Original Study

Increased Utilization of Positron Emission Tomography/Computed Tomography (PET/CT) Imaging and Its Economic Impact for Patients Diagnosed With Bladder Cancer

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Abstract

The American Society of Clinical Oncology's Value of Cancer Care Task Force is promoting sustainable high-quality and high−value-based cancer care. This study examines utilization trends and costs associated with advanced imaging in patients with bladder cancer, using a large population-based cancer registry data. We found a significant shift from low-cost to high-cost imaging without evidence documenting clinical superiority.

Background: The purpose of this study was to examine temporal nationwide utilization patterns and predictors for use of positron emission tomography/computed tomography (PET/CT) in comparison with magnetic resonance imaging (MRI) and computed tomography (CT) among patients diagnosed with bladder cancer. **Materials and Methods:** A total of 36,855 patients aged 66 years or older diagnosed with clinical stage TI-IV, N0M0 bladder cancer from 2004 to 2011 were analyzed. We used multivariable logistic regression analyses to discern factors associated with receipt of imaging within 12 months from diagnosis. The Cochran-Armitage test for trend was used to determine changes in the proportion of patients receiving imaging after cancer diagnosis. **Results:** Independent of clinical stage, there was marked increase in use of PET/CT throughout the study period (2011 vs. 2004: odds ratio, 17.55; 95% confidence interval, 10.14-30.38; $P < .001$). Although use of CT imaging remained stable during the study period, there was significantly decreased utilization of MRI (odds ratio, 0.60; 95% confidence interval, 0.49-0.75; $P < .001$) in 2011 versus 2004. The mean incremental cost of PET/CT versus CT and MRI was $1040 and $612 (in 2016 dollars), respectively. Extrapolating these findings to the patients with bladder cancer in the United States results in excess spending of $11.6 million for PET/CT imaging. **Conclusion:** We identified rapid adoption of PET/CT imaging independent of clinical stage, resulting in excess national spending of $11.6 million for this imaging modality alone. Further value-based research discerning the clinical versus economic benefits of advanced imaging among patients with bladder cancer are needed.

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Introduction

There were an estimated 76,960 new cases and 16,390 deaths from bladder cancer in the United States in 2016.[1] Clinical staging for bladder cancer commonly includes transurethral resection of the bladder tumor and upper tract imaging.[2-4] Imaging techniques such as positron emission tomography/computed tomography (better known as PET/CT), magnetic resonance imaging (MRI), and computed tomography (CT) can improve preoperative staging and follow-up surveillance.

Prior studies have explored the utility of PET/CT imaging in primary bladder cancer with limited evidence suggesting clinical superiority.[5-7] Moreover, meta-analyses have suggested PET/CT is 'good' in detecting metastatic disease but could not recommend this as the preferred imaging modality over other imaging owing to limited studies and lack of comparative effectiveness research.[7] Taking the above into account, current guidelines recommend CT and/or MRI as the preferred abdominal imaging modality in staging patients with bladder cancer.[2-4]

The American Board of Internal Medicine's Choosing Wisely campaign and the American Society of Clinical Oncology's Value of Cancer Care Task Force have collaborated to encourage sustainable high-quality and high—value-based cancer care.[8] Widespread adoption of costlier advanced imaging modalities such as PET/CT with lack of well-documented superiority over other imaging techniques can have a significant impact on the national health care system. Indeed, the Institute of Medicine recently conveyed a workshop aimed at controlling use of expensive advanced cancer care and treatments in the absence of comparative effectiveness research documenting superiority over less costly alternatives.[9] Utilization patterns regarding advanced imaging in bladder cancer remain largely unknown. Given this void in understanding, we used a large population-based cancer registry to analyze utilization trends and costs associated with advanced imaging in patients with bladder cancer.

Methods

Database

We used the Surveillance, Epidemiology, and End Results (SEER) Medicare-linked database. The SEER registry, supported by the National Cancer Institute, contains patients' demographic and cancer diagnosis information for approximately 30% of the United States (US) population from 18 geographic regions, including Alaska, Arizona, Cherokee Nation, Connecticut, Detroit, Georgia, San Francisco-Oakland, San Jose-Monterey, Greater California, Hawaii, Iowa, Kentucky, Los Angeles, Louisiana, New Jersey, New Mexico, Seattle-Puget Sound, and Utah. The Medicare program contains health care claims and payments for 97% of US citizens aged 65 years and older. The SEER registry data is linked with Medicare claims data using a unique encrypted patient identifier.

Patient Selection Criteria

The study population consisted of patients aged 66 years and older with an incident of bladder cancer diagnosed with clinical stage I to IV, N0, M0 transitional cell or urothelial carcinoma (American Joint Committee on Cancer Modified third edition; International Classification of Diseases for Oncology, third edition, codes 8120 and 8130) from January 1, 2004 through December 31, 2011. We excluded the following patients: those with a bladder cancer diagnosis from a death certificate or autopsy, those without pathologic confirmation, those without continuous Part A and Part B insurance coverage within 12 months of their cancer diagnosis, those without continuous Part A and Part B insurance coverage until death, and finally, those that had health maintenance organization enrollment during the same period (See Supplemental Table 1 in the online version).

