Original Article

Physician and Facility Drivers of Spending Variation in Locoregional Prostate Cancer

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BACKGROUND: Prostate cancer is the most common male cancer, with a wide range of treatment options. Payment reform to reduce unnecessary spending variation is an important strategy for reducing waste, but its magnitude and drivers within prostate cancer are unknown. **METHODS:** In total, 38,971 men aged ≥66 years with localized prostate cancer who were enrolled in Medicare fee-for-service and were included in the Surveillance, Epidemiology, and End Results-Medicare database from 2009 to 2014 were included. Multilevel linear regression with physician and facility random effects was used to examine the contributions of urologists, radiation oncologists, and their affiliated facilities to variation in total patient spending in the year after diagnosis within geographic region. The authors assessed whether spending variation was driven by patient characteristics, disease risk, or treatments. Physicians and facilities were sorted into quintiles of adjusted patient-level spending, and differences between those that were high-spending and low-spending were examined. **RESULTS:** Substantial variation in spending was driven by physician and facility factors. Differences in cancer treatment modalities drove more variation across physicians than differences in patient and disease characteristics (72% vs 2% for urologists, 20% vs 18% for radiation oncologists). The highest spending physicians spent 46% more than the lowest and had more imaging tests, inpatient care, and radiotherapy spending. There were no differences across spending quintiles in the use of robotic surgery by urologists or the use of brachytherapy by radiation oncologists. **CONCLUSIONS:** Significant differences were observed for patients with similar demographics and disease characteristics. This variation across both physicians and facilities suggests that efforts to reduce unnecessary spending must address decision making at both levels. ***Cancer* 2020;126:1622-1631**. *© 2020 American Cancer Society*.

KEYWORDS: cancer cost of care, health economics, health services research, practice variation, prostate cancer.

INTRODUCTION

Prostate cancer is the most common cancer among men in the United States, with more than 160,000 men diagnosed in 2017.[1] The cost of caring for these affected individuals is correspondingly large, with an estimated $11.85 billion spent in the United States in 2010 and a nearly 20% increase projected by 2020.[2] Benchmarks for appropriate spending have been difficult to establish because of the range of treatment options available and the introduction of novel and expensive technologies over the last decade, which vary widely in their costs and clinical appropriateness.[3-6] However, a large body of research, including in oncology, has demonstrated that significant differences in health care spending across and within geographic regions are not necessarily associated with better quality, access to care, or survival.[7-10]

To reduce inappropriate variation in care and its associated costs, payers and oncology professional associations are spearheading payment reform efforts that include hybrid systems of bundled and episode-based payments, with some pay-for-performance metrics.[11,12] Medicare's new Merit-Based Incentive Payment System (MIPS) evaluates total spending and will implement both financial penalties and rewards based on adherence to specific practice patterns. With >60% of prostate cancer cases diagnosed in individuals aged >65 years,[13] initiatives to reduce low-value prostate cancer care in Medicare could have a significant impact on public resource use and spending. Determining the sources and drivers of variation in prostate cancer spending will be more important in identifying opportunities

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for intervention to reduce inefficiencies and overuse and to ensure the delivery of value-based care under these new payment methods.

There is a growing body of evidence examining the association of patient and provider factors with the choice of treatment in prostate cancer.[14-16] However, the contribution of physicians and facilities to variation in overall spending within geographic regions, and whether this variation is related to differences in clinical presentations and comorbidities or to other factors, remains unknown. To bring evidence to bear on this question, we analyzed variation in medical spending within geographic regions during the first year after the diagnosis of locoregional prostate cancer, which is the primary decision-making period for most patients.[17] We focused on variation within, rather than across, geographic regions to elucidate heterogeneity in practice within these regions, which would not be caused by variation in reimbursement levels or regional practice patterns. We examined the extent to which differences across facilities and across physicians within facilities contributed to spending variation and quantified the proportion of physician and facility variation that could be explained by differences in patient characteristics, disease risk, the treatment modalities provided, or by other discretionary management decisions.

MATERIALS AND METHODS

Data Source and Study Sample

We analyzed the Surveillance, Epidemiology, and End Results-Medicare database, which includes cancer registries from 18 catchment areas across the United States covering approximately 34% of the population linked to Medicare claims.[18] Our data included men enrolled in fee-for-service Medicare who were diagnosed with locoregional prostate cancer during 2010 through 2013 and had corresponding medical claims for 2009 through 2014.

