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Physician and Facility Drivers of Spending Variation in Locoregional Prostate Cancer

Running Title: Spending Variation in Prostate Cancer

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Precis: This study evaluates the drivers of spending variation in the treatment of localized prostate cancer and found that the highest spending urologists and radiation oncologists spent 46% and 43%, respectively, more than the lowest on men with similar individual and disease characteristics; across facilities, this difference was 36% and 48% for urology and radiation oncology, respectively. Differences in primary treatment modalities and discretionary decision-making for similar patients were the most important drivers of spending variation, and to improve value, interventions should target decision-making along the primary treatment pathway and be directed at both individual physicians and facilities.

Abstract

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 to reduce waste, but its magnitude and drivers within prostate cancer are unknown.

Subjects: 38,971 men ≥ 66 years with localized prostate cancer enrolled in Medicare fee-for service and contained within the Surveillance, Epidemiology, and End Results-Medicare 2009-2014 database.

Methods: Using multi-level linear regression with physician and facility random effects, we examined the contributions of urologists, radiation oncologists, and their affiliated facilities to variation in total patient spending in the year following diagnosis within geographic region. We 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- 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 utilization of robotic surgery by urologists or 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.

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

Total Numbers: 1) 23 text pages and 45 references, 2) three tables, 3) two figures, 4) nine supporting files

INTRODUCTION

Prostate cancer is the most common cancer among men in the United States (US), 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 US 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 more than 60% of prostate cancer cases diagnosed in individuals over the age of 65,[13] initiatives to reduce low-value prostate cancer care in Medicare could have significant impact on public resource use and spending. Determining sources and drivers of variation in prostate cancer spending will be more important to identify opportunities 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 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 due to other factors, is unknown. To bring evidence to bear on this question, we analyzed variation in medical spending within geographic regions during the first year following 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 due to 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 (SEER)-Medicare database, which includes cancer registries from 18 catchment areas across the US covering approximately 34% of the population linked to Medicare claims.[18] Our data included men enrolled in fee-for-service Medicare diagnosed with locoregional prostate cancer in 2010-2013, with corresponding medical claims for 2009-2014.

We excluded 65-year old men 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, as their care needs are significantly different; death within one 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. Patients 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 living in a Hospital Referral Region (HRR) with fewer than 10 patients due to computational limitations, so these patients were also excluded. The final sample included 35,545 men (see Supplemental Digital Content 1 for full sample construction).

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 (Part D). We defined three 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 prior to 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 the National Comprehensive Cancer Network (NCCN) criteria[20] on T-stage, Gleason score, and PSA, which is the classification system primarily used to drive decision-making amongst urologists and radiation oncologists. We were unable to distinguish between very low-risk and low-risk

due to the absence of information on PSA density and number of positive cores. Patients were classified as very high-risk based on T-stage 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 providing the plurality of their care. Patients with at least one visit with a radiation oncologist (RO) were also attributed to the RO 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 two different facilities (57% of patients). While 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 two sets of multi-level linear regression models that included physician and facility random effects, where 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 of a third set of models including 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 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. Additional methodological details and model output is available in the Appendix.

We report results in three ways: (1) the percent 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 one standard deviation 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 and stratified by NCCN risk groups.[20] All statistical analyses were completed using Stata (Version 14).

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 two 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 Supplemental Digital Content 2.

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

are high- and low-spending. We used model output from the multi-level 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 for decisions to provide each of the treatment modalities. We then sorted physicians and facilities into quintiles according to their adjusted spending (1 – lowest; 5 – highest) 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.

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 the likelihood of receiving of brachytherapy, EBRT (3D-conformal radiotherapy), IMRT, stereotactic body radiation therapy (SBRT), or proton beam therapy (PBT) among patients receiving radiation. Logistic regression was used for all binary outcomes (whether a patient had 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 following diagnosis and very low spending in months 7-12 (Figure 1). Average spending increased with risk group, from $24,169 (SD $18,685) per year in very low- or low-risk patients to $32,833 (SD $19,940) per year among very-high risk patients ($p<0.001$) (see Supplemental Digital Content 3 for spending stratified by NCCN risk group). Cohort characteristics

presented in Table 1. A descriptive analysis of treatment choices by risk group is presented in Supplemental Digital Content 4.