Identification of Imaging Modalities

The primary outcome of this study was receipt of imaging, which included CT, MRI, and/or PET/CT, for the purpose of diagnosis and surveillance. This was determined using Medicare claims data within 1 year after the date of bladder cancer diagnosis. We identified the 3 imaging modalities using the following Healthcare Common Procedure Coding System codes: PET/CT (78,815 and 78,816), MRI (74,181-74,183, 74,185, 76,498, and 72,195-72,197), and CT (codes 72,191-72,194, 74,150-74,170, 74,176-74,178, and 76,497).

Patient Characteristics

Patient demographic information included age at cancer diagnosis (66-69, 70-74, 75-79, and 80 years or older), year of cancer diagnosis, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other), marital status (single, married, and unknown), US census region (West, Northeast, Midwest, and South), and neighborhood median household income (categorized into quartiles). Tumor characteristics, as reported by SEER data, included clinical stage, histologic grade, and presence of hydronephrosis. We used the modification by Klabunde et al of the Charlson Comorbidity Index to quantify severity of preexisting comorbidities.[10,11] Treatment within 1 year after bladder cancer diagnosis was determined from the Medicare claims using both the International Classification of Diseases (ninth revision) procedure codes and level II Healthcare Common Procedure Coding System: Current Procedural Terminology (CPT) codes (Supplemental Table 2 in the online version).

Cost Analysis

We measured the Medicare payments to these 3 imaging modalities within 1 year after bladder cancer diagnosis, and all reported costs were adjusted and normalized to 2016 US dollars using the medical care component of the Consumer Price Index.[12] We also extrapolated the national excess medical spending on advanced imaging for bladder cancer care. Using the estimated nationwide new cases of bladder cancer in 2016 from the SEER registry and its stage distribution, we multiplied the number of patients in each stage group by the proportion expected to receive the imaging. Finally, the number of patients who received advanced imaging was multiplied by the mean differences of costs between advanced imaging (PET/CT) and the 2 imaging modalities (CT and MRI).

Statistical Analysis

We compared the use of imaging modalities in patients with bladder cancer stratified by demographic and clinical variables with Pearson χ^2 tests. We performed a Cochran-Armitage test for trend to assess changes in the proportion of patients receiving imaging

Table 1 Patient Demographic and Clinical Characteristics by the Type of Imaging

Characteristic	PET/CT, N (%)			MRI, N (%)			CT, N (%)		
	Yes	No	*P*	Yes	No	*P*	Yes	No	*P*
Year of diagnosis			<.001			<.001			<.001
2004	14 (1.1)	5138 (14.4)		250 (15.1)	4902 (13.9)		2932 (12.3)	2220 (17.0)	
2005	41 (3.2)	4807 (13.5)		244 (14.8)	4604 (13.1)		2948 (12.4)	1900 (14.6)	
2006	160 (12.4)	4452 (12.5)		263 (15.9)	4349 (12.4)		2985 (12.5)	1627 (12.5)	
2007	159 (12.3)	4481 (12.6)		220 (13.3)	4420 (12.6)		3040 (12.8)	1600 (12.3)	
2008	226 (17.5)	4358 (12.3)		201 (12.2)	4383 (12.5)		3092 (13.0)	1492 (11.4)	
2009	246 (19.1)	4087 (11.5)		139 (8.4)	4194 (11.9)		2996 (12.6)	1337 (10.3)	
2010	259 (20.1)	4202 (11.8)		200 (12.1)	4261 (12.1)		3029 (12.7)	1432 (11.0)	
2011	186 (14.4)	4039 (11.4)		134 (8.1)	4091 (11.6)		2801 (11.8)	1424 (10.9)	
Age group, y			.002			.001			< .001
66-69	219 (17.0)	5464 (15.4)		256 (15.5)	5427 (15.4)		3837 (16.1)	1846 (14.2)	
70-74	288 (22.3)	7986 (22.5)		432 (26.2)	7842 (22.3)		5387 (22.6)	2887 (22.2)	
75-79	356 (27.6)	8668 (24.4)		404 (24.5)	8620 (24.5)		5822 (24.4)	3202 (24.6)	
80+	428 (33.2)	13,446 (37.8)		559 (33.9)	13,315 (37.8)		8777 (36.8)	5097 (39.1)	
Gender			<.001			<.001			<.001
Male	865 (67.0)	26,424 (74.3)		1088 (65.9)	26,201 (74.4)		17,066 (71.6)	10,223 (78.4)	
Female	426 (33.0)	9140 (25.7)		563 (34.1)	9003 (25.6)		6757 (28.4)	2809 (21.6)	
Race			.474			<.001			.033
Non-Hispanic White	1151 (89.2)	31,576 (88.8)		1405 (85.1)	31,322 (89.0)		21,119 (88.6)	11,608 (89.1)	
Non-Hispanic Black	53 (4.1)	1440 (4.0)		110 (6.7)	1383 (3.9)		984 (4.1)	509 (3.9)	
Hispanic	28 (2.2)	1026 (2.9)		67 (4.1)	987 (2.8)		720 (3.0)	334 (2.6)	
Other	59 (4.6)	1522 (4.3)		69 (4.2)	1512 (4.3)		1000 (4.2)	581 (4.5)	
Marital status			.533			.469			.003
Single	182 (14.1)	4638 (13.0)		226 (13.7)	4594 (13.0)		3133 (13.2)	1687 (12.9)	
Married	763 (59.1)	21,195 (59.6)		960 (58.1)	20,998 (59.6)		14,048 (59.0)	7910 (60.7)	
Unknown	346 (26.8)	9731 (27.4)		465 (28.2)	9612 (27.3)		6642 (27.9)	3435 (26.4)	
Census region			<.001			<.001			<.001
West	598 (46.3)	13,933 (39.2)		622 (37.7)	13,909 (39.5)		9171 (38.5)	5360 (41.1)	
Northeast	257 (19.9)	8984 (25.3)		543 (32.9)	8698 (24.7)		5978 (25.1)	3263 (25.0)	
Midwest	97 (7.5)	4207 (11.8)		163 (9.9)	4141 (11.8)		2725 (11.4)	1579 (12.1)	
South	339 (26.3)	8440 (23.7)		323 (19.6)	8456 (24.0)		5949 (25.0)	2830 (21.7)	