We excluded men aged 65 years because they did not have prior-year medical claims data to measure baseline health status. Patients with the following characteristics were also excluded: metastatic disease, a prior or synchronous cancer diagnosis (because the care needs for such patients are significantly different), death within 1 year of diagnosis, missing data on key study variables, lack of continuous coverage of Medicare Part B, or no claims with a urologist or a radiation oncologist (RO). Patients who were diagnosed with a second malignancy in the same month as their prostate cancer diagnosis were excluded. If another cancer was diagnosed after the first full month, patients would be included in the analysis until the time of the second malignancy diagnosis. Analyses could not be performed on patients who were living in a Hospital Referral Region (HRR) with <10 patients because of computational limitations, so these patients were also excluded. The final sample included 35,545 men (for the full sample construction, see Supporting Table 1).

Variables and Outcomes

Unadjusted monthly spending was estimated for all patients. The dependent variable in the analyses was total annual medical spending per patient, excluding outpatient pharmacy (Medicare Part D). We defined 3 categories of independent variables: 1) patient and disease characteristics, 2) patient receipt of treatment modalities, and 3) attributed physician and facility. Patient and disease characteristics included: age; race; health status measured using the Charlson comorbidity index with Klabunde modification,[19] based on the year before diagnosis; original reason for Medicare eligibility; dual enrollment in Medicaid; enrollment in a Part D plan; average income based on census tract residence; census tract education (proportion with some college or above); and prostate cancer risk group, defined using National Comprehensive Cancer Network (NCCN) criteria[20] on T-classification, Gleason score, and prostate-specific antigen, which is the classification system primarily used to drive decision-making among urologists and ROs. We were unable to distinguish between very-low-risk and low-risk patients because of the absence of information on prostate-specific antigen density and the number of positive cores. Patients were classified as very-high-risk based on T-classification and Gleason score.

Treatment modalities were measured as binary indicators of whether or not the patient was treated with active surveillance or watchful waiting (AS/WW) (defined as no treatment 6 months after diagnosis), surgery (open prostatectomy, minimally invasive prostatectomy [with or without robotic assistance], or cryosurgery), radiation (external beam radiation therapy [EBRT] and brachytherapy), and hormone therapy. AA and WW were grouped together because of the difficulty in accurately distinguishing them within the data[21] and because spending using previously published definitions[22] was observed to be similar in preliminary analyses.

Attribution

First, we attributed all patients to the urologist who provided the plurality of their care. Patients who had at least 1 visit with an RO were also attributed to the RO who was associated with the greatest number of their medical claims. We then attributed patients to facilities according to the plurality of their attributed physicians' billings. Thus, even if a physician practiced at multiple facilities, patients were attributed to the facility where the plurality of claims were made. Patients attributed to a urologist and an RO could be attributed to 2 different facilities (57% of patients). Although the availability of specific technology and services may drive treatment choices and spending across facilities,[23-25] understanding variation within facilities facilitates an understanding of the effect that local practice patterns may have on physicians who work together.

Variation Across Physicians and Facilities

To determine the contribution of physician and facility differences to variation in total spending, we estimated 2 sets of multilevel linear regression models that included physician and facility random effects, in which physicians were nested within a facility, and the unit of analysis was the patient-year. The first set of models included the full sample of patients, and the random effects identified the patient's attributed urologist and the urologist's attributed facility. The second set of models included only patients who were also attributed to an RO, and the random effects identified the patients' RO and the RO's attributed facility. A sensitivity analysis was also performed on a third set of models that included patients who were only attributed to a urologist. All models included time (calendar quarter of diagnosis) and region fixed effects to evaluate variation in spending within geographic areas and time periods, rather than between regions and time. Time was measured as the calendar quarter of diagnosis, and geographic region was measured as the HRR within which the patient received the plurality of his care. To lessen the influence of outliers, all observations of spending above the 99th percentile were set to the value of the 99th percentile (for additional methodological details and model output, see Supporting Materials and Supporting Table 2).

We report results in 3 ways: 1) the percentage of variation in total spending driven by physicians or by facilities, calculated as the physician or facility variance divided by the total variance in the model (total = physician + facility + residual); 2) the predicted additional spending for patients with physicians or facilities with spending 1 SD above the mean; and 3) the difference in spending driven by this level of variation between "high-spending" (top 20% of spending) versus "low-spending" (bottom 20% of spending). We estimated models for the full patient samples stratified by NCCN risk groups.[20] All statistical analyses were completed using Stata (version 14; Stata Corporation).