In the multi-level models with urologist and facility random effects, 4.5% of variation in spending was driven by differences across urologists and 5.5% by differences across facilities (Table 2). For a patient with spending one SD above the mean, this level of variation suggests that urologists and urologist-affiliated facilities were responsible for $3,743 and $4,130, respectively, in 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 is associated with a difference of $9,310 (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% by differences across RO facilities. This means that ROs and RO-affiliated facilities were responsible for $3,531 and $3,858, respectively, in above-average spending for a patient with spending one SD above the mean. This level of variation is also associated with a difference in average annual spending of $13,695 (36% over the mean) between high- and low-spending ROs and $14,797 (39% over the mean) between high- and low-spending RO-affiliated facilities.

Differences in patient characteristics and disease risk, which capture patient sorting across physicians (e.g. specialization of certain physicians in patients with more advanced disease), explained 2% of between-urologist variation and 1% of between-facility variation; differences in the treatment modalities provided to patients explained 72% (Figure 2). In models analyzing spending 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 (see Supplemental Digital Content 5 for model results by risk group). 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) (Supplemental Digital Content 6).

After adjusting for the characteristics and disease risk of a physician's patients and in the treatment modalities provided, the highest-spending quintile of urologists had 46% higher annual predicted spending compared to the lowest ($36,876 vs $25,191) (Table 3). There was no difference across quintiles in the likelihood of their patients undergoing AS/WW, duration on a surveillance regimen prior to treatment, or utilization of robotic surgery. Differences between quintiles were observed in use of inpatient care, imaging investigations, and radiotherapy. Compared to urologists in the lowest-spending quintile, urologists in the highest-spending quintile were associated with 44% greater spending on radiotherapy, with an 18% increased likelihood of IMRT ($p<0.001$), and a 75% increased likelihood of PBT ($p<0.001$). Differences between urologist spending quartiles and between urology facilities showed similar results. See Supplemental Digital Content 7 for results of physician and facility variation by quartile and Supplemental Digital Content 8 for results of facility variation by quintile.

The average spending per patient associated with ROs was 43% greater in the highest spending quintile than the lowest quintile ($45,372 vs $31,677, $p<0.001$) (Table 3), with quintile differences that were similar to those of urologists. Compared to the lowest quintile, ROs in the highest quintile were 25% more likely to use IMRT and six times more likely to use PBT ($p<0.001$), although overall use of PBT was low. There was no significant differences in AS/WW, imaging tests, or brachytherapy utilization between RO quintiles, although patients treated at facilities in the highest spending quintile were 23% less likely to undergo AS/WW ($p<0.001$) compared to those treated 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 have 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 be due to 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 find 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.

Prior and ongoing efforts to improve care and to optimize spending have included reducing variability in active surveillance,[28] promoting more appropriate use of imaging,[29] and refining approaches to screening.[30] There has also been evidence of overtreatment of men with localized disease[31] and concerns about overutilization of IMRT among self-referring urologist groups due to the higher reimbursement rates compared to conventional treatment.[32]. While uncertainty about current best practice guidelines for prostate cancer may contribute to some observed variation, 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 to other available technology.[33,34] We found that the highest-spending physicians are associated with greater use of PBT, though rates of use were low overall. Moreover, the risk of inappropriate overuse is likely to continue to increase over time. Since 2016, large phase III trials have demonstrated the non-inferiority of hypofractionated radiotherapy compared to longer, conventionally fractionated treatment for localized disease,[35-37] yet 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 four categories of performance, which include quality and resource use. Current prostate cancer quality indicators target use of imaging for low-risk patients, although our results suggest that it may also be productive to target variation in radiotherapy under this 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- and low-spending urologists. This paradox may be explained by the widespread diffusion of robotic technology in high-volume prostatectomy centers across the US[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 that 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 (e.g. 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 high- 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] Further, 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 (e.g., Medicaid or commercial insurance) or those with incomplete Medicare Part B coverage could not be assessed. However, over 60% of prostate cancer patients are diagnosed at age 65 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 following the diagnosis of locoregional prostate cancer was driven by both physicians as was 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 judicious use of high-cost interventions. Such interventions may improve the affordability and value of prostate cancer treatment. Further research is needed to understand in what circumstances higher spending may be associated with demonstrable benefit to prostate cancer patients.

