts recorded on each inpatient, outpatient, home health, skilled nursing, hospice, durable medical equipment, and professional service claim. We report all cost values in 2008 US dollars.

Statistical Analysis

For characteristics of patients in the incident cohorts, we present categorical variables as frequencies and age as a continuous variable with medians and interquartile ranges. Medicare beneficiaries report race/ethnicity at the time of enrollment. In this analysis, we used the categories black and white and combined all others and missing values as other/unknown.[13] We identified comorbid conditions using validated coding algorithms.[14,15] Specifically, we searched all inpatient, outpatient, and carrier claims for 365 days before the date of disease onset for evidence of cerebrovascular disease, chronic obstructive pulmonary disease, congestive heart failure, coronary heart disease, dementia, diabetes mellitus, hypertension, peripheral vascular disease, and renal disease (eTable 3).

We tested for associations between each categorical variable and the year of diagnosis using Cochran-Mantel-Haenszel χ^2 tests (row mean score statistic), stratifying by cancer type. We used an analogous test for continuous variables (ie, the Kruskal-Wallis test) to test for associations between age and year of diagnosis, stratifying by cancer type. We tabulated imaging rates as the mean number of imaging procedures per beneficiary by year of diagnosis in the 2 years after diagnosis from 1999 through 2006. For each cancer type and year of diagnosis, we calculated the percentage of total costs attributable to imaging procedures and plotted the percentage of beneficiaries who received 1 or more procedures in each imaging category.

We express changes in imaging rates as mean annual rate increases in the number of procedures per beneficiary from 1999 through 2006. We express changes in costs as mean annual rate increases in costs per beneficiary from 1999 through 2006. We estimated the mean annual increases separately for each imaging modality by using a generalized linear model with a Poisson count distribution and log link[15] for counts and a log link and normal distribution for costs. All generalized linear models controlled for age, demographic characteristics, and comorbid conditions. We obtained mean annual rates and corresponding 95% confidence intervals through exponentiation of the estimated coefficients and 95% confidence limits associated with the year of diagnosis. We used SAS version 9.2 (SAS Institute Inc, Cary, North Carolina) for all analyses, and we considered $P < .05$ to be statistically significant.

Table 1. Baseline Characteristics of the Study Population[a]

Characteristic	Year of Diagnosis 1999 (n = 12 393)	2003 (n = 12 317)	2006 (n = 12 843)	Stratified *P* Value[b]
Cancer type, No. (%)				
Breast cancer	2994 (24.2)	2812 (22.8)	3070 (23.9)	
Colorectal cancer	2475 (20.0)	2379 (19.3)	2185 (17)	
Leukemia	373 (3.0)	404 (3.3)	438 (3.4)	
Lung cancer	1936 (15.6)	2116 (17.2)	2114 (16.5)	
Non-Hodgkin lymphoma	610 (4.9)	634 (5.1)	824 (6.4)	
Prostate cancer	4005 (32.3)	3972 (32.2)	4212 (32.8)	
Age, median (interquartile range), y	76 (71-81)	76 (71-81)	76 (71-81)	.04
Male, No. (%)	6556 (52.9)	6643 (53.9)	6799 (52.9)	.59
Race, No. (%)				
Black	995 (8.0)	1016 (8.2)	1025 (8.0)	.06
Nonblack	11 398 (92.0)	11 301 (91.8)	11 818 (92.0)	
Comorbid conditions, No. (%)				
Cerebrovascular disease	1720 (13.9)	1870 (15.2)	2161 (16.8)	<.001
Chronic obstructive pulmonary disease	3117 (25.2)	3364 (27.3)	3546 (27.6)	<.001
Congestive heart failure	1797 (14.5)	1834 (14.9)	1850 (14.4)	.99
Coronary heart disease	3746 (30.2)	3851 (31.3)	4148 (32.3)	<.001
Dementia	406 (3.3)	438 (3.6)	481 (3.7)	<.001
Diabetes mellitus	2475 (20.0)	2887 (23.4)	3475 (27.1)	<.001
Hypertension	6943 (56.0)	8010 (65.0)	9279 (72.2)	<.001
Peripheral vascular disease	1679 (13.5)	1969 (16.0)	2357 (18.4)	<.001
Renal disease	352 (2.8)	562 (4.6)	875 (6.8)	<.001