Analysis of Drivers of Variation

We quantified the proportion of spending variation across physicians and facilities explained by observable differences in patient characteristics, in disease risk, or in provision of treatment modalities by estimating 2 additional sequential models. The first included independent variables measuring patient and disease characteristics. The second added variables indicating treatment modalities. The proportion of physician and facility variance explained by the added variables was measured as the difference between the physician and facility variance with and without the additional variables divided by the physician and facility variance without the additional variables. Patients with unknown risk group and with <12 month of claims were excluded from these models. Model results of all excluded patients are shown in Supporting Table 3.

Variation in Treatment Intensity by Spending Quintile

To identify other specific contributors to the variation across physicians and facilities, our final analyses examined differences in treatment intensity across those that were high-spending and low-spending. We used model output from the multilevel mixed regression models described above to estimate predicted physician and facility average per-patient annual spending, which was adjusted for differences in time, geography, patient population, disease characteristics, and decisions to provide each of the treatment modalities. We then sorted physicians and facilities into quintiles according to their adjusted spending (1, lowest quintile; 5, highest quintile) and examined differences in utilization and spending outcomes between those that were "high-spending" (the top quintile according to adjusted spending) versus "low-spending" (the lowest adjusted quintile). An additional sensitivity analysis sorting physicians and facilities into quartiles of spending was performed.

By using multivariate regression models, in which key independent variables were dummy variables indicating the spending quintile, we estimated values for each quintile in: average inpatient days and imaging tests per patient; likelihood of undergoing AS/WW; use of cryosurgery and open or robotic prostatectomy among patients undergoing surgery; and, among patients receiving radiation, spending on radiotherapy and their likelihood of receiving of brachytherapy, EBRT (3-dimensional

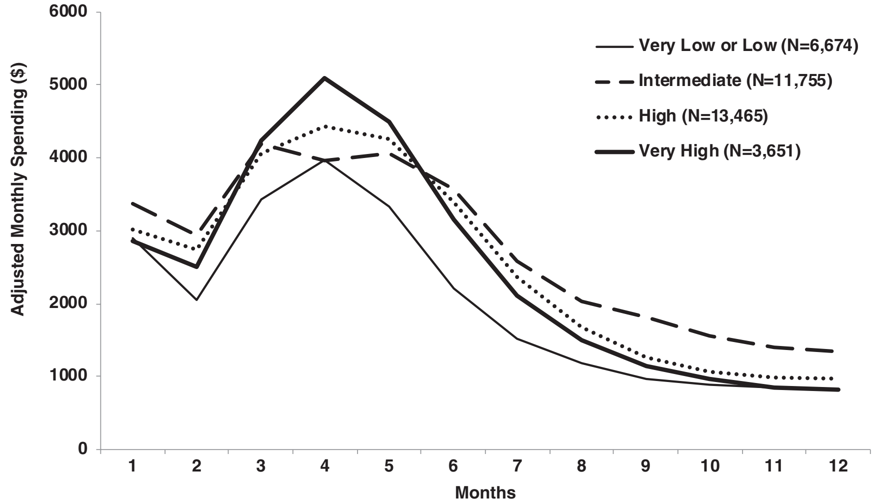

Figure 1. Average monthly patient spending in the first year after prostate cancer diagnosis is illustrated. The results are stratified by National Comprehensive Cancer Network (NCCN) disease risk group. The very-low-risk and low-risk groups were analyzed together because of a lack of prostate-specific antigen density data within the Surveillance, Epidemiology, and End Results program (numerical data are available in Supporting Table 4). Source: Authors' analysis of Surveillance, Epidemiology, and End Results-Medicare linked data, 2009 through 2014.

conformal radiotherapy), intensity-modulated radiation therapy (IMRT), stereotactic body radiation therapy, or proton beam therapy (PBT). Logistic regression was used for all binary outcomes (whether a patient received a particular type of treatment), and linear regression was used for all continuous outcomes (inpatient days, imaging tests, and spending). All regressions controlled for patient and disease characteristics, treatment modalities, time, and geography. We also tested for a linear trend in utilization and spending across quintiles. Standard errors were clustered on the attributed physician and facility.

RESULTS

Unadjusted monthly spending varied considerably throughout the year across all risk groups, with the majority of spending in the first 6 months after diagnosis and very low spending in months 7 through 12 (Fig. 1). Average (± SD) spending increased with risk group, from \$24,169 ± \$18,685 per year in very-low-risk or low-risk patients to \$32,833 ± \$19,940 per year in very-high-risk patients ($P < .001$) (for spending stratified by NCCN risk group, see Supporting Table 4). Cohort characteristics are presented in Table 1 (for a descriptive analysis of treatment choices by risk group, see Supporting Table 5).

