Advanced Imaging Among Health Maintenance Organization Enrollees With Cancer

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Abstract

Purpose: Fee-for-service (FFS) Medicare expenditures for advanced imaging studies (defined as computed tomography [CT], magnetic resonance imaging [MRI], positron emission tomography [PET] scans, and nuclear medicine studies [NM]) rapidly increased in the past two decades for patients with cancer. Imaging rates are unknown for patients with cancer, whether under or over age 65 years, in health maintenance organizations (HMOs), where incentives may differ.

Materials and Methods : Incident cases of breast, colorectal, lung, prostate, leukemia, and non-Hodgkin lymphoma (NHL) cancers diagnosed in 2003 and 2006 from four HMOs in the Cancer Research Network were used to determine 2-year overall mean imaging counts and average total imaging costs per HMO enrollee by cancer type for those under and over age 65.

Results: There were 44,446 incident cancer patient cases, with a median age of 75 (interquartile range, 71-81), and 454,029 imaging procedures were performed. The mean number of images per patient increased from 7.4 in 2003 to 12.9 in 2006. Rates of imaging were similar across age groups, with the exception of greater use of echocardiograms and NM studies in younger patients with breast cancer and greater use of PET among younger patients with lung cancer. Advanced imaging accounted for approximately 41% of all imaging, or approximately 85% of the \$8.7 million in imaging expenditures. Costs were nearly \$2,000 per HMO enrollee; costs for younger patients with NHL, leukemia, and lung cancer were nearly \$1,000 more in 2003.

Conclusion: Rates of advanced imaging appear comparable among FFS and HMO participants of any age with these six cancers.

Introduction

Medical imaging for Medicare beneficiaries represented one of the fastest growing categories of health care expenditures in 2006, accounting for \$14 billion in expenditures, or a 13% average annual rate of increase since 2000.^{1,2} More than half of the imaging expenditures (54%, or \$7.6 billion) in 2006 were for advanced imaging modalities (defined as magnetic resonance imaging [MRI], nuclear medicine [NM], computed tomography [CT], and positron emission tomography [PET]). In their reports, the Government Accountability Office and the Medicare Payment Advisory Committee suggested the growth in volume and complexity of advanced imaging might be attributable to inappropriate use.³⁻⁶ One particularly concerning explanation for increasing expenditures was “self-referral”: when a physician refers a patient for imaging to an imaging facility in which the ordering physician (or their family member[s]) have a financial interest.

As a consequence of this concern, Dinan et al⁷ examined the rate of advanced imaging among Medicare beneficiaries with cancer from 1999 to 2006. The authors hypothesized that physicians were ordering new, higher cost diagnostic and surveillance imaging in place of, and/or in addition to, lower-cost imaging modalities to enhance personal profits. Although this

study did demonstrate a significant rise in high-cost, advanced imaging and both replacement and substitution of advanced images for standard images during the study period, it was unclear whether these findings were due to financial incentives among fee for service providers or other factors, such as relatively uninhibited introduction of new imaging modalities, increased access to imaging technologies, patient demand, or broader shifts in professional practice patterns (eg, defensive medicine, increasing clinical applications, and, specific to cancer, increasing use of advanced imaging to assess treatment effect in response to an increasing number of lines of chemotherapy).^{1,2}

Dinan et al⁷ also did not address whether the observed trends in the use of high-cost imaging among elderly patients with cancer were found in an environment where referral-based financial incentives did not exist, such as health maintenance organizations (HMOs). Finally, because the original study relied on data from aged Medicare beneficiaries, the authors could not examine whether similar rates of advanced imaging are found among younger patients with cancer. The current study addresses both of these topics using a population of adult patients with cancer, under and over age 65 years, enrolled in four HMOs. We hypothesized that, consistent with previous studies

of imaging in HMOs,^{8,9} the pattern (ie, magnitude and direction) of rates of increase of high-cost, advanced imaging would be similar among Medicare Advantage (HMO) enrollees with cancer compared with their fee-for-service (FFS) counterparts. We also hypothesized that the pattern of rates of increase in imaging would be greater among younger patients with cancer compared with their elderly counterparts, likely reflecting a more aggressive approach to their care.