[a] eTable 4 shows data for all years in the study period.
[b] All analyses were stratified by cancer type. We used Kruskal-Wallis tests to test for associations between age and year of diagnosis. We used Cochran-Mantel-Haenszel tests to test for linear associations between categorical variables and year of diagnosis.

RESULTS

There were 100 954 incident cases of breast cancer, colorectal cancer, leukemia, lung cancer, non-Hodgkin lymphoma, and prostate cancer from 1999 through 2006. Median age at incidence was 76 years (interquartile range, 71-81) from 1999 through 2006, and a little more than half of the patients were men. The percentages of men and black patients remained similar during the study period. With the exception of congestive heart failure, the frequency of comorbid conditions increased over time. Diabetes mellitus and hypertension had the greatest increases, from 20.0% to 27.1% and 56.0% to 72.2%, respectively ($P < .001$ for both comparisons) (TABLE 1).

The mean number of imaging procedures per beneficiary during a 2-year period varied substantially by modality and cancer type (TABLE 2). Patients with lymphoma or lung cancer underwent the largest number of imaging procedures. By 2006, the average patient with lung cancer had 11 conventional radiographs, 6 CT scans, a PET scan, a separate nuclear medicine test, an MRI, 2 echocardiograms, and an ultrasound, all within 2 years of diagnosis. Similarly, the average patient with lymphoma in 2006 had 8 conventional radiographs, 6 CT scans, a PET scan, a nuclear medicine test, an MRI, 3 echocardiograms, and 3 ultrasounds within 2 years of diagnosis.

In each subset of cancer type, the number of PET scans per beneficiary increased at a mean annual rate of 35.9% to 53.6%. Patients with lung cancer or lymphoma had the largest increase in PET use, accompanied by an overall reduction of conventional nuclear medicine imaging tests in both cancer types and stabilized CT in the lymphoma group. Increases also occurred in the use of bone density scans (6.3%-20.0%), echocardiograms (5.0%-7.8%), MRI (4.4%-11.5%), and ultrasound (0.7%-7.4%). Use of CT increased in all cancer subgroups (4.5%-7.6%) except lymphoma. Use of conventional radiographs decreased or stayed the same in each cancer subgroup but remained the most heavily used imaging modality for all diagnoses, at a mean of 4.3 to 12.2 procedures per patient (Table 2).

Trends in the use of 1 or more imaging procedures per patient (FIGURE) were consistent with mean imaging rates per beneficiary (Table 2). Most patients (80% to 98%) received at least 1 conventional radiograph, with roughly 80% of patients with prostate cancer and 98% of patients with lung cancer receiving 1 or more radiographs. Roughly 90% of patients with lung cancer or lymphoma received a dedicated CT scan, not including PET/CT. The percentage of patients with breast cancer who received 1 or more bone density scans more than doubled between 1999 and 2006 from 16% to 37%. By 2005, roughly half of patients with lung cancer (57%) or lymphoma (46%) underwent PET.