In the multilevel models with urologist and facility random effects, 4.5% of variation in spending was driven by differences across urologists, and 5.5% was driven by differences across facilities (Table 2). For a patient who had spending 1 SD above the mean, this level of variation suggested that urologists and urologist-affiliated facilities were responsible for \$3743 and \$4130, respectively, of above-average spending. Comparing the highest and lowest quintiles of spending, a patient with a high-spending urologist would have \$11,685 higher average annual spending than if that patient had a low-spending urologist (39% over the mean); for urologist-affiliated facilities, this variation was associated with a difference of \$9310 (31% over the mean). Among patients who also saw an RO, 6.1% of the variation in their spending was driven by differences across ROs, and 5.8% was driven by differences across RO facilities. This means that ROs and RO-affiliated facilities were responsible for \$3531 and \$3858, respectively, of above-average spending for a patient who had spending 1 SD above the mean. This level of variation was also associated with a difference in average annual spending of \$13,695 (36% over the mean) between high-spending and low-spending ROs and \$14,797 (39% over the mean) between high-spending and low-spending RO-affiliated facilities.

Differences in patient characteristics and disease risk, which capture patient sorting across physicians (eg, specialization of certain physicians in patients with more advanced disease), explained 2% of between-urologist variation and 1% of between-facility variation, and differences in the treatment modalities provided to patients explained 72% (Fig. 2). In the models analyzing spending

TABLE 1. Sample Characteristics[a]

Characteristic	Attribution: No. (%) Urologist, N = 35,133	Radiation Oncologist, N = 20,419	Excluded Patients, N = 6209
Age at diagnosis: Mean ± SD, y	73.36 ± 5.68	73.07 ± 4.98	73.48 ± 5.80
66-75	24,297 (69.2)	14,442 (70.7)	4378 (69.1)
76-85	9587 (27.3)	5682 (27.8)	1687 (26.6)
≥85	1249 (3.6)	295 (1.4)	267 (4.2)
Nonwhite	6078 (17.3)	3506 (17.2)	1008 (17.9)
Census tract income: Mean ± SD, $	68,677 ± 33,313	69,736 ± 33,446	67,115.1 ± 32,607
Census tract: No. (%) with some college education	21,501 (61.2)	12,578 (61.6)	3869 (61.1)
Dual eligible	4697 (13.4)	2455 (12.0)	954 (15.1)
Originally eligible for Medicare based on disability	2790 (7.9)	1653 (8.1)	601 (9.5)
Medicare Part D drug coverage	17,888 (50.9)	10,437 (51.1)	2877 (45.4)
Charlson score: Mean ± SD	0.86 ± 1.29	0.85 ± 1.27	0.85 ± 1.36
0	19,323 (55.0)	11,234 (55.0)	3690 (58.3)
1	8390 (23.9)	4890 (23.9)	1328 (21.0)
≥2	7420 (21.1)	4295 (21.0)	1314 (20.8)
Stage of disease at diagnosis (AJCC)			
I	6961 (19.8)	3984 (19.5)	3953 (62.4)
IIA	11,478 (32.7)	8076 (39.6)	593 (9.4)
IIB	11,184 (31.8)	5711 (28.0)	503 (7.9)
III	2823 (8.0)	1421 (7.0)	103 (1.6)
Unknown	2687 (7.6)	1227 (6.0)	1180 (18.6)
Risk group			
Very low or low	6596 (18.8)	3970 (19.4)	313 (4.9)
Intermediate	11,614 (33.1)	7249 (35.5)	501 (7.9)
High	13,310 (37.9)	7153 (35.0)	735 (11.6)
Very high	3613 (10.3)	2047 (10.0)	193 (3.0)
Unknown	0 (0.0)	0 (0.0)	4590 (72.5)
Treatments[b]			
Watchful waiting or active surveillance	7089 (20.2)	2481 (12.2)	2851 (45.0)
Surgery	8783 (25.0)	2251 (11.0)	569 (22.9)
Radiation	17,864 (50.8)	17,057 (83.5)	1452 (11.0)
Hormone therapy	12,628 (35.9)	9069 (44.4)	696 (9.0)

Abbreviation: AJCC, American Joint Committee on Cancer.
[a]Source: Authors' analysis of Surveillance, Epidemiology, and End Results-Medicare linked data 2009 through 2014.
[b]Treatment modalities are not mutually exclusive and are defined as: active surveillance or watchful waiting (no treatment 6 months after diagnosis), surgery (open prostatectomy, minimally invasive prostatectomy [with or without robotic assistance], or cryosurgery), and radiation (external beam radiation therapy or brachytherapy).

variation across ROs, patient and disease characteristics explained 18% of variation in spending between physicians. Differences in treatment modalities provided to patients with similar characteristics explained 20% of variation across ROs and 34% of variation across facilities.