Materials and Methods

Data

Data were acquired from four nonprofit HMOs participating in the Cancer Research Network (<http://crn.cancer.gov/>), specifically: Group Health Cooperative, based in Seattle, WA, and the Northwest, Colorado, and Northern California regions of Kaiser Permanente. Together these sites cover nearly 5 million people, of whom approximately 14% are 65 years or older. All sites maintain comprehensive, longitudinal data on health services use for all enrollees maintained in a decentralized interoperable virtual data warehouse.^{10,11} The virtual data warehouse supports multisite studies by sharing common definitions of variables in identically formatted relational databases at each site, from which the full range of demographic, enrollment, diagnostic, procedural, and encounter data can be drawn using standardized programs. Data were compiled and analyzed at the Group Health Research Institute, which served as the coordinating research center. This study was approved by the institutional review boards at the participating sites.

Study Population

To facilitate comparison, we replicated all study methods described in the previous Medicare-based study⁷ in our HMO-based cancer population, with the following exceptions: (1) the study start date (this study begins with cancers diagnosed in 2001 *v* 1999) due to limitations in data availability; (2) data analysis: although we analyzed data for cancers diagnosed in 2001 to 2006, we focus our presentation of data on results from 2003 and 2006, consistent with the original Dinan⁷ publication, and (3) cost analysis: we limited our cost analysis to total imaging costs (rather than total health care costs) because a more complete accounting of costs was outside the scope of this project. This study population included Medicare Advantage beneficiaries 67 years or older and HMO enrollees 63 years or younger. The limitations on subjects' age were designed to (1) prevent subjects from "aging into Medicare" during the required 2 years of observation after a cancer diagnosis for those under 65 at the time of the cancer diagnosis and (2) ensure that a 2-year cancer-free window, before the cancer diagnosis, could be observed within the Medicare Advantage setting among those age 65 or older at the time of cancer diagnosis.

The study defined incident patient cases as individuals with at least two cancer-related professional or in- or outpatient claims with an International Classification of Disease, Ninth Edition, Clinical Modification (ICD-9-CM) diagnosis code of leukemia, non-Hodgkin lymphoma, breast, colorectal, lung, or

prostate cancer. Claims or utilization events had to be no more than 60 days apart, with no prior cancer-related diagnoses in the 2 preceding years. Date of diagnosis was defined as the date of the first observed claim or utilization event. Incident patient cases must have survived for at least 60 days following diagnosis. Comorbidity burden was determined by using a prespecified list of ICD-9-CM codes for hospital and outpatient health care utilization and claims as was done in the original Medicare study; the codes used were based on revisions to Deyo and Elixhauser comorbidity algorithms.^{12,13} Comorbidity was coded as present or absent on the basis of the appearance (or lack thereof) of these codes in the year before cancer diagnosis.

Diagnostic Imaging

Imaging procedures were identified by using utilization and/or claims data and were counted for the 2-year period after cancer diagnosis to determine costs and rates of imaging procedures per incident patient case. Eight imaging categories were used in this study: bone density scans, CT, echocardiography, MRI, NM, PET or PET-CT, radiography, and ultrasound. Costs were assigned to imaging procedures by using an algorithm developed by Rosetti et al¹⁴ that converts HMO utilization events to Medicare-equivalent monetary values, measuring costs from the payer's perspective. We used Medicare reimbursement rates to assign costs to imaging procedures rather than health plan-specific costs to allow a direct comparison with the costs of care among seniors in Medicare fee for service. We used national weights for all procedure specific costs and report results in 2008 dollars.

Statistical Analysis

Demographic information for incident patient cases is presented as frequencies for categorical variables and medians and interquartile ranges for continuous variables. Racial and ethnic categories were condensed to black and nonblack, with individuals with unknown or missing race/ethnicity counted within the nonblack category. Comorbid conditions were identified as described above for the year before the date of cancer diagnosis. Cochran-Mantel-Haenszel χ^2 tests, stratifying by cancer type, were used to test for associations between each categorical variable and the year of diagnosis, and the Kruskal-Wallis test was used to test for associations between age and year of diagnosis by cancer type.