Table 1 Continued

Characteristic	PET/CT, N (%)			MRI, N (%)			CT, N (%)		
	Yes	No	*P*	Yes	No	*P*	Yes	No	*P*
Urban/rural			.501			.050			.955
Urban	1261 (97.7)	34,834 (97.9)		1628 (98.6)	34,467 (97.9)		23,331 (97.9)	12,764 (97.9)	
Rural	30 (2.3)	730 (2.1)		23 (1.4)	737 (2.1)		492 (2.1)	268 (2.1)	
Median household income, $			.256			<.001			.736
≤23,364	346 (26.8)	9335 (26.2)		359 (21.7)	9322 (26.5)		6276 (26.3)	3405 (26.1)	
23,365-31,906	336 (26.0)	8729 (24.5)		403 (24.4)	8662 (24.6)		5834 (24.5)	3231 (24.8)	
31,907-41,719	288 (22.3)	8762 (24.6)		453 (27.4)	8597 (24.4)		5825 (24.5)	3225 (24.7)	
≥41,720	321 (24.9)	8738 (24.6)		436 (26.4)	8623 (24.5)		5888 (24.7)	3171 (24.3)	
Stage			<.001			<.001			<.001
I	413 (32.0)	29,155 (82.0)		912 (55.2)	28,656 (81.4)		17,326 (72.7)	12,242 (93.9)	
II	424 (32.8)	3768 (10.6)		349 (21.1)	3843 (10.9)		3648 (15.3)	544 (4.2)	
III	125 (9.7)	1103 (3.1)		136 (8.2)	1092 (3.1)		1125 (4.7)	103 (0.8)	
IV	329 (25.5)	1538 (4.3)		254 (15.4)	1613 (4.6)		1724 (7.2)	143 (1.1)	
Hydronephrosis			<.001			<.001			<.001
No	1141 (88.4)	34,017 (95.7)		1488 (90.1)	33,670 (95.6)		22,487 (94.4)	12,671 (97.2)	
Yes	150 (11.6)	1547 (4.3)		163 (9.9)	1534 (4.4)		1336 (5.6)	361 (2.8)	
Grade			<.001			<.001			<.001
Low	167 (12.9)	14,341 (40.3)		421 (25.5)	14,087 (40.0)		8027 (33.7)	6481 (49.7)	
High	1028 (79.6)	15,851 (44.6)		1061 (64.3)	15,818 (44.9)		12,631 (53.0)	4248 (32.6)	
Unknown	96 (7.4)	5372 (15.1)		169 (10.2)	5299 (15.1)		3165 (13.3)	2303 (17.7)	
Comorbidity score			.293			.006			.000
0	671 (52.0)	18,505 (52.0)		824 (49.9)	18,352 (52.1)		12,328 (51.7)	6848 (52.5)	
1	336 (26.0)	9150 (25.7)		428 (25.9)	9058 (25.7)		6289 (26.4)	3197 (24.5)	
2	132 (10.2)	4134 (11.6)		181 (11.0)	4085 (11.6)		2744 (11.5)	1522 (11.7)	
3+	152 (11.8)	3775 (10.6)		218 (13.2)	3709 (10.5)		2462 (10.3)	1465 (11.2)	
Radical cystectomy			<.001			<.001			<.001
No	1009 (78.2)	33,485 (94.2)		1372 (83.1)	33,122 (94.1)		21,527 (90.4)	12,967 (99.5)	
Yes	282 (21.8)	2079 (5.8)		279 (16.9)	2082 (5.9)		2296 (9.6)	65 (0.5)	
Chemotherapy			<.001			<.001			<.001
No	712 (55.2)	33,194 (93.3)		1278 (77.4)	32,628 (92.7)		21,120 (88.7)	12,786 (98.1)	
Yes	579 (44.8)	2370 (6.7)		373 (22.6)	2576 (7.3)		2703 (11.3)	246 (1.9)	

Table 1 Continued

Characteristic	PET/CT, N (%)			MRI, N (%)			CT, N (%)		
	Yes	No	*P*	Yes	No	*P*	Yes	No	*P*
Radiation therapy			<.001			<.001			<.001
No	1043 (80.8)	34,398 (96.7)		1456 (88.2)	33,985 (96.5)		22,453 (94.2)	12,988 (99.7)	
Yes	248 (19.2)	1166 (3.3)		195 (11.8)	1219 (3.5)		1370 (5.8)	44 (0.3)	

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

after cancer diagnosis, and also the various types of imaging modalities utilized from 2004 to 2011. Multivariable logistic regression models were used to determine adjusted odds ratios (ORs) for use of the 3 imaging modalities. We assessed goodness-of-fit using the Hosmer and Lemeshow test. All statistical analyses were conducted using the SAS (version 9.4; SAS Institute, Cary, NC) software suite. The criterion for statistical significance was a *P* value less than .05. Our study was exempted for approval by The University of Texas MD Anderson Cancer Center and The University of Texas Medical Branch Institutional Review Boards.