When models were stratified by disease risk, a greater proportion of variation was explained by differences across physicians and across facilities in low-risk patients (for model results by risk group, see Supporting Fig. 1). However, the contribution of patient, disease, and treatment characteristics was similar across risk groups. In a sensitivity analysis of patients who were never evaluated by an RO, patient and disease characteristics were responsible for a great proportion of variation across physicians and facilities (13% and 16%, respectively) (see Supporting Table 6).

After adjusting for the characteristics and disease risk of a physician's patients and the treatment modalities provided, the highest spending quintile of urologists had 46% higher annual predicted spending compared with the lowest spending quintile ($36,876 vs $25,191) (Table 3). There was no difference across quintiles in the likelihood of their patients undergoing AS/WW, duration on a surveillance regimen before treatment, or undergoing robotic surgery. Differences between quintiles were observed in the use of inpatient care, imaging investigations, and radiotherapy. Compared with urologists in the lowest spending quintile, urologists in the highest spending quintile were associated with 44% greater spending on radiotherapy, with an 18% increased likelihood of IMRT ($P < .001$) and a 75% increased likelihood of PBT ($P < .001$). Differences between urologist spending quartiles and between urology facilities showed similar results (for results of physician and facility variation by quartile, see Supporting Table 7; for results of facility variation by quintile, see Supporting Table 8).

TABLE 2. Proportion of Variance in Medical Spending Driven by Physician and Facility Factors[a,b]

Variable	Annual Spending: Average ± SD, $	% Unadjusted Variation Driven by:		% Adjusted Variation Driven by:		For Spending 1 SD Above Mean, Dollars of Spending Driven by:		Difference in Adjusted Patient Spending Associated With:[c,d]	
		Physician Factors, %	Facility Factors, %	Physician Factors, %	Facility Factors, %	Physician Factors, $	Facility Factors, $	High-Spending vs Low-Spending Physicians, $	High-Spending vs Low-Spending Facilities, $
Urology[e]									
All patients	30,264 ± 20,691	4.5	5.5	4.9	6.0	3743	4130	11,685	9310
Very-low-risk and low-risk	24,989 ± 20,039	8.7	9.1	8.9	8.8	4935	4907	11,811	11,031
Intermediate-risk and high-risk	31,392 ± 20,655	4.9	4.6	5.1	4.9	3828	3736	11,658	8827
Radiation oncology[f]									
All patients	37,837 ± 18,990	6.1	5.8	5.5	6.6	3531	3858	13,695	14,797
Very-low-risk and low-risk	31,746 ± 19,002	9.0	10.0	9.0	10.0	4667	5033	14,016	17,862
Intermediate-risk and high-risk	39,358 ± 18,773	5.6	5.3	5.3	6.2	3405	3694	13,602	14,057

[a]Source: Authors' analysis of Surveillance, Epidemiology, and End Results-Medicare linked data, 2009 to 2014.
[b]Results are based on multilevel models with physician and facility random effects, controlling for time (calendar quarter) and Hospital Referral Region variables.
[c]Spending 1 SD above the mean is reported as the square root of the physician and facility variance from these models, adjusted for patient and disease characteristics.
[d]The highest spending and lowest spending physicians and facilities refer to patients in the highest and lowest quintiles of physician-level and facility-level adjusted patient spending.
[e]Urology results are based on a model with random effects for urologist and urologist-affiliated facilities.
[f]Radiation oncology results are based on a model with random effects for attributed radiation oncologist and radiation oncologist-affiliated facility.

The average spending per patient associated with ROs was 43% greater in the highest spending quintile than in the lowest quintile ($45,372 vs $31,677; $P < .001$) (Table 3), with quintile differences that were similar to those of urologists. Compared with the lowest quintile, ROs in the highest quintile were 25% more likely to use IMRT and 6 times more likely to use PBT ($P < .001$), although the overall use of PBT was low. There was no significant differences in AS/WW, imaging tests, or brachytherapy use between RO quintiles, although patients who received treatment at facilities in the highest spending quintile were 23% less likely to undergo AS/WW ($P < .001$) compared with those who received treatment at facilities in the lowest quintile.