Mean imaging procedure counts and imaging costs per beneficiary by year of diagnosis in the 2 years after diagnosis were calculated. Although all years (2001 to 2006) were used in the analyses, only results from 2003 and 2006 were presented to mirror results in the original manuscript. Changes in rates were presented as mean annual percent increases for each imaging modality. We used Poisson regression to analyze procedure rates and a generalized linear model with Gaussian distribution and log link to analyze imaging costs. Multivariable regressions controlled for age, demographics and comorbidity. Annual percent increases and corresponding 95% CIs were calculated via exponentiation of the estimated coefficients and 95% confidence limits associated with the year of diagnosis. SAS version

Table 1. Baseline Characteristics of the Study Population, by Age Group

Age Group and Characteristic	Year of Diagnosis				Stratified <i>P</i> *
	2003		2006		
	No.	%	No.	%	
≤ 63-year-old population					
Cancer type	1,278	100	1,272	100	
Breast	580	45.4	606	48.6	
Colorectal	178	13.9	162	12.7	
Leukemia	40	3.1	47	3.7	
Lung	139	10.9	125	9.8	
Non-Hodgkin lymphoma	87	6.8	85	6.7	
Prostate	254	19.9	247	19.4	
Age, years					.2
Median	56		56		
Interquartile range	50-60		51-60		
Male	474	37.1	478	37.6	.3
Race					
Black	59	5.2	51	4.4	.3
Nonblack	1,069	94.8	1,110	95.6	
Comorbid conditions					
Cerebrovascular disease	11	0.9	24	1.9	.070
Chronic obstructive pulmonary disease	167	13.1	186	14.6	.077
Congestive heart failure	12	0.9	13	1.0	.5
Coronary heart disease	52	4.1	65	5.1	.12
Dementia		—		—	
Diabetes mellitus	127	9.9	137	10.8	.4
Hypertension	267	20.9	363	28.5	< .001
Peripheral vascular disease	18	1.4	17	1.3	.9
Renal disease	13	1.0	22	1.7	.095
≥ 67-year-old population					
Cancer type	4,118	100	4,144	100	
Breast	1,125	27.3	1,104	26.6	
Colorectal	824	20.0	817	19.7	
Leukemia	136	3.3	127	3.1	
Lung	784	19.0	803	19.4	
Non-Hodgkin lymphoma	270	6.6	252	6.1	
Prostate	979	23.8	1,041	25.1	
Age, years	76	71-81	76	71-81	.3
Median					
Interquartile range					
Male	1,974	47.9	2,033	49.1	.4
Race					
Black	192	4.7	183	4.4	.6
Nonblack	3,926	95.3	3,961	95.6	
Comorbid conditions					
Cerebrovascular disease	328	5.7	336	5.0	.5
Chronic obstructive pulmonary disease	908	15.7	1,048	15.5	< .001
Congestive heart failure	407	7.0	386	5.7	.9
Coronary heart disease	753	13.0	786	11.6	.8
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Table 1. (continued)

Age Group and Characteristic	Year of Diagnosis				Stratified <i>P</i> *
	2003		2006		
	No.	%	No.	%	
Dementia	41	0.7	39	0.6	.9
Diabetes mellitus	746	12.9	842	12.4	.025
Hypertension	2,207	38.1	2,598	38.4	< .001
Peripheral vascular disease	294	5.1	385	5.7	< .001
Renal disease	109	1.9	353	5.2	< .001

* Within each group (above or below 65 years of age), analyses were further stratified by cancer type. Kruskal-Wallis tests were used to test for associations between (within category) age and year of diagnosis. Cochran-Mantel-Haenszel tests were used to test for linear associations between categorical variables and year of diagnosis.

9.2 (SAS Institute Inc, Cary, North Carolina) and STATA 12.0 (StataCorp LP, College Station, TX) were used for all analyses, with $P < .05$ considered to be statistically significant.

Results

Between 2001 and 2006, there were 44,446 total incident patient cases of leukemia, non-Hodgkin lymphoma, breast, colorectal, prostate, or lung cancer. The median age for the entire population was 75 years (interquartile range, 71 to 81 years). No statistically significant differences were observed by year of diagnosis for race, sex, or age for either age group (Table 1). The prevalence of comorbid disease did vary by year of diagnosis in both age groups, with significant differences being more common in the elderly. Specifically, renal disease (1.9% in 2003 v 5.2% in 2006), peripheral vascular disease (5.1% v 5.7%) and hypertension (38.1% v 38.4%) occurred more frequently in patients age ≥ 67 years from 2003 to 2006, whereas rates of chronic obstructive pulmonary disease (15.7% v 15.5%) and diabetes (12.9% v 12.4%) declined. Hypertension was the only condition significantly more common over time among younger HMO patients (20.9% v 28.5%).