Overall 2-year costs per beneficiary increased annually for all cancer types at a mean annual rate of 1.8% to 4.6%

Table 2. Mean Imaging Procedure Counts per Beneficiary by Cancer Type and Year of Diagnosis During 2 Years of Follow-up[a]

	Procedures/Beneficiary, Mean No. (Beneficiaries, No.)			
	Diagnosed in 1999	Diagnosed in 2003	Diagnosed in 2006	Annual Increase, % (95% CI)
Breast cancer				
Bone density study	0.2 (561)	0.3 (970)	0.5 (1443)	16.5 (15.3 to 17.8)
CT scan	1.2 (3731)	2.0 (5580)	2.2 (6739)	7.6 (6.7 to 8.6)
Echocardiogram	1.0 (2853)	1.5 (4297)	1.7 (5359)	7.8 (6.7 to 8.9)
MRI scan	0.3 (829)	0.5 (1515)	0.6 (1974)	11.0 (9.6 to 12.5)
Nuclear medicine	1.0 (2936)	1.3 (3751)	1.4 (4367)	5.2 (4.4 to 6.0)
PET scan	<0.1 (5)	0.1 (327)	0.2 (681)	53.6 (48.9 to 58.4)
Radiograph	6.8 (20 380)	7.4 (20 701)	6.6 (20 132)	–0.8 (–1.3 to –0.3)
Ultrasound	1.0 (3103)	1.5 (4081)	1.6 (4947)	5.8 (5.0 to 6.6)
Colorectal cancer				
Bone density study	0.1 (186)	0.1 (207)	0.1 (242)	6.3 (4.0 to 8.8)
CT scan	3.3 (8056)	4.3 (10 318)	4.8 (10 553)	5.9 (5.2 to 6.6)
Echocardiogram	1.4 (3576)	2.0 (4832)	2.1 (4686)	5.5 (4.4 to 6.6)
MRI scan	0.3 (633)	0.4 (971)	0.4 (959)	7.9 (6.1 to 9.7)
Nuclear medicine	0.6 (1586)	0.9 (2246)	1.0 (2101)	5.2 (4.0 to 6.5)
PET scan	<0.1 (40)	0.2 (423)	0.3 (711)	41.6 (38.0 to 45.2)
Radiograph	8.3 (20 577)	8.0 (18 980)	7.9 (17 361)	–1.1 (–1.9 to –0.4)
Ultrasound	1.1 (2786)	1.3 (3183)	1.5 (3197)	3.4 (2.5 to 4.4)
Leukemia				
Bone density study	0.1 (27)	0.1 (41)	0.1 (52)	7.8 (1.6 to 14.3)
CT scan	1.7 (640)	2.4 (973)	3.1 (1367)	7.6 (5.4 to 9.9)
Echocardiogram	1.8 (676)	2.3 (945)	2.3 (1015)	5.2 (2.8 to 7.7)
MRI scan	0.2 (87)	0.3 (135)	0.5 (225)	11.5 (7.2 to 15.9)
Nuclear medicine	0.6 (221)	0.7 (294)	0.7 (309)	4.0 (0.9 to 7.2)
