Variation in Positron Emission Tomography Use After Colon Cancer Resection

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Abstract

Purpose: Colon cancer surveillance guidelines do not routinely include positron emission tomography (PET) imaging; however, its use after surgical resection has been increasing. We evaluated the secular patterns of PET use after surgical resection of colon cancer among elderly patients and identified factors associated with its increasing use.

Patients and Methods: We used the SEER-linked Medicare database (July 2001 through December 2009) to establish a retrospective cohort of patients age ≥ 66 years who had undergone surgical resection for colon cancer. Postoperative PET use was assessed with the test for trends. Patient, tumor, and treatment characteristics were analyzed using univariable and multivariable logistic regression analyses.

Results: Of the 39,221 patients with colon cancer, 6,326 (16.1%) had undergone a PET scan within 2 years after surgery. The use rate steadily increased over time. The majority of PET scans had been performed within 2 months after surgery. Among patients who had undergone a PET scan, 3,644 (57.6%) had also undergone preoperative imaging, and 1,977 (54.3%) of these patients had undergone reimaging with PET within 2 months after surgery. Marriage, year of diagnosis, tumor stage, preoperative imaging, postoperative visit to a medical oncologist, and adjuvant chemotherapy were significantly associated with increased PET use.

Conclusion: PET use after colon cancer resection is steadily increasing, and further study is needed to understand the clinical value and effectiveness of PET scans and the reasons for this departure from guideline-concordant care.

Introduction

Colorectal cancer (CRC) is the third most common and lethal cancer in the United States.¹ Approximately two thirds of patients diagnosed with colon cancer are treated with surgery with curative intent, with or without adjuvant therapy.² Unfortunately, 10% to 50% of these patients will develop recurrent disease either locally or at a distant site within 5 years.³ The early detection of recurrent disease is essential for timely therapy and improved survival.⁴

Multiple imaging modalities, including computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography, are used for the early detection of recurrent disease. Positron emission tomography (PET) has recently been introduced into the armamentarium. PET is a noninvasive molecular imaging technique that uses a radiolabeled compound ($[^{18}\text{F}]$ fluorodeoxyglucose [FDG]) to distinguish between cancer cells and normal cells by detecting differences in their metabolic activities.⁵ Currently, PET is combined with CT to provide both molecular and anatomic imaging. When these modalities are combined, the sensitivity and specificity of detecting recurrent CRC range from 87% to 95% and 85% to 95%, respectively.⁶

The use of PET for oncologic applications has been increasing in the United States. PET is widely used in the diagnosis and initial staging or restaging of multiple cancers, including lymphoma, head and neck cancer, and esophageal cancers. The role of PET/CT in the management and follow-up of patients with CRC has increasingly been the subject of investigation.^{5,7,8} Some of this interest has been based on the observation of high

sensitivity and specificity of PET for the detection and staging of recurrent CRC.^{9,10}

PET is most sensitive and specific for the detection of recurrent CRC when used for patients with increasing carcinoembryonic antigen (CEA) levels who have undergone nondiagnostic CT imaging.¹¹ Most colon cancer surveillance guidelines do not routinely include PET imaging; however, the use of PET imaging after curative resection of colon cancer has been increasing.¹²⁻¹⁴ On the basis of our clinical experience, we hypothesized that PET imaging has been frequently performed in the early postoperative period. The primary aim of this study was to evaluate the variations in PET use within a population-based data set and to identify factors associated with its increasing use.

Patients and Methods

Data Sources

A retrospective cohort study was performed using the linked SEER-Medicare 2011 data set. The data set consists of all Medicare-eligible individuals appearing in the SEER data set between July 1, 2001, and December 31, 2009, and their Medicare claims through December 31, 2010. The National Cancer Institute–provided SEER-Medicare data refer to a series including SEER data (Patient Entitlement and Diagnosis Summary file) and Medicare data, such as the Medicare Provider Analysis and Review file, which collects all Part A institutional short-stay, long-stay, and skilled nursing facility claims; the National Claims History file, which collects Part B claims from nonin-

stitutional physicians or suppliers; the Outpatient Standard Analytic file, which collects Part B claims from institutional outpatient providers; and the Durable Medical Equipment file, which collects Part B claims not processed by carriers but by durable medical equipment regional carriers.