DISCUSSION

In our analysis of fee-for-service Medicare, there was wide variation in spending for men with locoregional prostate cancer who had similar demographics, comorbidities, and disease characteristics. This variation was driven by both physicians and facilities, and the proportion of variation that they explain is consistent with other studies of spending variation in cancer and other medical care.[26,27] The variation identified in our study is substantial, such that the highest spending urologists had an average of 46% ($11,685) greater spending for similar patients than the lowest spending urologists; for patients who saw ROs, the difference was $13,695.

Very little variation in spending across urologists, ROs, or their affiliated facilities was explained by observable differences in patient characteristics or disease severity, suggesting that the variation is unlikely to because of patients with different needs choosing to see different providers. The variation was also not explained by differences in prices or reimbursement across regions of the country, as our analysis focused on variation within HRRs. Instead, we found that spending variation across both physicians and facilities was largely explained by differences in the treatment modalities used, with significant differences in radiotherapy spending and the use of expensive technology.

Previous and ongoing efforts to improve care and to optimize spending have included reducing variability in AS,[28] promoting more appropriate use of imaging,[29] and refining approaches to screening.[30] There has also been evidence of overtreatment in men with localized disease[31] and concerns about the overuse of IMRT among self-referring urologist groups because of the higher reimbursement rates compared with conventional treatment.[32] Although uncertainty about current best practice guidelines for prostate cancer may contribute to some observed variation,

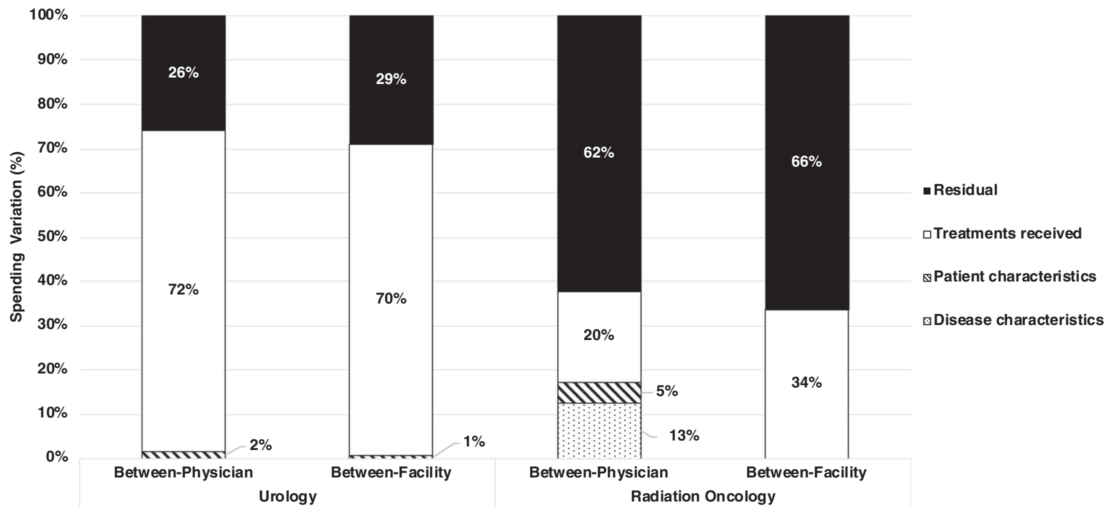

Figure 2. Factors that explain spending variation across physicians and facilities are illustrated. Each bar represents the explanatory factors of that component variation in spending. The results are based on regression models that include random effects for physicians and patients and fixed effects for time, health referral region, disease risk group at diagnosis, patient characteristics, and treatments. Patient characteristics include age, race, census tract income, census tract education, dual eligibility, Charlson score, Medicare Part D enrollment, and disability. Treatments include watchful waiting or active surveillance, surgery, radiation, hormone therapy, and chemotherapy. Spending is winsorized at the 99th percentile. Urology results are based on a model with random effects for urologist and urologist-affiliated facility. Radiation Oncology results are based on a model with random effects for attributed radiation oncologist and radiation oncologist-affiliated facility. Source: Authors' analysis of Surveillance, Epidemiology, and End Results-Medicare linked data 2009 through 2014.

these findings suggest that there is also evidence of inappropriate spending. More recently, the American Society for Radiation Oncology included PBT on its "Choosing Wisely" list as a service that is high cost but of no greater value to patients compared with other available technology.[33,34] We found that the highest spending physicians were associated with greater use of PBT, although the rates of use were low overall. Moreover, the risk of inappropriate overuse is likely to continue to increase over time. Since 2016, large phase 3 trials have demonstrated the noninferiority of hypofractionated radiotherapy compared with longer, conventionally fractionated treatment for localized disease[35-37]; however, because a fee-for-service system links reimbursement to the number of radiation treatment days, we are likely to see variability in the uptake of this data.