PET scan	<0.1 (2)	<0.1 (9)	0.1 (27)	36.6 (20.6 to 54.7)
Radiograph	7.9 (2951)	7.6 (3055)	7.3 (3201)	–0.5 (–2.4 to 1.4)
Ultrasound	1.1 (395)	1.4 (582)	1.5 (654)	3.0 (0.7 to 5.3)
Lung cancer				
Bone density study	<0.1 (70)	0.1 (129)	0.1 (137)	7.2 (3.8 to 10.7)
CT scan	4.3 (8250)	5.7 (11 974)	5.8 (12 266)	4.5 (3.8 to 5.1)
Echocardiogram	1.4 (2751)	1.9 (4016)	2.2 (4602)	5.0 (3.8 to 6.1)
MRI scan	0.7 (1311)	0.9 (1910)	1.1 (2267)	6.7 (5.4 to 7.9)
Nuclear medicine	1.2 (2385)	1.3 (2772)	1.2 (2490)	–1.6 (–2.4 to –0.7)
PET scan	<0.1 (87)	0.6 (1329)	1.0 (2177)	35.9 (34.1 to 37.8)
Radiograph	12.1 (23 432)	12.2 (25 806)	11.4 (24 178)	–1.1 (–1.7 to –0.5)
Ultrasound	0.9 (1647)	1.1 (2287)	1.3 (2666)	4.1 (3.0 to 5.2)
Non-Hodgkin lymphoma				
Bone density study	0.1 (64)	0.1 (69)	0.2 (138)	10.6 (6.4 to 14.8)
CT scan	7.1 (4331)	8.1 (5112)	6.3 (5207)	–0.9 (–2.0 to 0.1)
Echocardiogram	1.8 (1081)	2.6 (1664)	2.8 (2325)	5.4 (3.6 to 7.2)
MRI scan	0.5 (314)	0.8 (499)	0.8 (683)	4.4 (1.6 to 7.3)
Nuclear medicine	1.2 (715)	1.3 (849)	1.0 (835)	–3.1 (–4.9 to –1.3)
PET scan	<0.1 (12)	0.7 (451)	1.1 (916)	38.7 (35.0 to 42.4)
Radiograph	8.0 (4882)	8.0 (5094)	7.8 (6412)	–1.8 (–3.0 to –0.5)
Ultrasound	1.2 (722)	1.5 (935)	2.5 (2099)	7.4 (5.3 to 9.5)
Prostate cancer				
Bone density study	<0.1 (93)	0.1 (232)	0.1 (384)	20.0 (17.1 to 23.1)
CT scan	1.5 (5918)	2 (7879)	2.1 (8665)	4.6 (3.9 to 5.3)
Echocardiogram	1.2 (4639)	1.6 (6422)	1.8 (7407)	5.5 (4.6 to 6.4)
MRI scan	0.3 (1132)	0.4 (1765)	0.5 (2047)	6.2 (5.0 to 7.5)
Nuclear medicine	1.2 (4778)	1.5 (5798)	1.5 (6372)	2.5 (1.9 to 3.1)
PET scan	<0.1 (6)	<0.1 (55)	<0.1 (148)	40.5 (33.3 to 48.0)
Radiograph	4.7 (18 957)	4.7 (18 560)	4.3 (18 215)	–2.2 (–2.8 to –1.5)
Ultrasound	1.7 (6903)	1.9 (7652)	2 (8488)	0.7 (0.2 to 1.3)