Patient Selection

Patients age ≥ 66 years diagnosed with stage I to III colon cancer between July 1, 2001, and December 31, 2009, were eligible for study inclusion. Tumor stage was determined according to the American Joint Committee on Cancer (seventh edition) schema. Younger patients were excluded because of a lack of available claims preceding diagnosis to allow for comorbidity index estimation. Medicare beneficiaries with health maintenance organization participation were excluded to ensure the completeness of claims reported to the Centers for Medicare and Medicaid Services. Other exclusion criteria included appendiceal cancer, nonadenocarcinoma, unknown socioeconomic status (SES), nonmicroscopically confirmed diagnosis, second primary cancer diagnosis within 24 months after the initially diagnosed colon cancer, and diagnosis noted only on a nursing or convalescent home report, hospice report, autopsy report, or death certificate.

Outcome Variables

The primary outcome evaluated in this study was postoperative PET use (for remainder of this article, PET refers to postoperative PET, unless otherwise stated). First, we identified patients who had undergone primary tumor resection within 3 months after diagnosis. Medicare inpatient files were used to identify the earliest claim indicating primary tumor resection (International Classification of Diseases [ninth edition; ICD-9] procedure codes 45.7X, 45.8X, and 17.31 to 17.39). Claims indicating the use of PET at any point within the 24-month postoperative period (Healthcare Common Procedure Coding System [HCPCS] codes 78810, 78811, 78812, 78813, 78814, 78815, 78816, G0213, G0214, G0215, G0163, and G0213) were identified from carrier/physician and outpatient files. Additional data were available for some patients with longer follow-up, which allowed for the performance of sensitivity analysis. We also evaluated the number and timing of PET examinations that had been performed.

Controlled Variables

Patient age at diagnosis, sex, race/ethnicity, marital status, SES, residence, year of diagnosis, SEER-based geographic location, tumor stage, tumor grade, and tumor location were obtained from the SEER file. SES was determined based on the following: the patient's annual household median income, percentage of persons in the household age at least 25 years with less than 12 years of education, and percentage of persons in the household living below the poverty line. Because these variables were highly correlated, they were standardized and equally weighted to create a composite SES variable categorized into four quartiles.¹⁵ We adopted the methodology developed by Charlson et al¹⁶ and later updated by Rumano et al¹⁷ to calculate the co-

morbidity score. The National Cancer Institute–provided SAS macro (SAS Institute, Cary, NC) was used to facilitate this task (<http://healthservices.cancer.gov/seermedicare/program/comorbidity.html>).¹⁸ The following were identified from Medicare claim files: receipt of adjuvant chemotherapy (HSPCS codes G0355 to G0363, J0640, J8520, J8521, J9190, J9263, Q0083, Q0084, and Q0085) and pre- and postoperative imaging services, including CT (HCPCS codes 71250 to 71270, 74150 to 74170, 72192 to 72194 and ICD-9 Clinical Modification codes 88.41, 88.01, and 88.38) and MRI (HCPCS codes 71550 to 71555, 74181 to 74185, and 72195 to 72198 and ICD-9 Clinical Modification codes 88.92, 88.95, and 88.97). The carrier files were employed to identify physicians specializing in hematology (82), hematology/oncology (83), or medical oncology (90).

Statistical Analyses

The characteristics of all patient cases in the study were compared with status of PET use using χ^2 tests. The rate of PET use was calculated as follows: number of patients undergoing PET within the 1- and 2-year postoperative period divided by number of patients with or without PET within the 1- and 2-year postoperative period for each study year. We also calculated the number of PET scans performed per patient within 1 and 2 years after surgical resection. Multivariable logistic regression analysis was used to measure factors in relation to PET use while controlling for the potential confounding effect of patient demographics, tumor-related factors, and treatment-related variables. Odds ratios (ORs) and 95% CIs were derived for all study variables. We employed the Kaplan-Meier method to illustrate the time to patient's first postsurgical PET scan, allowing graphical assessment of the time at which the proportion of patients was expected to have undergone PET. All reported *P* values are two sided and considered significant at the .05 level. We used SAS software (version 9.1.3) for data processing and STATA MP (version 11.0; STATA, College Station, TX) for statistical analyses. Our study is reported according to the STROBE (Strengthening Reporting of Observational Studies in Epidemiology) statement.