Overall, 454,029 imaging procedures (both advanced and not advanced imaging) were performed across all age groups; of these, 25% ($n = 113,507$) were advanced imaging procedures. The annual percent increase in imaging in women 63 years of age and under with breast cancer was higher than for women ≥ 67 years for both NM studies (≤ 63 years = 5.8%; 95% CI, 1.8 to 9.9 v ≥ 67 years = 23.9%; 95% CI, 16.7 to 31.5) and echocardiograms (≤ 63 years = 32.0%; 95% CI, 12.4 to 55.1, v ≥ 67 years = -8.4%; 95% CI, -16.1 to 0.0; Table 2 and Appendix Figure A1 [online only]), possibly reflecting assessment of cardiac function before and after anthracycline or trastuzumab chemotherapy. Annual imaging was also higher among younger versus older HMO patients for PET scans among patients with lung cancer (≤ 63 years = 53.5%; 95% CI, 35.1 to 74.4, v ≥ 67 years = 19.3%; 95% CI, 12.6 to 26.3). In no case did the annual rates of increase for patients with cancer age 67 years or older in HMO exceed that of their younger HMO counterparts. However, this may be due in part

Table 2. Mean Imaging Procedure Counts per Enrollee, by Cancer Type, Year of Diagnosis, and Age, During 2 Years of Follow-Up

Cancer Type and Procedure	≤ 63 Years				≥ 67 Years			
	Diagnosed in 2003		Diagnosed in 2006		Diagnosed in 2003		Diagnosed in 2006	
	Mean No. of Procedures per Beneficiary	No. of Beneficiaries	Mean No. of Procedures per Beneficiary	No. of Beneficiaries	Mean No. of Procedures per Beneficiary	No. of Beneficiaries	Mean No. of Procedures per Beneficiary	Total No. of Beneficiaries
Breast cancer								
Bone density study	0.2	130	0.4	253	0.2	279	0.5	562
CT scan	1.2	705	1.8	1,110	1.5	1,657	1.9	2,072
Echocardiogram	0.2	111	0.5	295	0.3	356	0.3	328
MRI scan	0.4	253	0.5	300	0.2	217	0.2	272
Nuclear medicine	0.9	528	1.7	1,034	0.9	1,019	1.1	1,235
PET scan	< 0.1	14	0.2	97	< 0.1	49	< 0.1	91
Radiograph	5.1	2,962	4.4	2,685	6.3	7,102	6.2	6,827
Ultrasound	1.1	658	1.4	866	0.8	923	1.1	1,195
Colorectal cancer								
Bone density study	< 0.1	10	< 0.1	5	< 0.1	44	< 0.1	73
CT scan	6.2	1,104	8.6	1,388	4.8	3,985	6.1	4,950
Echocardiogram	0.1	22	0.5	76	0.4	370	0.4	354
MRI scan	0.2	32	0.3	56	0.1	93	0.2	187
Nuclear medicine	0.3	47	0.4	70	0.4	347	0.4	308
PET scan	0.2	39	0.7	114	0.1	98	0.3	212
Radiograph	4.6	820	4.9	792	6.9	5,723	6.3	5,122
Ultrasound	0.8	142	1.3	209	0.8	699	0.9	738
Leukemia								
Bone density study	0.2	8	0.2	10	< 0.1	8	< 0.1	8
CT scan	3.6	142	3.9	184	1.8	241	4.2	532
Echocardiogram	1.0	40	1.3	62	0.8	108	0.7	90
MRI scan	0.7	27	0.4	19	0.2	25	0.2	27
Nuclear medicine	0.7	29	0.7	31	0.5	71	0.6	75
PET scan	—	—	—	—	< 0.1	4	< 0.1	9
Radiograph	7.4	294	5.8	273	5.6	768	7.1	906
Ultrasound	1.5	59	1.3	59	0.9	117	1.0	128
Lung cancer								
Bone density study	< 0.1	5	< 0.1	5	< 0.1	31	< 0.1	27
CT scan	6.8	946	8.7	1,087	4.4	3,436	6.0	4,838
Echocardiogram	0.6	88	0.8	99	0.4	311	0.3	235
MRI scan	0.5	63	0.6	70	0.3	233	0.3	242
Nuclear medicine	0.8	118	0.8	94	0.7	580	0.7	562
PET scan	0.4	50	1.2	148	0.4	329	0.7	529
Radiograph	8.9	1,244	8.0	1,002	8.7	6817	10.0	8,032
Ultrasound	0.7	95	0.7	92	0.5	423	0.7	598
Non-Hodgkin lymphoma								
Bone density study	< 0.1	6	0.1	9	< 0.1	23	< 0.1	17
CT scan	12.7	1,101	12.1	1,025	9.7	2,628	9.5	2,389
Echocardiogram	1.3	115	0.8	67	0.6	169	0.6	160
MRI scan	1.1	99	0.3	25	0.4	112	0.3	83
Nuclear medicine	0.8	66	0.8	65	0.8	222	1.0	254
PET scan	0.6	52	1.9	165	0.4	98	1.1	273
Radiograph	5.6	490	4.4	375	6.3	1,705	7.4	1,855
Ultrasound	1.0	86	0.7	59	0.9	244	1.0	242