Results

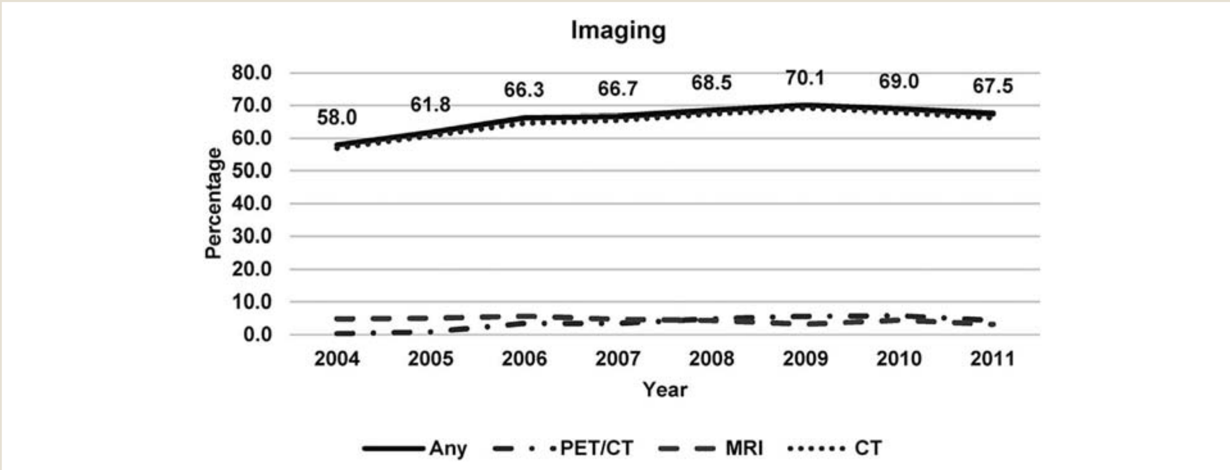
Patient demographics and clinical characteristics according to imaging modality are presented in Table 1. In total, 24,240 (65.8%) patients received one of these 3 imaging modalities within 12 months after bladder cancer diagnosis: 1291 (3.5%) PET/CT, 1495 (4.1%) MRI, and 21,454 (58.2%) CT. We also observed a greater use of PET/CT among female patients, residents in the West census region, patients diagnosed with hydronephrosis or high grade tumor, and patients who underwent surgery, chemotherapy, or radiation therapy.

When assessing trends in receipt of imaging, the use of PET/CT significantly increased over the time period of study, from < 0.5% in 2004 to 4.4% in 2011 (*P* trend < .001). At the same time, the percentage of patients who received an MRI significantly decreased over the study period (*P* trend < .001) (Figure 1). We further assessed trends in receipt of imaging according to clinical stage (Figure 2). PET/CT increased from 2001 to 2011 across all clinical stages: I, 0.1% to 1.2%; II, 1.0% to 13.6%; III, 0.0% to 11.9%; and IV, 1.4% to 27.0% (All *P* trend < .001), respectively (Figure 2). In contrast, utilization decreased for MRI (*P* trend = .08) for clinical stage I, II, and IV patients, whereas the use of CT imaging techniques remained essentially unchanged.

We used multivariable logistic regression models to evaluate factors associated with utilization of each of the 3 imaging modalities for patients diagnosed with bladder cancer. We noted a marked increase in use of PET/CT during the study period (2011 vs. 2004: OR, 17.55; 95% confidence interval [CI], 10.14-30.38; *P* < .001) (Table 2). Predictors associated with an increased likelihood of receiving PET/CT included female versus male gender (OR, 1.28; 95% CI, 1.12-1.46; *P* = .001), White versus non-White (non-Hispanic Black: OR, 0.74; 95% CI, 0.55-0.99; *P* = .047; Hispanic: OR, 0.54; 95% CI, 0.36-0.81; *P* = .003), married versus single marital status (OR, 1.21; 95% CI, 1.01-1.45; *P* = .034), being diagnosed with high versus low grade tumors (OR, 1.89; 95% CI, 1.56-2.28; *P* < .001), clinical stage higher than I (Stage I: OR, 6.17; 95% CI, 5.25-7.24; *P* < .001; Stage II: OR, 5.86; 95% CI, 4.67-7.35; *P* < .001, and Stage III: OR, 11.20; 95% CI, 9.39-13.35; *P* < .001), and the presence of hydronephrosis (yes vs. no OR, 1.40; 95% CI, 1.15-1.70; *P* < .001).