REFERENCES

1. Siegel RL, Miller KD, Jemal A. Cancer Statistics, 2017. CA Cancer J Clin. 2017;67: 7-30.

2. Mariotto AB, Robin Yabroff K, Shao Y, Feuer EJ, Brown ML. Projections of the Cost of Cancer Care in the United States: 2010–2020. J Natl Cancer Inst. 2011;103: 117-128.

3. Wang S-Y, Wang R, Yu JB, et al. Understanding Regional Variation in Medicare Expenditures for Initial Episodes of Prostate Cancer Care. Med Care. 2014;52: 680-687.

4. Barbash GI, Glied SA. New technology and health care costs--the case of robot-assisted surgery. N Engl J Med. 2010;363: 701-704.
5. Nguyen PL, Gu X, Lipsitz SR, et al. Cost Implications of the Rapid Adoption of Newer Technologies for Treating Prostate Cancer. J Clin Oncol. 2011;29: 1517-1524.
6. Jacobs BL, Zhang Y, Schroeck FR, et al. Use of advanced treatment technologies among men at low risk of dying from prostate cancer. JAMA. 2013;309: 2587-2595.
7. Tsugawa Y, Jha AK, Newhouse JP, Zaslavsky AM, Jena AB. Variation in Physician Spending and Association With Patient Outcomes. JAMA Intern Med. 2017;177: 675-682.
8. Fisher ES, Wennberg DE, Stukel TA, Gottlieb DJ, Lucas FL, Pinder EL. The implications of regional variations in Medicare spending. Part 1: the content, quality, and accessibility of care. Ann Intern Med. 2003;138: 273-287.
9. Brooks GA, Li L, Sharma DB, et al. Regional variation in spending and survival for older adults with advanced cancer. J Natl Cancer Inst. 2013;105: 634-642.
10. Zhang Y, Baik SH, Fendrick AM, Baicker K. Comparing local and regional variation in health care spending. N Engl J Med. 2012;367: 1724-1731.
11. Clough JD, Kamal AH. Oncology Care Model: Short- and Long-Term Considerations in the Context of Broader Payment Reform. J Oncol Pract. 2015;11: 319-321.
12. ASCO Proposes Payment Reforms to Support Higher Quality, More Affordable Cancer Care: American Society of Clinical Oncology, 2017.
13. Key statistics for prostate cancer. Available from URL: https://www.cancer.org/cancer/prostate-cancer/about/key-statistics.html.
14. Quek RG, Master VA, Ward KC, et al. Determinants of the combined use of external beam radiotherapy and brachytherapy for low-risk, clinically localized prostate cancer. Cancer. 2013;119: 3619-3628.
15. Quek RG, Master VA, Portier KM, et al. Association of reimbursement policy and urologists' characteristics with the use of medical androgen deprivation therapy for clinically localized prostate cancer. Urol Oncol. 2014;32: 748-760.

16. Quek RG, Ward KC, Master VA, et al. Association between urologist characteristics and radiation oncologist consultation for patients with locoregional prostate cancer. J Natl Compr Canc Netw. 2015;13: 303-309.
17. Chen CT, Li L, Brooks G, Hassett M, Schrag D. Medicare Spending for Breast, Prostate, Lung, and Colorectal Cancer Patients in the Year of Diagnosis and Year of Death. Health Serv Res. 2017.
18. Surveillance, Epidemiology, and End Results (SEER) Overview. Available from URL: https://seer.cancer.gov/about/factsheets/SEER_Overview.pdf [accessed September 25, 2019.
19. Klabunde CN, Potosky AL, Legler JM, Warren JL. Development of a comorbidity index using physician claims data. J Clin Epidemiol. 2000;53: 1258-1267.
20. Prostate Cancer (Version 3.2016). Available from URL: https://www.tri-kobe.org/nccn/guideline/urological/english/prostate.pdf [accessed March 1, 2017, 2017].
21. Measures that are limited or not available in the data. Available from URL: https://healthcaredelivery.cancer.gov/seermedicare/considerations/measures.html [accessed February 20, 2018.
22. Loeb S, Walter D, Curnyn C, Gold HT, Lepor H, Makarov DV. How Active is Active Surveillance? Intensity of Followup during Active Surveillance for Prostate Cancer in the United States. J Urol. 2016;196: 721-726.
23. Muralidhar V, Rose BS, Chen YW, Nezolosky MD, Nguyen PL. Association Between Travel Distance and Choice of Treatment for Prostate Cancer: Does Geography Reduce Patient Choice? Int J Radiat Oncol Biol Phys. 2016;96: 313-317.
24. Paravati AJ, Boero IJ, Triplett DP, et al. Variation in the Cost of Radiation Therapy Among Medicare Patients With Cancer. J Oncol Pract. 2015;11: 403-409.
25. Stitzenberg KB, Wong YN, Nielsen ME, Egleston BL, Uzzo RG. Trends in radical prostatectomy: centralization, robotics, and access to urologic cancer care. Cancer. 2012;118: 54-62.
26. Fung V, Schmittdiel JA, Fireman B, et al. Meaningful variation in performance: a systematic literature review. Med Care. 2010;48: 140-148.