Abbreviations: CI, confidence interval; CT, computed tomography; MRI, magnetic resonance imaging; PET, positron emission tomography.
[a] eTable 5 shows data for all years in the study period.

during the study period. For all cancer types, mean 2-year imaging costs per beneficiary increased between 5.1% and 10.3% per year, at least double the rate of increase in overall costs (TABLE 3). Imaging costs for all cancers studied also accounted for a larger percentage of total costs in the 2006 cohort than in all previous years.

COMMENT

Combined direct costs associated with breast cancer, colorectal cancer, leukemia, lung cancer, non-Hodgkin lymphoma, and prostate cancer accounted for 57% of all cancer costs in 2004,[3] suggesting that our study population represented the majority of cancer costs borne by Medicare beneficiaries. We found that the use of diagnostic imaging increased among all incident cancer cohorts from 1999 through 2006. Use of the newest imaging modality, PET, increased most markedly. These findings are consistent with other studies, which have consistently documented a rapid increase in the use of imaging among Medicare beneficiaries and other populations.[10,16-18] In our study, the cost of cancer care increased 1.8% to 4.6% per year, with imaging growing at 5.1% to 10.3% per year. Thus, imaging represented a larger share of total costs in 2006 than in 1999.

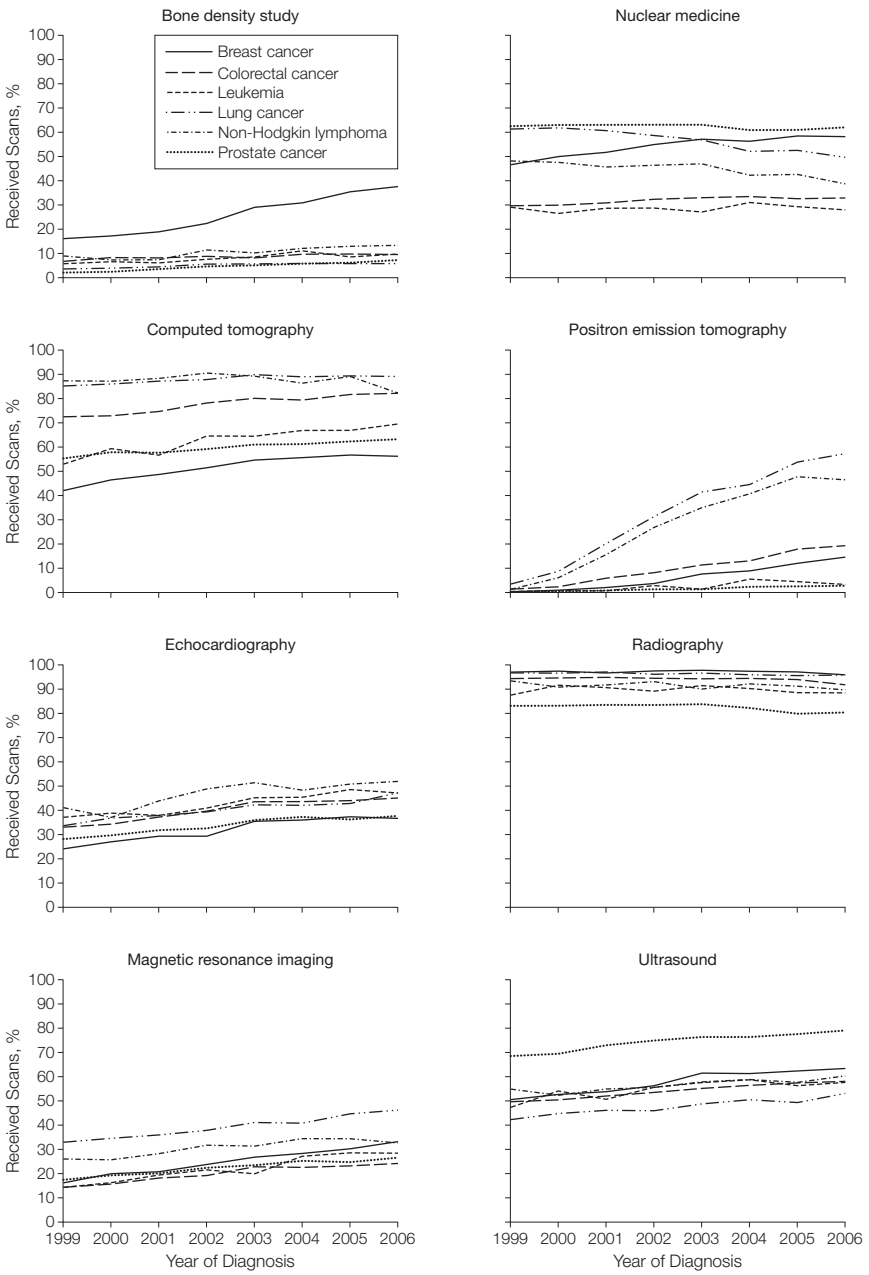
Although there is little debate that imaging use has increased rapidly, there is less agreement about what the increases mean for Medicare beneficiaries and the Medicare program. Concerns have included the high profit margins associated with imaging, payment incentives for imaging, and the notion that rapid adoption of new medical devices and imaging technologies may be influenced by US Food and Drug Administration approval requirements that are less stringent than requirements for new drugs.[5,10,19,20] Advanced imaging services are among the most frequent sources of competition among hospitals and physicians,[21] and the use of advanced imaging appears to be additive in nature rather than a substitute for conventional imaging methods.[22] However, advanced imaging methods,

such as PET, have been used to assess early response to costly biologic therapy in breast cancer.[23,24] Likewise, image-guided biopsy is more cost-effective than surgical biopsy in the evaluation of abnormal mammogram results.[25] Some researchers have suggested that increasing imaging rates reflect the greater value of health care[26] or an enhanced ability to help patients.[27]