In our multivariable analysis, there was significantly decreased utilization of MRI (OR, 0.60; 95% CI, 0.49-0.75; *P* < .001) in 2011 versus 2004, respectively. Predictors associated with increased likelihood of receiving MRI included female versus male gender (OR, 1.35; 95% CI, 1.21-1.50; *P* < .001), non-White (non-Hispanic black: OR, 1.50; 95% CI, 1.21-1.86; *P* < .001; Hispanic: OR, 1.49; 95% CI, 1.15-1.95; *P* = .003), Northwest versus West

Figure 1 Percent of Patients Receiving Any Imaging, CT, MRI, and PET/CT, After Bladder Cancer Diagnosis From 2004-2011 (Any Imaging: *P* Trend, *P* < .001; CT: *P* Trend, *P* < .001; MRI: *P* Trend, *P* < .001; PET/CT: P Trend, *P* < .001)



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

region (OR, 1.41; 95% CI, 1.24-1.60; $P < .001$), being diagnosed with high versus low grade tumors (OR, 1.41; 95% CI, 1.23-1.61; $P < .001$), clinical stage II, III, and IV versus I (Stage II: OR, 6.17; 95% CI, 5.25-7.24; $P < .001$; Stage III: OR, 5.86; 95% CI, 4.67-7.35; $P < .001$, and Stage IV: OR, 11.20; 95% CI, 9.39-13.35; $P < .001$), hydronephrosis yes versus no (OR, 1.57; 95% CI, 1.31-1.87; $P < .001$), and comorbidity score 3 or more (OR, 1.38; 95% CI, 1.18-1.62; $P < .001$).

Predictors associated with increased likelihood of receiving CT were younger age (70-74 years: OR, 0.89; 95% CI, 0.82-0.96; $P = .002$; 75-79 years: OR, 0.84; 95% CI, 0.78-0.90; $P < .001$; 80+ years: OR, 0.72; 95% CI, 0.67-0.78; $P < .001$; vs. patients aged 66-69 years old), female versus male gender (OR, 1.40; 95% CI, 1.32-1.48; $P < .001$), Hispanic versus non-Hispanic White and non-Hispanic Black race/ethnicity (Hispanic: OR, 1.19; 95% CI, 1.03-1.037; $P = .015$), married versus single marital status (OR, 1.09; 95% CI, 1.01-1.17; $P = .021$), highest median household income quartile (OR, 1.12; 95% CI, 1.04-1.20; $P = .002$), being diagnosed with high versus low grade tumors (OR, 1.61; 95% CI, 1.52-1.69; $P < .001$), clinical stage II, III, and IV versus I (Stage II: OR, 3.74; 95% CI, 3.39-4.13; $P < .001$; Stage III: OR, 5.91; 95% CI, 4.81-7.26; $P < .001$, and Stage IV: OR, 6.46; 95% CI, 5.42-7.70; $P < .001$), and hydronephrosis yes versus no (OR, 1.42; 95% CI, 1.25-1.61; $P < .001$).

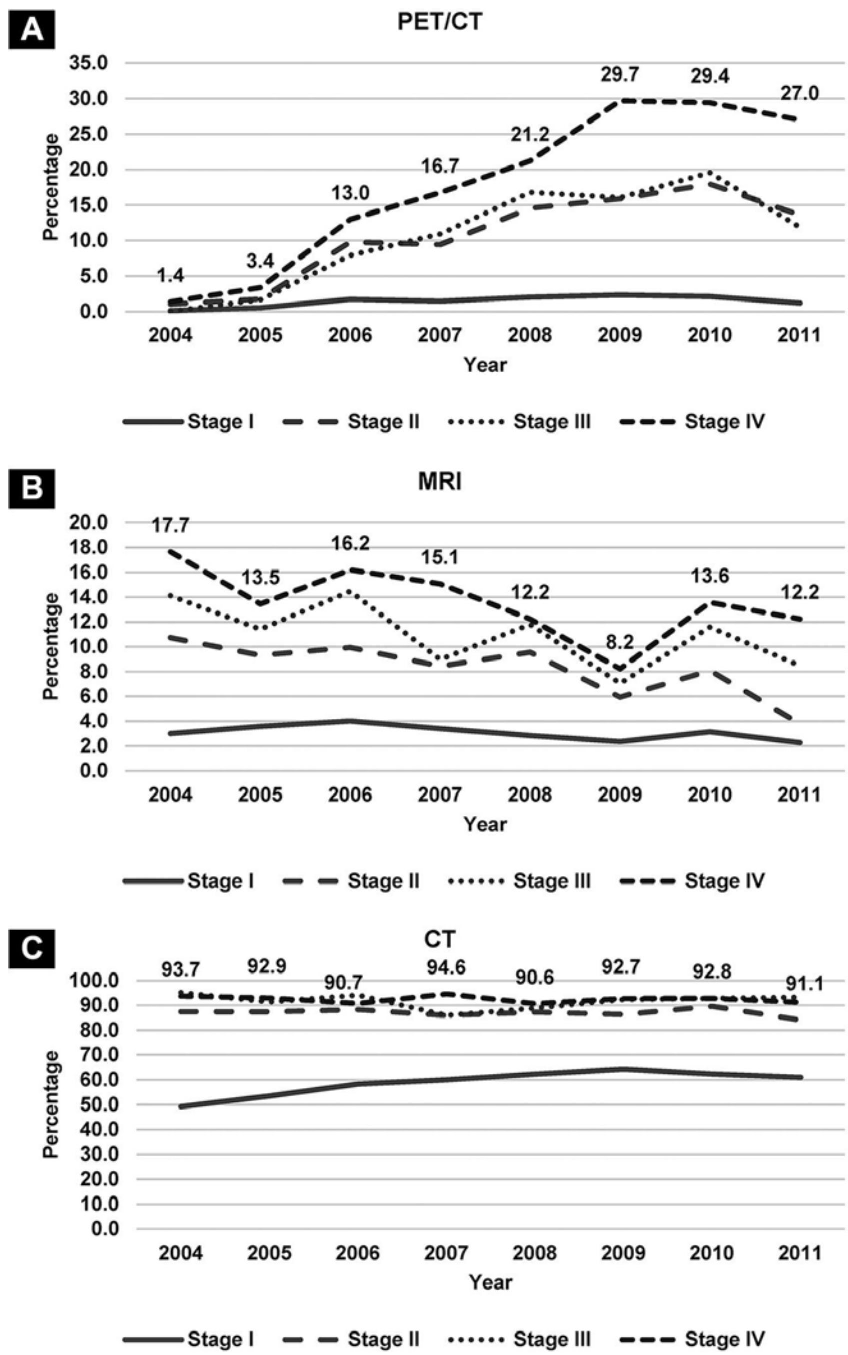
The mean incremental cost of PET/CT versus CT and MRI was $1040 and $612 (in 2016 dollars), respectively. The estimated national excess in health care costs for PET/CT imaging compared with less costlier CT and MRI techniques was $11.6 million (see Supplemental Table 3 in the online version).