27. Kelley AS, Ettner SL, Morrison RS, Du Q, Wenger NS, Sarkisian CA. Determinants of medical expenditures in the last 6 months of life. Ann Intern Med. 2011;154: 235-242.
28. Auffenberg GB, Lane BR, Linsell S, Cher ML, Miller DC. Practice- vs Physician-Level Variation in Use of Active Surveillance for Men With Low-Risk Prostate Cancer: Implications for Collaborative Quality Improvement. JAMA Surg. 2017;152: 978-980.
29. Makarov DV, Desai R, Yu JB, et al. Appropriate and inappropriate imaging rates for prostate cancer go hand in hand by region, as if set by thermostat. Health Affair. 2012;31: 730-740.
30. Wilt TJ, Scardino PT, Carlsson SV, Basch E. Prostate-specific antigen screening in prostate cancer: perspectives on the evidence. J Natl Cancer Inst. 2014;106: dju010.
31. Daskivich TJ, Chamie K, Kwan L, et al. Overtreatment of men with low-risk prostate cancer and significant comorbidity. Cancer. 2011;117: 2058-2066.
32. Mitchell JM. Intensity-modulated radiation therapy for prostate cancer. N Engl J Med. 2014;370: 679-680.
33. Hahn C, Kavanagh B, Bhatnagar A, et al. Choosing wisely: the American Society for Radiation Oncology's top 5 list. Pract Radiat Oncol. 2014;4: 349-355.
34. Allen AM, Pawlicki T, Dong L, et al. An evidence based review of proton beam therapy: the report of ASTRO's emerging technology committee. Radiother Oncol. 2012;103: 8-11.
35. Dearnaley D, Syndikus I, Mossop H, et al. Conventional versus hypofractionated high-dose intensity-modulated radiotherapy for prostate cancer: 5-year outcomes of the randomised, non-inferiority, phase 3 CHHiP trial. Lancet Oncol. 2016;17: 1047-1060.
36. Catton CN, Lukka H, Gu CS, et al. Randomized Trial of a Hypofractionated Radiation Regimen for the Treatment of Localized Prostate Cancer. J Clin Oncol. 2017;35: 1884-1890.
37. Lee WR, Dignam JJ, Amin MB, et al. Randomized Phase III Noninferiority Study Comparing Two Radiotherapy Fractionation Schedules in Patients With Low-Risk Prostate Cancer. J Clinical Oncol. 2016;34: 2325-2332.

38. Kaye DR, Miller DC, Ellimoottil C. Alternative payment models and urology. Curr Opin Urol. 2017;27: 360-365.
39. Printz C. MACRA paves way for changes in reimbursements: Physicians hopeful law will lead to more value-based care. Cancer. 2015;121: 2103-2104.
40. Yaxley JW, Coughlin GD, Chambers SK, et al. Robot-assisted laparoscopic prostatectomy versus open radical retropubic prostatectomy: early outcomes from a randomised controlled phase 3 study. Lancet. 2016;388: 1057-1066.
41. Health Quality Ontario. Robotic Surgical System for Radical Prostatectomy: A Health Technology Assessment. Ont Health Technol Assess Ser. 2017;17: 1-72.
42. Cancer Stat Facts: Prostate Cancer. Available from URL: https://seer.cancer.gov/statfacts/html/prost.html [accessed October 1, 2019.
43. Fizazi K, Tran N, Fein L, et al. Abiraterone plus Prednisone in Metastatic, Castration-Sensitive Prostate Cancer. N Engl J Med. 2017;377: 352-360.
44. Norum J, Nieder C. Treatments for Metastatic Prostate Cancer (mPC): A Review of Costing Evidence. Pharmacoeconomics. 2017.
45. Martin AB, Hartman M, Washington B, Catlin A, National Health Expenditure Accounts T. National Health Spending: Faster Growth In 2015 As Coverage Expands And Utilization Increases. Health Affair. 2017;36: 166-176.