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Table 2. (continued)

Cancer Type and Procedure	≤ 63 Years				≥ 67 Years			
	Diagnosed in 2003		Diagnosed in 2006		Diagnosed in 2003		Diagnosed in 2006	
	Mean No. of Procedures per Beneficiary	No. of Beneficiaries	Mean No. of Procedures per Beneficiary	No. of Beneficiaries	Mean No. of Procedures per Beneficiary	No. of Beneficiaries	Mean No. of Procedures per Beneficiary	Total No. of Beneficiaries
Prostate cancer								
Bone density study	< 0.1	9	< 0.1	4	< 0.1	39	< 0.1	62
CT scan	1.3	327	1.6	394	1.6	1,521	2.0	2,035
Echocardiogram	0.2	59	0.5	135	0.4	380	0.4	418
MRI scan	0.1	37	0.3	62	0.2	206	0.3	325
Nuclear medicine	0.7	168	0.7	177	0.8	748	0.9	944
PET scan	< 0.1	7	< 0.1	2	< 0.1	10	< 0.1	28
Radiograph	2.2	568	2.0	496	3.6	3,539	3.7	3,801
Ultrasound	0.8	200	0.7	178	0.9	859	0.8	839

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging; PET, positron emission tomography.

to the small sample size of HMO patients with cancer under age 63 and the resulting wide 95% CIs.

The total cost of imaging during this study exceeded \$1 million per year, with a total of \$8.7 million, or approximately \$2,000 per beneficiary. Nearly 85% of expenditures were for advanced images (CT, MRI, PET, and NM). Nearly 28% of total expenditures, or approximately \$2.4 million, was spent on imaging for patients with lung cancer alone. The mean cost of imaging were similar across older and younger HMO enrollees in 2003, with the exception of NHL (≤ 63 years = \$6,155, standard deviation [SD] = \$6,310, $\nu \geq 67$ years = \$4,314, [SD = \$3,327]), leukemia (≤ 63 years = \$2,487 [SD = \$3,663], $\nu \geq 67$ years = \$1,259 [SD = \$1,371]), and lung cancer (≤ 63 years = \$3,494 [SD = \$3,017], $\nu \geq 67$ years = \$2,527 [SD = \$2,269]), which cost approximately \$1,000 more per year, on average, for younger enrollees (Table 3). By 2006, the mean imaging costs were also greater among those age 63 years or younger with colorectal cancer (≤ 63 years = \$4,086, [SD = \$3,842], $\nu \geq 67$ years = \$2,880, [SD = \$2,917]). In contrast, differences in mean imaging costs resolved as a result of faster annual rates of increase in imaging among elderly HMO patients with leukemia, compared with their younger HMO counterparts (≤ 63 years = -1.0 ; 95% CI, -14.8 to 15.1 , $\nu \geq 67$ years = 28.0 ; 95% CI, 15.2 to 42.3).