As Medicare continues to move away from volume-based fee-for-service and to link reimbursement to value-oriented targets, eligible health care providers are expected to enter into either MIPS or an alternative payment model, such as an accountable care organization or bundled payment.[38,39] Under MIPS, physician reimbursement is tied to a Composite Performance Score based on 4 categories of performance, which include quality and resource use. Current prostate cancer quality indicators target the use of imaging for low-risk patients, although our results suggest that it may also be productive to target variation in radiotherapy under the MIPS program. Although the continued implementation of this program is uncertain, the concept of value-based reimbursement has broad bipartisan support and is also favored by private insurers.

Although the benefit of robotics over open surgery has been questioned[40] and its higher cost has led to debates over its funding in some jurisdictions,[41] we found that the use of robotic surgery did not differ between high-spending and low-spending urologists. This paradox may be explained by the widespread diffusion of robotic technology in high-volume prostatectomy centers across the United States[25] and suggests that payment reform will need to be applied equally across urologists, instead of targeting only the highest resource users.

This study must be considered in the context of its strengths and limitations. The analysis of administrative claims are linked with cancer registry data facilitates a robust evaluation of spending variation in the context of important disease-related factors. However, variation in treatment choices may be affected by other clinical or patient factors (eg, preference for more vs less intensive treatment) that are not captured within the data and that may have contributed to the unexplained variation in our analysis. We were also unable to control for differences in physician characteristics, which may have influenced treatment patterns.[14-16] Our comparison of

TABLE 3. Differences in Treatment Intensity Across Physician Quintiles[a]

	Quintiles of Spending[b,c]						
Variable	1	2	3	4	5	Quintile 1 vs 5, %	P^d
Urology							
No. of providers	555	554	554	554	554		
No. of patients	10,732	5433	3835	5906	9227		
Average total spending per patient per y, $	25,191	27,268	29,925	32,130	36,876	46	<.001
No. of inpatient d/y	1.29	1.30	1.34	1.47	1.65	28	<.001
Likelihood of undergoing WW/AS, %	21	23	19	19	20	−5	.17
Likelihood of referral to radiation oncologist, %	56	58	59	58	59	5	.001
No. of imaging tests per patient							
CT chest, abdomen, pelvis	0.73	0.76	0.81	0.86	0.95	30	<.001
Bone scan	0.51	0.51	0.53	0.53	0.57	12	<.001
PET scan	0.02	0.03	0.03	0.03	0.03	50	<.001
MRI prostate	0.15	0.17	0.17	0.14	0.17	13	.64
Total	1.16	1.22	1.27	1.29	1.43	23	<.001
Among patients undergoing WW/AS							
Time between diagnosis and first treatment, mo	24.70	24.40	25.10	25.20	23.80	−4	.10
Among patients receiving surgery							
Likelihood of receiving open prostatectomy, %	19	18	16	19	19	0	.93
Likelihood of receiving robot prostatectomy, %	63	67	68	65	67	6	.08
Likelihood of receiving cryosurgery, %	13	8	9	10	7	−46	<.001
Among patients receiving radiation							
Spending on radiation, $	12,719	14,122	15,595	16,244	18,281	44	<.001
Likelihood of receiving any EBRT, %	82	88	91	91	93	13	<.001
Likelihood of receiving brachytherapy, %	56	50	50	51	52	−7	.02
Likelihood of receiving IMRT, %	74	80	84	84	87	18	<.001
Likelihood of receiving SBRT, %	7	7	4	4	4	−43	.001
Likelihood of receiving proton beam therapy, %	12	18	20	21	21	75	<.001
Radiation oncology							
No. of providers	228	228	228	228	228		
No. of patients	5810	3272	2388	3305	5644		
Average total spending per patient per y, $	31,677	34,283	38,129	39,109	45,372	43	<.001
Likelihood of undergoing WW/AS, %	13	14	13	12	11	−15	.02
No. of imaging tests ordered							
CT chest, abdomen, and/or pelvis	0.86	0.86	0.93	0.97	0.97	13	.03
Bone scan	0.61	0.60	0.63	0.63	0.61	0	.77
PET scan	0.03	0.03	0.03	0.04	0.04	33	.13
MRI prostate	0.23	0.26	0.27	0.20	0.17	−26	.09
Total	1.41	1.47	1.52	1.50	1.47	4	.44
Among patients receiving radiation							
Spending on radiation, $	20,915	22,438	26,042	26,350	30,348	45	<.001
Likelihood of receiving any EBRT, %	80	86	92	94	95	19	<.001
Likelihood of receiving brachytherapy, %	54	56	53	53	50	−7	.34
Likelihood of receiving IMRT, %	71	78	84	87	89	25	<.001
Likelihood of receiving SBRT, %	8	8	6	7	0.1	−88	<.001
Likelihood of receiving proton beam therapy, %	4	8	24	25	24	500	<.001