Figure 1: Average Monthly Patient Spending in the First Year after Prostate Cancer Diagnosis

Source: Authors' analysis of Surveillance, Epidemiology, and End Results (SEER)-Medicare linked data 2009-2014. Results are stratified by National Comprehensive Cancer Network (NCCN) disease risk group. Very-low risk grouped with low-risk because of lack of PSA density data within SEER.
Note: Numerical data available in Supplemental Digital Content 3.

Figure 2. Factors that Explain Spending Variation Across Physicians and Facilities

Source: Authors' analysis of Surveillance, Epidemiology, and End Results (SEER)-Medicare linked data 2009-2014.

Note: Each bar represents the explanatory factors of that component variation in spending. Results based on regression models 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, 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 based on model with random effects for urologist and urologist-affiliated facility. Radiation Oncology results based on model with random effects for attributed radiation oncologist and radiation oncologist-affiliated facility.

List of Supplemental Digital Content:

Supplemental Digital Content 1.docx
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Supplemental Digital Content 6.docx
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Table 1. Sample Characteristics

	Attribution					
	Urologist (N=35,133)		Radiation Oncologist (N=20,419)		Excluded Patients (N=6,209)	
	%	**N**	**%**	**N**	**%**	**N**
Age at diagnosis (mean, SD)	73.36 (5.68)		73.07 (4.98)		73.48 (5.80)	
66-75	69.2%	24,297	70.7%	14,442	69.1%	4,378
76-85	27.3%	9,587	27.8%	5,682	26.6%	1,687
85+	3.6%	1,249	1.4%	295	4.2%	267
Non-white	17.3%	6,078	17.2%	3,506	17.9%	1,008
Census tract income (mean, SD)	$68,677 ($33,313)		$69,736 ($33,446)		$67,115.1 ($32,607)	
Census tract, % with some college education	61.2%	21,501	61.6%	12,578	61.1% (19.3%)	
Dual eligible	13.4%	4,697	12.0%	2,455	15.1%	954
Originally eligible for Medicare based on disability	7.9%	2,790	8.1%	1,653	9.5%	601
Part D Drug coverage	50.9%	17,888	51.1%	10,437	45.4%	2,877
Charlson score (mean, SD)	0.86 (1.29)		0.85 (1.27)		0.85 (1.36)	
0	55.0%	19,323	55.0%	11,234	58.3%	3,690
1	23.9%	8,390	23.9%	4,890	21.0%	1,328
2+	21.1%	7,420	21.0%	4,295	20.8%	1,314
Stage of disease at diagnosis						
Stage 1	19.8%	6,961	19.5%	3,984	62.4%	3,953
Stage 2a	32.7%	11,478	39.6%	8,076	9.4%	593

Stage 2b	31.8%	11,184	28.0%	5,711	7.9%	503
Stage 3	8.0%	2,823	7.0%	1,421	1.6%	103
Unknown	7.6%	2,687	6.0%	1,227	18.6%	1,180
Risk group						
Very low or low	18.8%	6,596	19.4%	3,970	4.9%	313
Intermediate	33.1%	11,614	35.5%	7,249	7.9%	501
High	37.9%	13,310	35.0%	7,153	11.6%	735
Very high	10.3%	3,613	10.0%	2,047	3.0%	193
Unknown	0.0%	0	0.0%	0	72.5%	4,590
Treatments						
Watchful waiting or active surveillance	20.2%	7,089	12.2%	2,481	45.0%	2,851
Surgery	25.0%	8,783	11.0%	2,251	22.9%	569
Radiation	50.8%	17,864	83.5%	17,057	11.0%	1,452
Hormone therapy	35.9%	12,628	44.4%	9,069	9.0%	696

Source: Authors' analysis of Surveillance, Epidemiology, and End Results (SEER)-Medicare linked data 2009-2014.