Results

Patient Characteristics

There were 39,221 patients who met the study criteria and were included in the analysis. Overall, the median age at diagnosis was 78 years. Patients who underwent PET were more likely to have been age younger than 80 years at diagnosis, been married, been diagnosed after 2006, presented with higher-stage disease (stage IIIB or IIIC), received chemotherapy, been seen by a medical oncologist postsurgery, and undergone preoperative imaging (PET, CT, or MRI) within 3 months before surgical resection compared with patients who had not undergone PET (Table 1).

PET Use

The primary outcome of this study was the rate of PET use over time. For patients who had undergone a PET scan within 1 year

Table 1. Characteristics of Patients Age ≥ 66 Years Diagnosed With Colon Cancer Between Study Period of July 1, 2001, and December 31, 2009

Characteristic	Postoperative PET				P	χ ²
	No (n = 32,895)		Yes (n = 6,326)			
	No.	%	No.	%		
Age at diagnosis, years					< .001	730.0
66-69	4,265	13.0	1,237	19.6		
70-74	6,592	20.0	1,764	27.9		
75-79	7,966	24.2	1,628	25.7		
80-84	7,975	24.2	1,178	18.6		
≥ 85	6,097	18.5	519	8.2		
Sex					< .001	13.9
Male	13,729	41.7	2,800	44.3		
Female	19,166	58.3	3,526	55.7		
Race/ethnicity					< .001	15.6
White	28,922	87.9	5,537	87.5		
Black	2,536	7.7	447	7.1		
Other/unknown	1,437	4.4	342	5.4		
Marital status at diagnosis					< .001	139.4
Unmarried	2,517	7.7	445	7		
Married	16,210	49.3	3,585	56.7		
Separated/divorced	2,077	6.3	423	6.7		
Widowed	11,039	33.6	1,690	26.7		
Other/unknown	1,052	3.2	183	2.9		
Socioeconomic status at diagnosis, quartile					.029	9.0
First	8,247	25.1	1,564	24.7		
Second	8,234	25.0	1,566	24.8		
Third	8,284	25.2	1,525	24.1		
Fourth (poorest)	8,130	24.7	1,671	26.4		
Residence					.763	1.85
Big metropolitan	17,145	52.1	3,302	52.2		
Metropolitan	9,767	29.7	1,913	30.2		
Urban	2,011	6.1	377	6.0		
Less urban	3,225	9.8	600	9.5		
Rural	747	2.3	134	2.1		
Comorbidity score at diagnosis					< .001	46.13
0	17,979	54.7	3,705	58.6		
1	8,369	25.4	1,574	24.9		
≥ 2	6,547	19.9	1,047	16.6		
Year of diagnosis*					< .001	605.3
2001	2,183	6.6	190	3.0		
2002	5,037	15.3	542	8.6		
2003	4,773	14.5	655	10.4		
2004	4,068	12.4	743	11.7		
2005	3,780	11.5	823	13.0		
2006	3,468	10.5	886	14.0		
2007	3,362	10.2	854	13.5		
2008	3,181	9.7	882	13.9		
2009	3,043	9.3	751	11.9		

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Table 1. (continued)

Characteristic	Postoperative PET				P	χ ²
	No (n = 32,895)		Yes (n = 6,326)			
	No.	%	No.	%		
SEER region					< .001	145.1
West	12,143	36.9	2,571	40.6		
Midwest	4,748	14.4	602	9.5		
Northeast	7,670	23.3	1,345	21.3		
South	8,334	25.3	1,808	28.6		
AJCC tumor stage (ed 7)					< .001	2080.6
I	9,711	29.5	623	9.8		
IIA	12,092	36.8	1,816	28.7		
IIB	943	2.9	215	3.4		
IIC	623	1.9	199	3.1		
IIIA	973	3.0	279	4.4		
IIIB	5,510	16.8	1,849	29.2		
IIIC	3,043	9.3	1,345	21.3		
Tumor grade					< .001	140.0
Well or moderately differentiated	25,465	77.4	4,571	72.3		
Poorly differentiated	6,007	18.3	1,497	23.7		
Undifferentiated	397	1.2	124	2.0		
Unknown	1,026	3.1	134	2.1		
Tumor location in colon					.001	16.7
Proximal	19,193	58.3	3,554	56.2		
Transverse	3,415	10.4	640	10.1		
Distal	9,734	29.6	2,001	31.6		
Not otherwise specified	553	1.7	131	2.1		
Adjuvant chemotherapy					< .001	3269.9
No	26,356	80.1	2,907	46.0		
Yes	6,539	19.9	3,419	54.0		
Postoperative medical oncology visit					< .001	2277.0
No	16,221	49.3	1,062	16.8		
Yes	16,674	50.7	5,264	83.2		
Preoperative imaging*					< .001	132.6
No	16,546	50.3	2,682	42.4		
Yes	16,349	49.7	3,644	57.6		

Abbreviations: AJCC, American Joint Committee on Cancer; PET, positron emission tomography.