Positron emission tomography is particularly noteworthy for its expansion of reimbursement and its potential impact on care and outcomes. A study of a large private insurer in California from 2000 through 2004 found a nearly 4-fold increase in PET use.[18] We found a 6-fold to 14-fold increase in PET use among Medicare beneficiaries with cancer during the same period. This rapid increase is largely due to the expanding number of indications for PET since the technology was approved in 1998 for the characterization of single pulmonary nodules and initial staging of non–small cell lung cancer.[28] Use of PET in colorectal cancer and lymphoma was initially approved in 1999. In 2001, use of PET was expanded to include diagnosis, staging, and restaging for colorectal cancer, lung cancer, and lymphoma. In late 2002, PET was approved for staging and restaging for locally advanced or metastatic breast cancer. Early rates of PET use correlated with the timing of Medicare approval for each cancer type. In January 2005, Medicare approved the use of PET in all cancers, provided the use was part of a prospective clinical trial designed to aid in care management. The 2007 National Comprehensive Cancer Network task force report on PET/CT use in cancer recommended the use of PET in lymphoma, non–multiply metastatic non–small cell lung cancer, and locally advanced or suspected metastatic breast and colorectal cancers.[29] For patients with these cancers, the proportion of patients receiving 1 or more PET scans increased substantially between 1999 and 2006.

It is unclear whether the rapid increase in use of advanced imaging is a result of the novelty of the technologies, better outcomes, or a shift to new revenue sources after the enactment of the MMA. Previously observed patterns of technology diffusion may offer some insight into the dynamics of advanced imaging modality adoption. A study of imaging in the Medicare population before 2001 found a negative correlation between the growing use of an imaging modality and the time since its initial introduction. The same study found that geographic regions with early adoption of imaging experienced slower subsequent increases in

Figure. Trends in the Use of Imaging Modalities by Selected Cancer Types



The vertical axis indicates the percentage of patients who received 1 or more of the imaging procedures within 2 years of diagnosis. Trends are shown separately for patients diagnosed with breast cancer, colorectal cancer, leukemia, lung cancer, lymphoma, or prostate cancer.

Table 3. Imaging Procedure Costs Per Patient by Cancer Type and Year of Diagnosis During 2 Years of Follow-up[a]

	Cost, Mean (SD), $[b]			
	Diagnosed in 1999	Diagnosed in 2003	Diagnosed in 2006	Annual Increase, % (95% CI)
Breast cancer				
Total costs	23 549 (26 087)	31 413 (33 034)	33 609 (33 375)	4.1 (3.5-4.7)
Imaging costs	840 (868)	1462 (1631)	1681 (1811)	9.9 (9.2-10.6)
Imaging costs/total costs, %	3.6	4.7	5.0	
Colorectal cancer				
Total costs	43 655 (38 724)	51 715 (47 969)	56 839 (51 816)	3.4 (2.9-4.0)
Imaging costs	1009 (1053)	1686 (1973)	1918 (1994)	10.3 (9.5-11.1)
Imaging costs/total costs, %	2.3	3.3	3.4	
Leukemia				
Total costs	39 423 (53 168)	46 174 (55 756)	46 471 (53 765)	3.0 (1.2-4.9)
Imaging costs	730 (837)	958 (1163)	1257 (1349)	8.4 (6.5-10.3)
Imaging costs/total costs, %	1.9	2.1	2.7	
Lung cancer				
Total costs	45 830 (36 549)	55 540 (40 852)	55 934 (42 426)	2.6 (2.1-3.2)
Imaging costs	1482 (1601)	2903 (2846)	3260 (2756)	9.5 (7.1-12.0)
Imaging costs/total costs, %	3.2	5.2	5.8	
Non-Hodgkin lymphoma				
Total costs	41 603 (37 774)	60 421 (49 660)	63 411 (54 207)	4.6 (3.6-5.7)
Imaging costs	1934 (1765)	3658 (3455)	3667 (3189)	8.8 (7.6-10.0)
Imaging costs/total costs, %	4.6	6.1	5.8	
Prostate cancer				
Total costs	25 445 (26 766)	31 034 (30 582)	31 127 (33 082)	1.8 (1.3-2.2)
Imaging costs	875 (840)	1183 (1196)	1304 (1213)	5.1 (4.6-5.6)
Imaging costs/total costs, %	3.4	3.8	4.2	