Abbreviations: CT, computed tomography; EBRT, external beam radiation therapy; IMRT, intensity-modulated radiation therapy; MRI, magnetic resonance imaging; PET, positron emission tomography; SBRT, stereotactic body radiation therapy; WW/AS, watchful waiting/active surveillance.

[a]Source: Authors' analysis of Surveillance, Epidemiology, and End Results-Medicare linked data, 2009 to 2014.

[b]Quintiles are shown from 1 (lowest) to 5 (highest).

[c]Models assigning physicians to quintiles include patient and physician random and fixed effects for time (calendar quarter of diagnosis), patient characteristics (age, race, census tract income, census tract education, disability, dual eligibility, enrollment in Medicare Part D, Charlson score), disease risk group at diagnosis, treatments (WW/AS, surgery, hormone therapy, and radiation therapy), and Hospital Referral Region in which patients received the plurality of their care. Models predicting total spending, inpatient days, imaging tests, and radiation costs include the aforementioned patient, disease, time, and geography variables and an indicator for physician quintile. Models predicting the likelihood of receiving specific treatment modalities also include treatment variables.

[d]*P* values are reported for the differences between quintiles 1 and 5.

high-spending and low-spending physicians and facilities treating similar patients elucidated some of the potential sources of the unexplained variation, although there was a high degree of unexplained variation across ROs, and we did not have long-term outcome data to examine whether differences in spending contribute to outcomes.

Our analysis focused on elderly men with locoregional disease, which may limit its generalizability to younger patients and to those with metastatic disease (approximately 6% of new diagnoses[42]), who are increasingly being treated with a variety of new high-cost agents.[43,44] Furthermore, although we excluded men who died within their first year of diagnosis, the 5-year relative survival from locoregional prostate cancer is nearly 100%.[42] Thus, the vast majority of men with new prostate cancer diagnoses were included in our sample. All patients were insured by Medicare, so drivers of variation in spending among other types of patients (eg, Medicaid or commercial insurance) or among those with incomplete Medicare Part B coverage could not be assessed. However, >60% of patients with prostate cancer are diagnosed at age 65 years or older,[12] and many others will obtain Medicare coverage within the course of their disease. Moreover, these findings may have broader impact as many policy and payment structures piloted within Medicare are subsequently adopted by commercial insurers.[45]

Conclusions

Variation in medical spending for men with similar demographics and disease risk in the year after the diagnosis of locoregional prostate cancer was driven by both physicians as well as facilities and was largely explained by differences in the primary treatment pathway for patients. The significant differences observed suggest that there is a pressing need to design interventions to improve adherence to clinical practice guidelines and to promote the judicious use of high-cost interventions. Such interventions may improve the affordability and value of prostate cancer treatment. Further research is needed to understand the circumstances in which higher spending may be associated with demonstrable benefit to patients with prostate cancer.

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AUTHOR CONTRIBUTIONS

Danielle Rodin: Conceptualization, data curation, funding acquisition, formal analysis, writing–original draft, and writing–review and editing. **Alyna T. Chien:** Formal analysis and writing–review and editing. **Chad Ellimoottil:** Formal analysis and writing–review and editing. **Paul L. Nguyen:** Writing–review and editing. **Pragya Kakani:** Formal analysis and writing–review and editing. **Matthew Mossanen:** Writing–review and editing. **Meredith Rosenthal:** Conceptualization, data curation, funding acquisition, formal analysis, and writing–review and editing. **Mary Beth Landrum:** Formal analysis and writing–review and editing. **Anna D. Sinaiko:** Conceptualization, data curation, funding acquisition, formal analysis, and writing–review and editing.

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