* Within 3 months before surgical resection.

after resection, the rate increased steadily from 4.8% in 2001 to 18.8% in 2009 ($P_{\text{trend}} < .001$; Figure 1). In contrast, for patients who received their first PET scan > 1 year after resection, the rate was approximately 3.0% to 4.0% from 2001 through 2008 ($P_{\text{trend}} = .464$). Data for 2009 are not provided, because not all patients in the cohort reached > 1 year of postresection follow-up.

Kaplan-Meier analysis was applied to assess time to first PET scan. The median time to first PET scan was 6.2 months, and a total of 1,973 (31.2%) patients had undergone their first PET scan within 2 months after surgery. Among the patients who had undergone PET scan, 54% (n = 3,419) had received adjuvant chemotherapy, of whom 21.1% had stage II cancer and 77.7% had stage III cancer. There was also variation in the

timing of PET use. A total of 2,950 patients (46.7%) had PET scans performed during 2001 to 2005, and 3,372 patients (53.3%) had PET scans performed during 2006 to 2009. In the early (2001 to 2005) and late (2006 to 2009) study periods, 24.4% and 37.1% of patients had undergone their first PET scan within 2 months after surgery, and the corresponding median times to first PET scan were 8.2 and 4.0 months, respectively ($P < .001$; Figure 2).

In our cohort, 5,264 (83.2%) of the 6,326 patients who had undergone PET scans had also been seen by a medical oncologist after surgery. Among these patients, 1,845 (35%) had undergone their first PET scan within 2 months. The remaining 1,062 patients (16.8%) who had undergone PET scans had not been evaluated by a medical oncologist after surgery. Of these,

Figure 1. Rate of positron emission tomography (PET) use by year of diagnosis in patients with colon cancer age > 66 years who underwent postoperative PET within 1 year ($n = 5,059$; blue line) and > 1 year after surgical resection ($n = 1,267$; gold line).

128 (12%) had undergone their first PET scan within 2 months. The median time to first PET scan for patients who had and had not been evaluated by a medical oncologist after surgery was 5 and 10 months, respectively ($P < .001$). Moreover, among patients who had undergone a PET scan, 3,644 (57.6%) had undergone preoperative imaging, and 1,100 (30.2%) of these patients had also undergone their first PET scan within 2 months after surgery. Within this group, 1,032 patients (93.8%) were evaluated by a medical oncologist after surgery.

Univariable and Multivariable Analyses

We performed univariable and multivariable analyses of factors associated with PET use (Table 2). In multivariable analysis,

Figure 2. Time (in months) to first positron emission tomography (PET) scan of patients with colon cancer age ≥ 66 years after surgical resection by study period: 2001 to 2005 ($n = 2,950$; blue line) and 2006 to 2009 ($n = 3,372$; gold line).

significant factors associated with PET use included year of diagnosis ≥ 2003 , tumor stage II or III, receipt of chemotherapy, medical oncologist visit after surgery, and receipt of preoperative imaging ($P < .001$ for each variable). In addition, patients who were married were more likely than unmarried patients to have undergone a PET scan ($P = .011$). Age ≥ 75 years (v 66 to 60 years), black race (v white), and midwest and northeast (v west) SEER regions were associated with decreased PET use. Chemotherapy (OR, 2.34; 95% CI, 2.19 to 2.55; $P < .001$) and postoperative medical oncologist visit (OR, 2.49; 95% CI, 2.31 to 2.70; $P < .001$) had the strongest association with increased PET use.

Because receipt of chemotherapy was associated with visit to a medical oncologist, we used an interaction term in the final model. The P value for the test of interaction was statistically significant for all three outcomes versus no chemotherapy and no visit to a medical oncologist. Patients who had visited a medical oncologist and received chemotherapy were greater than six times more likely to have undergone PET than patients who had not visited a medical oncologist or received chemotherapy (OR, 6.34; 95% CI, 5.75 to 6.99; $P < .001$). Patients who had visited a medical oncologist but not received chemotherapy were also more likely to have undergone PET scans than patients who had not visited a medical oncologist or received chemotherapy (OR, 2.93; 95% CI, 2.69 to 3.20; $P < .001$).