Abbreviation: CI, confidence interval.
[a] eTable 6 shows data for all years in the study period.
[b] All cost values are reported in 2008 US dollars.

use compared with regions with later adoption of the same technologies.[27] A similar pattern emerged in our study. Patients with lymphoma had the most CT scans of any cancer group at the beginning of the study period and experienced the slowest increase in use during the study period. Similarly, patients with lung cancer had the most MRI scans in 1999 and experienced the slowest increase in MRI use during the study period. Positron emission tomography was still relatively new during the study period and underwent rapid increase in use throughout the study period, suggesting that PET use in the Medicare cancer population has not reached market saturation.

Although imaging costs have increased rapidly, as of 2006 they accounted for a small fraction of total Medicare cancer costs, making up less than 6% of total costs in all cancer types. Nevertheless, the federal government has been cautious about increases in imaging costs. The health reform legislation enacted by Congress in March 2010 aims to reduce imaging expenditures by reducing payment for imaging tests. The effects and consequences of legislative efforts to control medical imaging rates and costs among Medicare beneficiaries will likely become an increasingly active area of research.

Our study has some limitations. The analysis relied on claims data to identify incident cases. Although codes for leukemia in the *International Classification of Diseases, Ninth Revision, Clinical Modification*, distinguish between new and relapsed cases, information about the diagnosis of new-onset vs recurrent cancers was not available for other cancer types. Therefore, some incident cancers included in the study may represent relapsed cases. The analysis included imaging studies performed for any reason among patients with a recent diagnosis of cancer, and thus reflected imaging in these patients for both cancer and non–cancer-related purposes. Costs for noninjectable prescription drugs are not included in the Medicare standard analytic files, so the costs of oral prescription medications such as oral chemotherapy or supportive medications (eg, medications for nausea or pain) are excluded. Medicare reimbursement of PET for use in leukemia was not approved until 2005, which is reflected in the minimal use of PET imaging in these patients before 2003. Use of PET in leukemia before 2003 likely reflects non–cancer-related indications in neurology or cardiology.[30,31] A lack of data regarding stage and severity of disease at diagnosis prevented assessment of relationships between imaging and outcomes. In addition, it is possible that changes in screening or early diagnosis may have resulted in changes in imaging rates or costs during the study period. However, observation of similar trends in imaging across multiple cancer types makes this an unlikely explanation of the results.

CONCLUSION

Imaging costs among Medicare beneficiaries with cancer increased from 1999 through 2006, outpacing the rate of increase in total costs among Medicare beneficiaries with cancer.

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Study concept and design: Dinan, Curtis, Patz, Abernethy, Shea.
Acquisition of data: Shea.
Analysis and interpretation of data: Dinan, Curtis, Hammill, Patz, Abernethy, Shea, Schulman.
Drafting of the manuscript: Dinan, Shea.
Critical revision of the manuscript for important intellectual content: Dinan, Curtis, Hammill, Patz, Abernethy, Schulman.
Statistical analysis: Dinan, Curtis, Hammill, Shea.
Administrative, technical, or material support: Dinan, Curtis, Schulman.
Study supervision: Patz, Schulman.
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Online-Only Material: eTables 1 through 6 are available at http://www.jama.com.

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