Discussion

Guidelines recommend the use of CT and MRI as the principle imaging in the staging and management of bladder cancer.[2-4] Although there is uncertainty regarding use in metastatic patients, there are no evidence to suggest its clinical value in the non-metastatic setting.[7] In the present study, we assessed trends in use of PET/CT, MRI, and CT among patients with bladder cancer. Our study revealed a significant shift in the type of imaging modality performed during the study period. Specifically, we observed a marked 16-fold increased use of PET/CT regardless of clinical stage. This rapid adoption of PET/CT translated into excess national spending of approximately $11 million.

PET/CT has become the standard of care for other malignancies owing to improved sensitivity and specificity over CT or MRI.[13-15] However, whether or not PET/CT improves the accuracy in bladder cancer staging is a matter of debate. When PET/CT was used in detecting the primary tumor, the reported sensitivity ranged from 54% to 86.7% with a specificity from 25% to 100%.[5,7,16,17] Conversely, the sensitivity dropped for PET/CT in preoperative staging, ranging from 46% to 60%.[17-19] There have been only a few studies that have reported PET/CT to be more sensitive than CT for preoperative staging.[17,20] Although PET/CT may offer the ability to detect additional lesions and more frequently upstage patients, the final clinical impact on actual treatment changes may be relatively low and not adequately quantified in these studies.[6,7,21,22] Owing to the limited number of comparative effectiveness studies available, as well as the relatively small number of patients included in these studies, current guidelines do not recommend the use of PET/CT imaging for bladder cancer staging.[2-4] One major challenge of using PET in patients with bladder cancer is that the fluorodeoxyglucose is excreted into the urinary system. Some have refuted this benefit as an acceptable initial imaging modality for staging patients with bladder cancer.[18,23] Recent studies have found that use of other tracers than fluorodeoxyglucose, such as C11-methionine and C11-choline, may improve the visualization of PET imaging in bladder cancer.[23,24] However, further research is needed to support the application of these new tracers into clinical practice.

Figure 2 Percent of Patients Receiving PET/CT, MRI, or CT Imaging After a Bladder Cancer Diagnosis. (A) PET/CT (Stage I: Cochrane Armitage Test of Trend, $P < .001$; Stage II: Cochrane Armitage Test of Trend, $P \leq .001$; Stage III: *P* Trend, $P < .001$; Stage IV: *P* Trend, $P < .001$). (B) MRI (Stage I: *P* Trend, $P = .001$; Stage II: *P* Trend, $P < .001$; Stage III: *P* Trend, $P = .083$; Stage IV: *P* Trend, $P = .031$). (C) CT (Stage I: *P* Trend, $P < .001$; Stage II: *P* Trend, $P = .379$; Stage III: *P* Trend, $P = .658$; Stage IV: *P* Trend, $P = .480$)



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

In the present study, predictors for receipt of advanced imaging largely included clinical and pathologic determinants. Patients with high grade tumors, > T2 or greater clinical stage, and those with increased comorbidities were the most likely to receive advanced imaging. Our finding that patients who underwent chemotherapy were more likely to receive advanced imaging may reflect a higher index of suspicion for more advanced disease in this population. Moreover, we also observed geographic variation in receipt of

Table 2 Multivariable Model Discerning Predictors for Receipt of PET/CT, MRI, and CT