Note: Treatment modalities 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); radiation = external beam radiation therapy or brachytherapy.

Table 2. Proportion of Variance in Medical Spending Driven by Physician and Facility Factors

	Average annual spending (SD)	% Unadjusted variation driven by:		% Adjusted variation driven by:		For spending one SD above mean, dollars of spending driven by:		Difference in adjusted patient spending associated with:	
		Physician factors	Facility factors	Physician factors	Facility factors	Physician factors	Facility factors	High vs low spending physicians	High vs low spending facilities
Urology									
All patients	$30,264 ($20,691)	4.5%	5.5%	4.9%	6.0%	$3,743	$4,130	$11,685	$9,310
Very Low- and Low-risk	$24,989 ($20,039)	8.7%	9.1%	8.9%	8.8%	$4,935	$4,907	$11,811	$11,031
Intermediate- and High-risk	$31,392 ($20,655)	4.9%	4.6%	5.1%	4.9%	$3,828	$3,736	$11,658	$8,827
Radiation Oncology									
All patients	$37,837 ($18,990)	6.1%	5.8%	5.5%	6.6%	$3,531	$3,858	$13,695	$14,797
Very Low and Low-risk	$31,746 ($19,002)	9.0%	10.0%	9.0%	10.0%	$4,667	$5,033	$14,016	$17,862

Intermediate- and High-risk	$39,358 ($18,773)	5.6%	5.3%	5.3%	6.2%	$3,405	$3,694	$13,602	$14,057

Source: Authors' analysis of Surveillance, Epidemiology, and End Results (SEER)-Medicare linked data 2009-2014.

Note: Results are based on multi-level models with physician and facility random effects, controlling for time (quarter-calendar) and HRR variables. Urology results based on model with random effects for urologist and urologist-affiliated facilities. Radiation oncology results based on model with random effects for attributed radiation oncologist and radiation oncologist-affiliated facility. Spending one 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. The highest and lowest spending physicians and facilities refer to patients in the highest and lowest quintiles of physician-level and facility-level adjusted patient spending.

Table 3. Differences in Treatment Intensity across Physician Quintiles

	Quintiles of spending (1 = lowest, 5 = highest)					Quintile 1 vs 5	P-value
	1	2	3	4	5		
Urology							
Number of providers	555	554	554	554	554		
Number of patients	10732	5433	3835	5906	9227		
Average total spending per patient per year ($)	25,191	27,268	29,925	32,130	36,876	46%	<0.001
Inpatient days per year	1.29	1.30	1.34	1.47	1.65	28%	<0.001
Likelihood of undergoing WW/AS	21%	23%	19%	19%	20%	-5%	0.17
Likelihood of referral to radiation oncologist	56%	58%	59%	58%	59%	5%	0.001
Imaging tests per patient							
CT Chest, Abdomen, Pelvis	0.73	0.76	0.81	0.86	0.95	30%	<0.001
Bone Scan	0.51	0.51	0.53	0.53	0.57	12%	<0.001
PET Scan	0.02	0.03	0.03	0.03	0.03	50%	<0.001
MRI Prostate	0.15	0.17	0.17	0.14	0.17	13%	0.64
Total	1.16	1.22	1.27	1.29	1.43	23%	<0.001
Among patients undergoing WW/AS							
Months between diagnosis and first treatment	24.70	24.40	25.10	25.20	23.80	-4%	0.10