Discussion

This study investigated the rate of growth of advanced imaging and expenditures for adult patients with cancer, both older and younger than age 65, enrolled in four HMOs. We compared those rates with previously published rates of advanced imaging and costs for FFS Medicare enrollees. In this study, rates of imaging were largely similar for all patients with cancer regardless of age or care setting in 2003 and 2006. However, annual rates of increase in imaging among elderly FFS Medicare beneficiaries with cancer appear significantly greater for three im-

aging services (PET scanning for breast and lung cancer and echocardiogram for breast cancer) than that of comparably aged HMO enrollees. On the other hand, annual rates of increase in imaging for elderly HMO enrollees were greater than those for FFS Medicare beneficiaries for CT scanning in patients with leukemia. Among younger, HMO-enrolled patients with breast cancer, rates of increase were higher for NM studies than among elderly HMO or FFS Medicare enrollees. Rates of increase were also higher for younger, HMO-based patients for echocardiogram in breast cancer and PET scans for lung cancer when compared with their elderly HMO counterparts.

Given these findings, it appears unlikely that increases in rates of advanced imaging in this period were predominantly due to referral patterns or financial arrangements that economically rewarded physicians for ordering greater numbers of advanced images, as this incentive does not exist in the usual HMO environment. However, since the original Medicare study was published (and this research was completed), several policy and research papers on self-referral practices have been published highlighting this problem.¹⁵⁻²⁰

Further, to control growth and expenditures, policy makers passed the Deficit Reduction Act of 2005, which was enacted in January 2007.^{21,22} At least two components of the law apply to advanced imaging: (1) a 25% reduction in payments for CT, MRI, and ultrasound on consecutive body parts during the same scanning session and (2) caps on outpatient physician fees for imaging to make these payments consistent with payments under Medicare's hospital outpatient prospective payment system.² These approaches appear to have had an effect, as recent research suggests the rate of overall imaging has slowed and expenditures have decreased.^{2,23,24} Whether the foregone imaging represented "inappropriate" or "unnecessary" imaging, or its effect on patients with cancer in particular, is unknown. However, research focusing on the clinical encounter as the unit of analysis seems to suggest that clinicians may be more carefully selecting when to obtain imaging.^{25,26}

Table 3. Imaging Procedure Costs per Patient, by Cancer Type and Year of Diagnosis, During 2 Years of Follow-Up in Managed Care and Medicare Fee for Service

Cancer Type	Cost (\$)*						Annual Increase		
	Diagnosed in 2003			Diagnosed in 2006					
	Fee for Service† ≥ 67 yr	Managed Care		Fee for Service† ≥ 67 yr	Managed Care				
		≤ 63 yr	≥ 67 yr		≤ 63 yr	≥ 67 yr			
Breast cancer									
Mean	1,462	1,389	1,301	1,681	1,968	1,602			
SD	1,631	1,795	1,443	1,811	2,471	1,847			
%							9.9	11.8	5.9
95% CI							9.2 to 10.6	6.9 to 17.0	2.9 to 9.0
Colorectal cancer									
Mean	1,686	2,660	2,246	1,918	4,086	2,880			
SD	1,973	2,678	2,157	1,994	3,842	2,917			
%							10.3	13.5	9.2
95% CI							9.5 to 11.1	6.5 to 20.9	6.2 to 12.4
Leukemia									
Mean	958	2,487	1,259	1,257	2,275	2,146			
SD	1,163	3,663	1,373	1,349	2,423	3,136			
%							8.4	−1.0	28.0
95% CI							6.5 to 10.3	−14.8 to 15.1	15.2 to 42.3
Lung cancer									
Mean	2,903	3,494	2,527	3,260	4,761	3,458			
SD	2,846	3,017	2,269	2,756	4,495	3,086			
%							9.5	13.2	11.4
95% CI							7.1 to 12.0	5.7 to 21.2	8.3 to 14.6
NHL									
Mean	3,658	6,155	4,314	3,667	5,810	4,817			
SD	3,455	6,310	3,327	3,189	4,336	3,260			
%							8.8	1.7	5.3
95% CI							7.6 to 10.0	−6.4 to 10.4	1.2 to 9.6
Prostate cancer									
Mean	1,183	846	1,095	1,304	1,083	1,362			
SD	1,196	1,220	1,274	1,213	1,488	1,700			
%							5.1	8.2	7.1
95% CI							4.6 to 5.6	0.4 to 16.6	3.7 to 10.7

Abbreviation: NHL, non-Hodgkin lymphoma.