Characteristic	PET/CT			MRI			CT		
	OR	95% CI	*P* Value	OR	95% CI	*P* Value	OR	95% CI	*P* Value
Year of diagnosis									
2004	1.00			1.00			1.00		
2005	3.00	1.63-5.52	<.001	1.02	0.84-1.22	.877	1.16	1.06-1.26	<.001
2006	13.30	7.67-23.07	<.001	1.15	0.96-1.38	.136	1.39	1.28-1.51	<.001
2007	13.25	7.64-22.98	<.001	0.95	0.79-1.15	.591	1.46	1.34-1.59	<.001
2008	19.89	11.54-34.29	<.001	0.86	0.71-1.04	.119	1.60	1.47-1.75	<.001
2009	23.94	13.90-41.22	<.001	0.62	0.50-0.77	<.001	1.73	1.59-1.89	<.001
2010	25.21	14.65-43.39	<.001	0.89	0.74-1.09	.261	1.69	1.55-1.85	<.001
2011	17.55	10.14-30.38	<.001	0.60	0.49-0.75	<.001	1.55	1.42-1.70	<.001
Age group, y									
66-69	1.00			1.00			1.00		
70-74	0.91	0.76-1.10	.348	1.16	0.98-1.36	.08	0.89	0.82-0.96	.002
75-79	1.04	0.86-1.25	.694	0.92	0.78-1.08	.31	0.84	0.78-0.90	<.001
80+	0.66	0.55-0.79	<.001	0.76	0.65-0.89	<.001	0.72	0.67-0.78	<.001
Gender									
Male	1.00			1.00			1.00		
Female	1.28	1.12-1.46	<.001	1.35	1.21-1.50	<.001	1.40	1.32-1.48	<.001
Race									
Non-Hispanic White	1.00			1.00			1.00		
Non-Hispanic Black	0.74	0.55-0.99	.047	1.50	1.21-1.86	<.001	0.86	0.76-0.97	.012
Hispanic	0.54	0.36-0.81	.003	1.49	1.15-1.95	.003	1.19	1.03-1.37	.015
Other	0.86	0.64-1.14	.287	0.94	0.73-1.21	.615	0.95	0.85-1.06	.327
Marital status									
Single	1.00			—			1.00		
Married	1.21	1.01-1.45	.034	—			1.09	1.01-1.17	.021
Unknown	1.06	0.87-1.30	.558	—			1.06	0.98-1.15	.128
Census region									
West	1.00			1.00			1.00		
Northeast	0.71	0.61-0.83	<.001	1.41	1.24-1.60	<.001	1.11	1.041.17	.001
Midwest	0.50	0.40-0.63	<.001	0.89	0.74-1.07	.215	1.05	0.98-1.14	.179
South	0.94	0.81-1.08	.37	0.89	0.77-1.03	.128	1.30	1.22-1.39	<.001

Table 2 Continued

Characteristic	PET/CT			MRI			CT		
	OR	95% CI	*P* Value	OR	95% CI	*P* Value	OR	95% CI	*P* Value
Median household income, $									
≤23,364	–			1.00			1.00		
23,365-31,906	–			1.18	1.01-1.37	.038	1.04	0.98-1.11	.207
31,907-41,719	–			1.25	1.07-1.47	.005	1.07	1.00-1.14	.065
≥41,720	–			1.21	1.03-1.43	.019	1.12	1.04-1.20	.002
Grade									
Low	1.00			1.00			1.00		
High	1.89	1.56-2.28	<.001	1.41	1.23-1.61	<.001	1.61	1.52-1.69	<.001
Unknown	0.94	0.72-1.22	.641	1.07	0.88-1.29	.506	0.97	0.91-1.04	.44
Clinical stage									
I	1.00			1.00			1.00		
II	6.17	5.25-7.24	<.001	2.41	2.09-2.78	<.001	3.74	3.39-4.13	<.001
III	5.86	4.67-7.35	<.001	3.14	2.57-3.85	<.001	5.91	4.81-7.26	<.001
IV	11.20	9.39-13.35	<.001	3.88	3.29-4.56	<.001	6.46	5.42-7.70	<.001
Hydronephrosis									
No	1.00			1.00			1.00		
Yes	1.40	1.15-1.70	<.001	1.57	1.31-1.87	<.001	1.42	1.25-1.61	<.001
Comorbidity score									
0	–			1.00			1.00		
1	–			1.08	0.96-1.22	.209	1.12	1.07-1.19	<.001
2	–			1.04	0.88-1.23	.64	1.03	0.96-1.11	.456
3+	–			1.38	1.18-1.62	<.001	0.93	0.86-1.00	.059

Abbreviations: CI = confidence interval; CT = computed tomography; MRI = magnetic resonance imaging; OR = odds ratio; PET/CT = positron emission tomography/computed tomography.

advanced imaging. Patients residing in the western US regions were significantly more likely to receive advanced imaging. This variability in practice patterns may be a reflection of a larger number of PET/CT scanners in the western region compared with other SEER regions with inherent improved access to this imaging and/or market influences.[25] A prior study has associated the increased use of advanced imaging with physician self-referral arrangements as a major driver of health care costs.[26] Interestingly, that study was derived from a large private insurer in California.

The cost difference between PET/CT and other imaging methods was substantial at a national level. Our study estimated that the excess spending on advanced imaging will impose about $12 million in cost-expenditures. This may be an underestimate as our analysis used Medicare reimbursement rates for imaging, which are historically lower than private insurance payers. The substantial economic costs of adopting advanced technology from diagnosis to treatment is an important issue of current health care reform.[27,28] The cost of PET was only 1.5% of the Medicare spending on cancer care; however, the contribution of PET to cancer care spending will continue to increase owing to the higher growth rate of imaging cost than the cost of cancer care.[29] Our data highlights the need for health policy measures to limit utilization and the associated costs of advanced imaging methods that are not guideline-recommended over less costly imaging modalities.[9]

Our findings must be interpreted in the context of the study design. First, the SEER-Medicare database provides a national representative sample of elderly patients; thus findings may not be generalizable to younger populations. Second, Medicare claims data do not collect information on glomerular filtration rate and urine creatinine clearance. Both of these are determinants are often used as surrogates regarding appropriateness of using CT or MRI in patients with poor renal function. Third, claims data do not contain information regarding patient and physician preference, which are important determinants in the decision-making process on imaging selection.[30,31] Fourth, we did not require a corresponding diagnosis code for bladder cancer when an imaging was identified because we found in the sensitivity analysis that only 20% of patients with bladder cancer received imaging billed with this diagnosis code, which would have largely underestimated the utilization of imaging. Finally, with limited clinical information available from claims data to determine the intent of advanced imaging, our study merely focused on the national trends in advanced imaging adoption. We made no attempt to discern trends in the appropriateness of the various imaging modalities used in bladder cancer. The appropriateness of various imaging modalities remains to be determined, given recent guideline panel recommendations on appropriateness of use of the varying imaging modalities in bladder cancer.[4,32,33]

Conclusions

We identified rapid adoption of PET/CT imaging without comparative effectiveness research documenting clinical superiority over less costlier guideline-recommended imaging. These findings have important implications regarding health policy decision-making and the need for improved value-based bladder cancer care.