Discussion

In this population-based study, we demonstrated variation in surveillance practices with PET imaging among patients with colon cancer. We identified multiple factors, including type of provider seen, that were significantly associated with increased PET use. We observed that one third of PET scans had been performed within 2 months after surgical resection. Additionally, we observed a significant rate of early PET scan use, even among patients who had undergone preoperative imaging. Our study demonstrated substantial variation from guideline-based clinical surveillance among elderly patients with colon cancer.

The FDG tracer used for PET imaging accumulates in areas of high metabolic activity and is useful for detecting malignant growth; however, other areas of increased metabolic activity will also be FDG avid, which increases the likelihood of a false-positive test results and the need for further testing. Furthermore, small lesions identified on conventional contrast-enhanced CT may not be FDG avid on PET imaging and can be missed. Although a PET scan may have significant clinical utility in evaluating patients for metastatic disease or monitoring treatment response, its role has not been established in routine postsurgery cancer surveillance.^{12,13} Our finding of increasing PET use during this surveillance period suggests that clinicians may be finding PET imaging to be of clinical use in routine practice, although this utility has not been objectively demonstrated. It is important to determine and understand the patterns of PET use not only because of the relatively high cost of PET imaging but also because this use does not agree with current guideline-based practice. The Institute of Medicine has noted this discrepancy and has identified investigation of post-

Table 2. Univariable and Multivariable Logistic Regression for Factors Associated With PET Use Among Patients Age ≥ 66 Years Diagnosed With Colon Cancer Between July 1, 2001, and December 31, 2009

Characteristic	Univariable			Multivariable		
	OR	95% CI	P	OR	95% CI	P
Age at diagnosis, years						
66-69	1	—	—	1	—	—
70-74	0.92	0.84 to 1.00	.055	1.01	0.93 to 1.12	.677
75-79	0.70	0.64 to 0.76	< .001	0.86	0.79 to 0.94	.001
80-84	0.50	0.46 to 0.55	< .001	0.72	0.65 to 0.80	< .001
≥ 85	0.29	0.26 to 0.32	< .001	0.50	0.45 to 0.57	< .001
Sex						
Male	1	—	—	1	—	—
Female	0.90	0.85 to 0.95	< .001	1.03	0.97 to 1.10	.327
Race/ethnicity						
White	1	—	—	1	—	—
Black	0.92	0.82 to 1.02	.121	0.85	0.76 to 0.96	.011
Other/unknown	1.24	1.10 to 1.40	< .001	0.95	0.83 to 1.10	.514
Marital status at diagnosis						
Unmarried	1	—	—	1	—	—
Married	1.25	1.12 to 1.39	< .001	1.16	1.04 to 1.31	.011
Separated/divorced	1.15	0.99 to 1.33	.056	1.03	0.88 to 1.21	.672
Widowed	0.86	0.77 to 0.96	.013	1.05	0.93 to 1.20	.368
Other/unknown	0.98	0.81 to 1.18	.865	1.07	0.88 to 1.32	.470
Socioeconomic status at diagnosis, quartile						
First	1	—	—	1	—	—
Second	1.00	0.92 to 1.08	.942	1.06	0.98 to 1.15	.160
Third	0.97	0.89 to 1.04	.448	0.98	0.90 to 1.07	.698
Fourth (poorest)	1.08	1.00 to 1.16	.037	1.07	0.97 to 1.18	.155
Residence						
Big metropolitan	1	—	—	1	—	—
Metropolitan	1.01	0.95 to 1.08	.592	1.00	0.94 to 1.08	.842
Urban	0.97	0.86 to 1.09	.649	1.01	0.89 to 1.16	.788
Less urban	0.96	0.87 to 1.06	.474	0.93	0.83 to 1.05	.254
Rural	0.93	0.77 to 1.12	.458	0.91	0.74 to 1.14	.430
Comorbidity score at diagnosis						
0	1	—	—	1	—	—
1	0.91	0.85 to 0.97	.005	0.95	0.89 to 1.03	.231
≥ 2	0.77	0.72 to 0.83	< .001	0.92	0.85 to 1.00	.053
Year of diagnosis						
2001	1	—	—	1	—	—
2002	1.23	1.04 to 1.46	.016	1.15	0.96 to 1.38	.123
2003	1.57	1.33 to 1.86	< .001	1.51	1.27 to 1.81	< .001
2004	2.09	1.77 to 2.48	< .001	2.19	1.84 to 2.62	< .001
2005	2.50	2.11 to 2.95	< .001	2.73	2.30 to 3.26	< .001
2006	2.93	2.48 to 3.46	< .001	3.35	2.81 to 4.00	< .001
2007	2.91	2.47 to 3.44	< .001	3.17	2.66 to 3.79	< .001
2008	3.18	2.69 to 3.76	< .001	3.70	3.11 to 4.43	< .001
2009	2.83	2.39 to 3.35	< .001	3.21	2.68 to 3.84	< .001