* All cost values are reported in 2008 US dollars.

† Fee-for-service data reprinted with permission.⁷

Future research should extend the present analysis to more recent years to observe whether downward trends in overall imaging rates are observed in cancer populations in both care settings. Although cancer care expenditures (\$104.1 billion in direct medical care expenditures in the United States in 2006) made up a relatively small proportion of the \$2.2 trillion in national health expenditures in 2006, they were expected to continue to rise at a rate faster than overall medical expenditures.^{27,28} This has been hypothesized to be due to a relative increase in cancer prevalence compared with other diseases in an aging population; improved survival (leading to a longer continuing care phase and possibly second cancers); and the use of new, expensive treatments and technologies, such as ad-

vanced imaging. As patients with cancer live longer and the number of lines of chemotherapy grows, the greater likelihood is that advanced imaging will continue to increase as a now relatively well-accepted part of oncologic care for screening, staging, assessing treatment response and surveillance.

Our study did take into account rates of comorbid conditions. The Medicare FFS cancer population may have had higher rates of certain comorbidities than HMO enrollees. Also, while the Medicare FFS population contained a higher proportion of black beneficiaries, the HMO elderly population in this study was 3 years older on average. Although the most likely effect of each factor is a reduction in imaging relative to healthier, white, and younger populations, the actual effect of

these sociodemographic differences on advanced imaging rates is unknown.

There are several limitations of this study. First, Medicare Advantage enrollees comprise 28% of Medicare beneficiaries overall (14.4 million individuals in 2013),²⁹ and this study includes a fraction of that subset, largely from the western United States. Similarly the sample of HMO enrollees under age 63 in this study is relatively small. Nevertheless, studies such as this that systematically collect data about cancer patients under the age of 65 represent an important alternative to the prevailing research conducted using SEER-Medicare linked data in the United States. For this reason, studying differences in cost and utilization across different economic and care models is a critical exercise and may advance comparative effectiveness research in this area.

A second limitation is the current method of identifying cancer patient cases via ICD-9-CM codes. Although unchanged from the previously published methodology, this technique was not validated (eg, against a tumor registry). Therefore over- or under-counting of cancer patient cases may occur, as well as misclassification, leading to bias in the estimates of advanced imaging procedures by cancer type. Additionally, dependence on ICD-9-CM codes to identify imaging in an HMO may be suboptimal in light of less compelling incentives to completely and accurately assign codes in a capitated model compared with FFS (where payment, and fraud avoidance, is a function of proper coding). Arguing against this is the presence of a similar electronic medical record across all sites that required physicians to assign diagnoses to all ordered procedures or tests. To the extent this problem does exist, it is also countered by the greater likelihood of identifying patient cases (due to the ICD-9-CM based approach) among beneficiaries who are receiving their care outside of the integrated system. The plans in these cases function both like a traditional insurance company and like an HMO. The likely effect is that utilization for these HMO beneficiaries looks more like that of FFS beneficiaries. The expected bias would therefore be toward the null hypothesis of no differences between the two economic and care models.

Finally, similar to the original Dinan study⁷, this study measured all imaging among patients with cancer rather than imaging directly related to the cancer diagnosis and treatment. Significantly more information and effort would be necessary to determine the extent to which imaging was truly cancer related.

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HMOs with electronic medical records that can capture ordering physician and (possibly) the motivation for imaging patients (for those who receive all of their care within the plan's network) are likely best positioned to study this question. This and other studies focused on the value and comparative effectiveness of advanced imaging for patients with cancer could inform interventions to appropriately curb utilization.

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Appendix

Figure A1. Annual percent increase in imaging procedure counts per patient with 95% percent confidence intervals in fee-for-service (FFS) versus managed care settings by age group. (A) computed tomography scan, (B) positron emission tomography scan, (C) nuclear medicine, (D) magnetic resonance imaging scan, (E) radiograph, (F) echo, (G) bone density study, (H) ultrasound. FFS data reprinted with permission.⁷