Clinical Practice Points

- Current European and United States Guidelines on bladder cancer recommend CT and/or MRI as the preferred abdominal imaging modality over PET/CT in preoperative staging and follow-up surveillance.
- The American Board of Internal Medicine's Choosing Wisely campaign and American Society of Clinical Oncology's Value of Cancer Care Task Force have collaborated to encourage sustainable high-quality and high—value-based cancer care.
- Data from this large population-based cancer registry analysis of utilization patterns and economic impact regarding advanced imaging in bladder cancer showed a sharp increase in the use of advanced PET/CT imaging during the study period, accompanied with an excess national spending of approximately $11 million.
- These findings suggested that value-based bladder cancer care is needed in community practice. Researches on comparative effectiveness of PET/CT imaging over less costlier imaging techniques are lacking to support contemporary trend of PET/CT imaging.

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Disclosure

The authors have stated that they have no conflicts of interest.

Supplemental Data

Supplemental tables accompanying this article can be found in the online version at http://dx.doi.org/10.1016/j.clgc.2017.07.018.

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Supplemental Table 1 Derivation of the Study Cohort

Step	Criteria	SEER-Medicare	
		Inclusion	Exclusion
1	Diagnosis of bladder cancer from 2004 to 2011	89,461	
2	Urothelial carcinoma or transitional cell carcinoma only (ICD-O-3 codes 8120 and 8130 only)	83,180	6281
3	Age at diagnosis: 66-90 y	65,185	17,995
4	Clinical stage T1-T4	62,940	2245
5	Exclude if diagnosis was from death certificate or autopsy, or no pathologic confirmation	62,755	185
6	Exclude patients with any other cancer prior/post to bladder cancer	57,560	5195
7	Exclude if no Medicare Part A&B coverage, or with HMO coverage	36,855	20,705

Abbreviations: HMO = Health Maintenance Organization; ICD-O-3 = International Classification of Diseases for Oncology, third revision; SEER = Surveillance, Epidemiology, and End Results.

Supplemental Table 2 ICD-9 and CPT Codes Used to Identify Patients Diagnosed With Bladder Cancer Who Received PET/CT, MRI, CT, Radical Cystectomy, Chemotherapy, and Other Clinical Conditions

	ICD-9 Diagnosis Codes	ICD-9 Procedure Codes	CPT Codes
Bladder cancer	188		
PET/CT			78,815, 78,816
MRI			74,181, 74,182, 74,183, 74,185 72,195, 72,196, 72,197, 76,498
CT			72,191, 72,192, 72,193, 72,194, 74,150, 74,160, 74,170, 74,176, 74,177, 74,178, 76,497
Radical cystectomy		57.71, 57.79, 68.8	51,570, 51,575, 51,580, 51,585, 51,590, 51,595, 51,596, 51,597
Radiation therapy		92.2, 92.20—92.27, 92.29, 92.3, 92.30—92.39, 92.4, 92.41	77,371—77,373, 77,401—77,525, 77,761—77,799, G0174, G0251, G0339, G0340, G0173, 0082T, 61,793, 0182T
Chemotherapy			J6360, J9000, J9001, J9060, J9062, J9201, J9250, J9260, J9000, J9001, J9010, J9250, J9260, J9360, J9070, J9080, J9090, J9091, J9092, J9093, J9094, J9095, J9096, J9097, J9098, J9201, J9265, J9170, J9208, J9999, J9045
Hydronephrosis	591		

Abbreviations: CPT = current procedural terminology; CT = computed tomography; ICD-9 = International Classification of Diseases, Ninth Revision; MRI = magnetic resonance imaging; PET/CT = positron emission tomography/computed tomography.

Supplemental Table 3 Estimates of Excess Medical Spending on Using Advanced Imaging

Parameters[a]	N	Imaging	Cost, $
No. bladder cancer	76,960	PET	1604.85
Assumed proportion of urothelial cell carcinoma	90%	MRI	992.41
Assumed proportion of muscle-invasive bladder cancer	30%	CT	564.69
Spending extrapolation			
Stages[a]	**Proportion of PET use in the last year of study**	**Excess cost scenario 1: PET/CT replaced by MRI**	**Excess cost scenario 2: PET/CT replaced by CT**
Stage I	1.19%	151,439	257,204
Stage II	13.57%	1,726,917	2,932,989
Stage III	11.86%	1,509,303	2,563,394
Stage IV	27.00%	3,436,018	5,835,719
Total excess spending, $		6,823,677	11,589,307

Abbreviations: CT = computed tomography; MRI = magnetic resonance imaging; PET/CT = positron emission tomography/computed tomography.
[a]Data source: SEER Stat Fact Sheets: Bladder Cancer: The Surveillance Research Program, in NCI's Division of Cancer Control and Population Sciences, 2016.