Among patients receiving surgery							
Likelihood of receiving open prostatectomy	19%	18%	16%	19%	19%	0%	0.93
Likelihood of receiving robot prostatectomy	63%	67%	68%	65%	67%	6%	0.08
Likelihood of receiving cryosurgery	13%	8%	9%	10%	7%	-46%	<0.001
Among patients receiving radiation							
Spending on radiation ($)	12,719	14,122	15,595	16,244	18,281	44%	<0.001
Likelihood of receiving any EBRT	82%	88%	91%	91%	93%	13%	<0.001
Likelihood of receiving brachytherapy	56%	50%	50%	51%	52%	-7%	0.02
Likelihood of receiving IMRT	74%	80%	84%	84%	87%	18%	<0.001
Likelihood of receiving SBRT	7%	7%	4%	4%	4%	-43%	0.001
Likelihood of receiving proton beam therapy	12%	18%	20%	21%	21%	75%	<0.001
Radiation Oncology							
Number of providers	228	228	228	228	228		
Number of patients	5810	3272	2388	3305	5644		
Average total spending per patient per year ($)	31,677	34,283	38,129	39,109	45,372	43%	<0.001
Likelihood of undergoing WW/AS	13%	14%	13%	12%	11%	-15%	0.02
Number of Imaging Tests Ordered							
CT Chest, Abdomen, and/or Pelvis	0.86	0.86	0.93	0.97	0.97	13%	0.03
Bone Scan	0.61	0.60	0.63	0.63	0.61	0%	0.77

PET Scan	0.03	0.03	0.03	0.04	0.04	33%	0.13
MRI Prostate	0.23	0.26	0.27	0.20	0.17	-26%	0.09
Total	1.41	1.47	1.52	1.50	1.47	4%	0.44
Among patients receiving radiation							
Spending on radiation ($)	20,915	22,438	26,042	26,350	30,348	45%	<0.001
Likelihood of receiving any EBRT	80%	86%	92%	94%	95%	19%	<0.001
Likelihood of receiving brachytherapy	54%	56%	53%	53%	50%	-7%	0.34
Likelihood of receiving IMRT	71%	78%	84%	87%	89%	25%	<0.001
Likelihood of receiving SBRT	8%	8%	6%	7%	0.1%	-88%	<0.001
Likelihood of receiving proton beam therapy	4%	8%	24%	25%	24%	500%	<0.001

Source: Authors' analysis of Surveillance, Epidemiology, and End Results (SEER)-Medicare linked data 2009-2014.

Notes: 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 part D, Charlson Score), disease risk group at diagnosis, treatments (WW/AS, surgery, hormone therapy, and radiation therapy), and Hospital Referral Region (HRR) where patients received the plurality of their care. Models predicting total spending, inpatient days, imaging tests, and radiation cost include the aforementioned patient, disease, time and geography variables and an indicator for physician quintile. Models predicting likelihood of receiving specific treatment modalities also include treatment variables. P-value reported of differences between quintiles 1 and 5.

Abbreviations: WW/AS = watchful waiting/active surveillance; EBRT = external beam radiation therapy; IMRT = intensity modulated radiation therapy; SBRT = stereotactic body radiation therapy; CT = computed tomography; PET = Positron Emission Tomography; MRI = Magnetic Resonance Imaging.

Figure 1. Average Monthly Patient Spending in the First Year after Prostate Cancer Diagnosis