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Table 2. (continued)

Characteristic	Univariable			Multivariable		
	OR	95% CI	P	OR	95% CI	P
SEER region						
West	1	—	—	1	—	—
Midwest	0.59	0.54 to 0.65	< .001	0.53	0.48 to 0.59	< .001
Northeast	0.82	0.77 to 0.88	< .001	0.78	0.72 to 0.85	< .001
South	1.02	0.95 to 1.09	.472	0.96	0.89 to 1.04	.364
AJCC tumor stage (ed 7)						
I	1	—	—	1	—	—
IIA	2.34	2.12 to 2.57	< .001	1.71	1.55 to 1.90	< .001
IIB	3.55	3.00 to 4.20	< .001	2.52	2.10 to 3.02	< .001
IIC	4.97	4.16 to 5.95	< .001	2.83	2.34 to 3.44	< .001
IIIA	4.46	3.82 to 5.22	< .001	1.73	1.46 to 2.06	< .001
IIIB	5.23	4.74 to 5.76	< .001	2.35	2.10 to 2.63	< .001
IIIC	6.88	6.21 to 7.63	< .001	2.93	2.60 to 3.31	< .001
Tumor grade						
Well or moderately differentiated	1	—	—	1	—	—
Poorly differentiated	1.38	1.30 to 1.48	< .001	1.02	0.95 to 1.10	.539
Undifferentiated	1.74	1.41 to 2.13	< .001	1.06	0.85 to 1.34	.567
Unknown	0.72	0.60 to 0.87	.001	0.92	0.73 to 1.13	.462
Tumor location in colon						
Right	1	—	—	1	—	—
Transverse	1.01	0.92 to 1.10	.797	1.01	0.92 to 1.12	.807
Left	1.11	1.04 to 1.17	.001	1.05	0.99 to 1.13	.111
Not otherwise specified	1.27	1.05 to 1.55	.013	1.25	1.01 to 1.54	.037
Adjuvant chemotherapy/oncologist visit						
No/no	1	—	—	1	—	—
Yes/no	6.60	5.60 to 7.78	< .001	4.94	4.14 to 5.90	< .001
No/yes	3.62	3.32 to 3.93	< .001	2.93	2.69 to 3.20	< .001
Yes/yes	10.20	9.39 to 11.0	< .001	6.34	5.75 to 6.99	< .001
Preoperative imaging						
No	1	—	—	1	—	—
Yes	1.37	1.30 to 1.45	< .001	1.16	1.09 to 1.23	< .001

Abbreviations: AJCC, American Joint Committee on Cancer; OR, odds ratio; PET, positron emission tomography.

treatment PET imaging as a priority for comparative-effective-ness research.¹⁹

Our study demonstrates substantial overuse of an expensive resource. Approximately one third of patients in our study underwent PET within 2 months after surgery, and many of these patients had already undergone preoperative imaging. It is possible that advanced imaging studies performed within 6 months after surgery were done so for postoperative complications rather than for surveillance.^{20,21} However, there is no role for PET in evaluating postoperative complications. Although these early PET scans could have been performed to establish a post-surgical baseline, there is no established role for early postoperative imaging in the routine care of patients with CRC who had been preoperatively staged.

Overall, we observed an increase and greater variation in PET scans over time. During the more recent years of the study period (2006 to 2009), more PET scans were performed, and

patients were more likely to have undergone their first PET scan early in the postoperative period (median, 4 months). The increase in PET use among Medicare patients may be related to the fact that in July 2001, the Centers for Medicare and Medicaid Services approved payment for PET scans performed for restaging and monitoring response to treatment after colon cancer resection. However, this change does not explain the increase in PET scans performed in the early months after surgery.