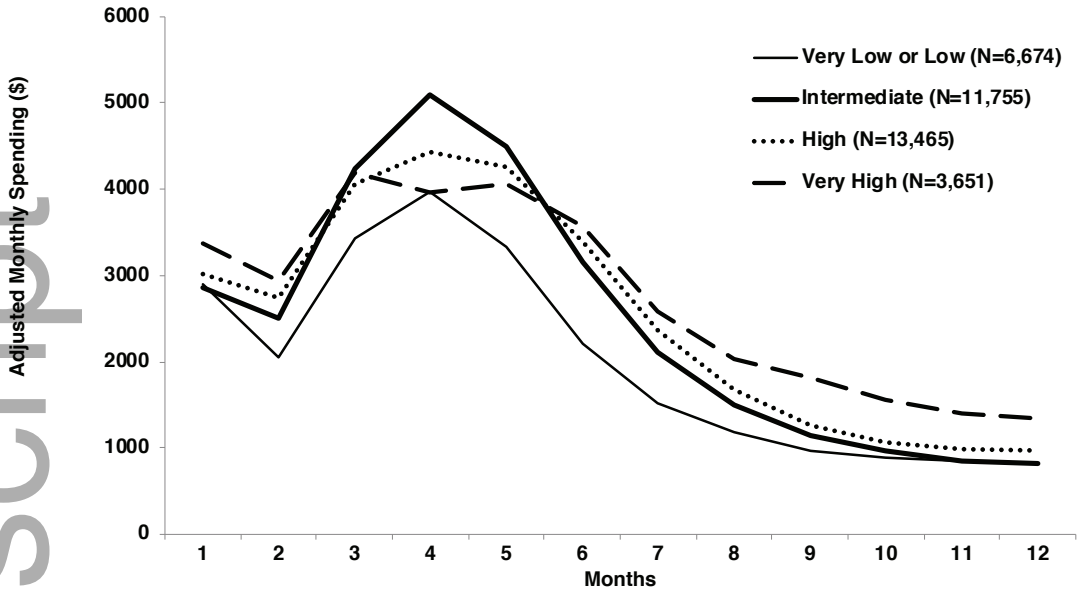

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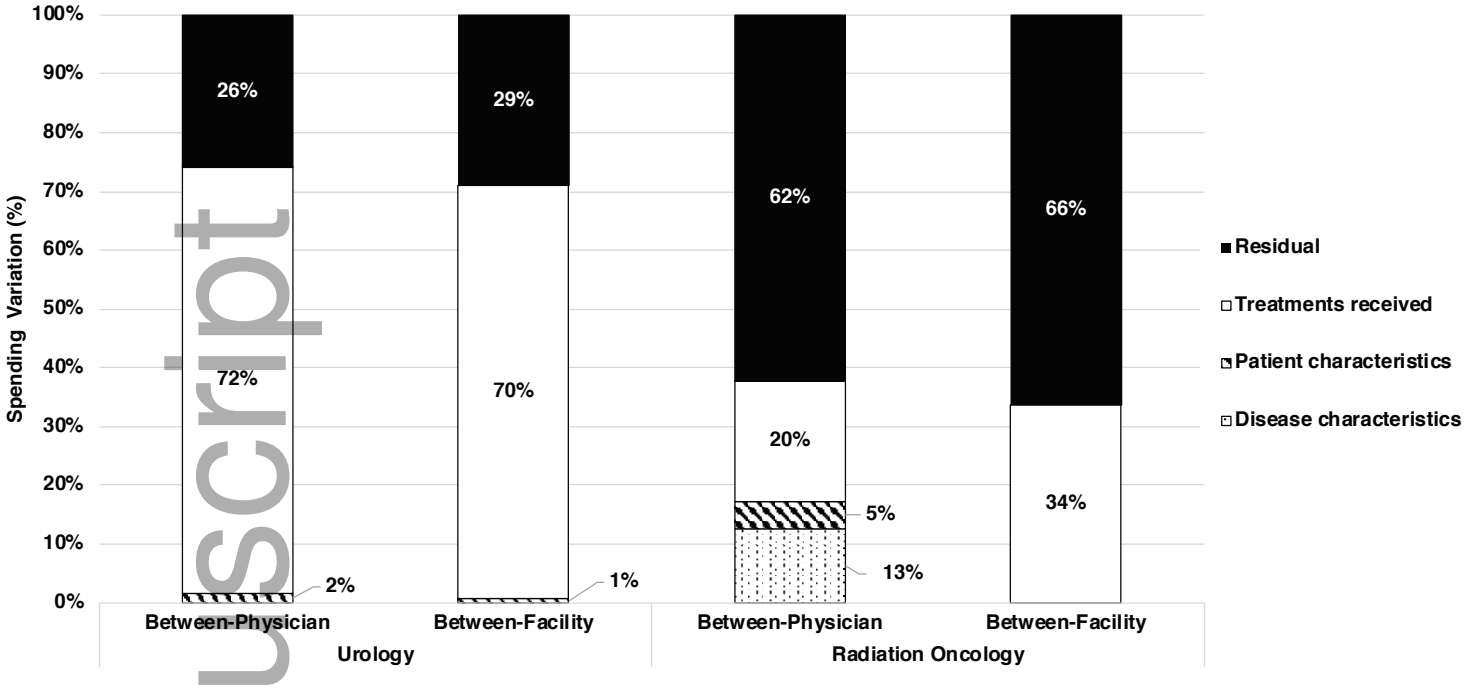
Figure 2. Factors that Explain Spending Variation Across Physicians and Facilities



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