Although a prior report demonstrated approximately 10% of patients with colon cancer underwent a PET scan after surgery,¹⁴ we have demonstrated significant additional increases in the rate of PET use. In addition, we have identified receipt of chemotherapy and postoperative visit to a medical oncologist (regardless of preoperative imaging) as independent positive predictors of PET use.

Our findings highlight an important gap between clinical guidelines and clinical decision making that may be contribu-

tory to the wide variation in clinical practice observed in this study. Specialist care may improve guideline adherence, but the increased use of tests is perhaps a function of differential access to health care resources.^{21,22} In our study, > 80% of the patients who had visited a medical oncologist after surgery had undergone a PET scan, and these patients were more likely to have undergone an early postsurgery scan. Also, patients who had visited a medical oncologist postsurgery and had received chemotherapy were greater than six times more likely to have undergone a PET scan compared with patients who had not visited a medical oncologist postsurgery or received chemotherapy. Our study highlights the need for additional data regarding clinician decision making to bring new insight into understanding the reasons for the underlying treatment variation.

Our study is not without limitations. Medicare-linked SEER data provide an excellent window into the patterns of care for elderly patients with cancer in the United States. However, because our data set included only patients age ≥ 66 years with Medicare Parts A and B, our findings may not be applicable to younger patients or those with supplemental private insurance. Moreover, the regional distributions of the various SEER registries should be considered in the interpretation of our data. Because the SEER-Medicare database consists of claims-based administrative data, we could not determine the indications or results of imaging tests or whether the imaging test resulted in the identification of treatable recurrence or further testing. For example, only the highest pretreatment CEA is available in the SEER-Medicare data set. There is no information regarding post-treatment CEA; therefore, we could not determine if elevated post-treatment CEA led to PET imaging. However, among patients who did not undergo a PET during the first year after surgery, the overall rate of PET use was < 4% during the second year after surgery, and it continued to decrease over time (overall rate of first PET use was between 0.5% and 2% for patients with 3, 4, and 5 years of follow-up data). Perhaps these patients underwent PET to follow-up suspicious or nondiagnostic findings on routine CT imaging. These findings suggest that the increasing trend observed during the first year after surgery was not the result of an increased use for follow-up testing. Also, we focused our analysis on PET with or without concurrent CT and did not compare the rate of conventional CT in our cohort. Finally, with such a large sample size, small differences may be statistically significant; however,

because PET scans are not recommended in any surveillance guidelines, our study demonstrated a large rate of use, which is also clinically significant. Our study demonstrated a high rate of PET use after colon cancer resection that increased steadily between 2001 and 2009, and an increasing number of PET scans were performed during the early postoperative period. Post-treatment surveillance is an important health care issue, particularly with respect to the type and frequency of surveillance imaging, and there currently exists marked variation in clinical practice, with limited evidence to inform decisions. Clinicians are currently performing PET scans despite no support from current guidelines. Further study is needed to determine the clinical value and effectiveness of this costly resource for post-treatment surveillance and the factors that are driving clinician behavior.

Acknowledgment

Supported in part by National Institutes of Health/National Cancer Institute Grants No. T32CA009599 (C.E.B.), K07-CA133187 (G.J.C.), and CA16672 (to The University of Texas MD Anderson Cancer Center). Presented at the 67th Annual Cancer Symposium of the Society of Surgical Oncology, Phoenix, AZ, March 12-15, 2014.

Authors' Disclosures of Potential Conflicts of Interest

Disclosures provided by the authors are available with this article at jop.ascpubs.org.

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DOI: [10.1200/JOP.2014.001933](https://doi.org/10.1200/JOP.2014.001933); published online ahead of print at jop.ascpubs.org on April 7, 2015.

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AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST**Variation in Positron Emission Tomography Use After Colon Cancer Resection**

The following represents disclosure information provided by authors of this manuscript. All relationships are considered compensated. Relationships are self-held unless noted. I = Immediate Family Member, Inst = My Institution. Relationships may not relate to the subject matter of this manuscript. For more information about ASCO's conflict of interest policy, please refer to www.asco.org/rwc or jop.ascopubs.org/site/misc/ifc.xhtml.

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No relationship to disclose

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No relationship to disclose

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No relationship to disclose

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No relationship to disclose

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No relationship to disclose

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Consulting or Advisory Role: Ethicon

Research Funding: Agendia

Travel, Accommodations, Expenses: Ethicon