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RESEARCH ARTICLE

Appropriateness of Prostate Cancer Imaging among Veterans in a Delivery System without Incentives for Overutilization

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Objective. To determine the frequency of appropriate and inappropriate prostate cancer imaging in an integrated health care system.

Data Sources/Study Setting. Veterans Health Administration Central Cancer Registry linked to VA electronic medical records and Medicare claims (2004–2008).

Study Design. We performed a retrospective cohort study of VA patients diagnosed with prostate cancer ($N = 45,084$). Imaging (CT, MRI, bone scan, PET) use was assessed among patients with low-risk disease, for whom guidelines recommend against advanced imaging, and among high-risk patients for whom guidelines recommend it.

Principal Findings. We found high rates of inappropriate imaging among men with low-risk prostate cancer (41 percent) and suboptimal rates of appropriate imaging among men with high-risk disease (70 percent). Veterans utilizing Medicare-reimbursed care had higher rates of inappropriate imaging [OR: 1.09 (1.03–1.16)] but not higher rates of appropriate imaging. Veterans treated in middle [OR: 0.51 (0.47–0.56)] and higher [OR: 0.50 (0.46–0.55)] volume medical centers were less likely to undergo inappropriate imaging without compromising appropriate imaging.

Conclusions. Our results highlight the overutilization of imaging, even in an integrated health care system without financial incentives encouraging provision of health care services. Paradoxically, imaging remains underutilized among high-risk patients who could potentially benefit from it most.

Key Words. Health care organizations and systems, VA health care system, surgery

With the introduction of prostate-specific antigen (PSA) screening, stage migration has made the routine use of diagnostic staging imaging obsolete (Han et al. 2001; Cooperberg et al. 2004). Numerous professional societies and policy organizations have issued guidelines and quality measures seeking to reduce utilization of imaging among those with low-risk disease (Middleton, Thompson, and Austenfeld 1995; Roach et al. 1995; Aus et al. 2001; Thompson et al. 2008; Miller et al. 2010; Schnipper et al. 2012; 2013a; 2013b). In some countries, these efforts have successfully reduced inappropriate imaging (Makarov et al. 2013), but in the United States inappropriate imaging remains a significant problem (Kindrick et al. 1998; Cooperberg et al. 2002; Saigal et al. 2002; Abraham et al. 2007; Choi et al. 2011; Lavery et al. 2011; Makarov et al. 2012b; Prasad et al. 2012; Skolarus et al. 2013). The American Society of Clinical Oncology (ASCO) and the American Urological Association both recently highlighted reduction of inappropriate prostate cancer imaging as a priority for *Choosing Wisely*, a campaign to reduce unnecessary medical testing, decrease overuse of health care resources, and improve quality of care (American Board of Internal Medicine 2012; Cassel and Guest 2012; Schnipper et al. 2012). Why are rates of imaging among low-risk prostate cancer patients 3 percent in Sweden and almost 50 percent in a U.S. fee-for-service setting?

Health system factors such as reimbursement, local culture surrounding the use of health care resources, and staff training may explain this variation (Donabedian 1988; Rubenstein et al. 2000). The fee-for-service model employed throughout the United States encourages provision of more health care services (Thomson et al. 2012) through direct physician reimbursement (Hollingsworth et al. 2010; Office 2013), self-referral, and an incentive to encourage sometimes unnecessary care (Emanuel and Fuchs 2008). A study of

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prostate cancer imaging in Sweden, where physicians are mostly salaried government employees, suggests an integrated delivery system may reduce inappropriate testing (Makarov et al. 2013). It is unknown whether these results are generalizable to integrated health care delivery systems outside Sweden.

The U.S. Veterans Health Administration (VA) is the largest integrated health care system in the United States, representing approximately 5 percent of the total market share for hospital services (Kazis et al. 1998). The system serves over 9 million eligible Veterans, who are often older, poorer, and less educated than non-VA patients (Randall et al. 1987; Rogers et al. 2004; Frayne et al. 2006), but nevertheless represent an important segment of U.S. citizens with prostate cancer (Kazis et al. 1998). Most physicians who practice in the VA receive a salary without financial incentives to provide more health care services (Roselle et al. 2003). There is a knowledge gap regarding the rate of appropriate and inappropriate prostate cancer imaging in the VA. Would imaging rates in the VA be similar to those of the Swedish integrated health care system or the U.S. fee-for-service system? It is important to understand these imaging patterns to determine both how to optimize care for men with prostate cancer and understand the factors influencing use of diagnostic testing generally.

The aim of this study was to assess imaging patterns among veterans with incident prostate cancer and their concordance with established guidelines. To do this, we utilized the VA Central Cancer Registry (VACCR), a resource with uniformly reported data on all cancer patients diagnosed at any of 127 VA Medical Centers (VAMC)s, linked to administrative claims and Medicare utilization records (Keating et al. 2010). Documentation and characterization of appropriate and inappropriate prostate cancer imaging using VACCR is critical to improve quality of care in the nation's largest health care system. These results will help policy makers and physicians understand factors associated with appropriate imaging and provide insights to optimize VA prostate cancer imaging.

METHODS

We performed a retrospective cohort study analyzing prostate cancer imaging for a large national cohort diagnosed in the VA. Patients were identified through the VACCR; their records were linked to laboratory, pharmacy, inpatient, outpatient, radiology, surgery, and vital measure data from the VA's electronic medical records (Keating et al. 2010). We examined all care

received by these patients using International Classification of Disease, 9th Edition (ICD-9-CM) diagnosis and Common Procedural Terminology (CPT) codes. VA outsources patient care through contracts with local community providers when equipment or staff required to provide a specialized service is not readily available in local VAMCs and the patient is unable to travel. As many veterans aged 65 and older are dually covered by VA and Medicare, we linked to Medicare fee-for-service claims (Liu et al. 2011). Unlike the general population where patients under age 65 rarely utilize Medicare, up to 30 percent of veterans may be eligible for Medicare as a result of disability (Liu et al. 2011). We were unable to track outside utilization for anyone except Medicare enrollees. All outcomes are based on data from receipt of care from any of three locations: a VA facility, a community facility covered by VA through its fee-service program, or a community facility covered by Medicare.

Study Population

The study population consists of men from VACCR newly diagnosed with prostate cancer between January 1, 2004 and March 31, 2008 (Wilson and Kizer 1998; Zeliadt et al. 2011). All patients had to be under age 85 at diagnosis and have a pathologically confirmed, registry-documented diagnosis (i.e., no subjects diagnosed on autopsy or death certificate). We excluded 282 men who died within 3 months of diagnosis, 2 men missing all tumor risk characteristics (PSA, Gleason & clinical stage), 356 men diagnosed at a VA facility with a patient volume <25/year because of unreliability of clinical data from such institutions (Backhus et al. 2014), and 255 men without utilization of any health benefits in months 2–6 following diagnosis (a situation suggesting complete departure from federal health care). We excluded 2,290 men without high-risk features but missing at least one tumor risk characteristic (PSA, Gleason grade, clinical stage). This study was approved by Institutional Review Boards at VA New York Harbor and VA Puget Sound Healthcare Systems.

Definition of Variables

Receipt of Imaging. Our primary dependent variable was receipt of imaging including radionuclide bone scan, computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET).

Appropriateness of imaging was determined based on National Comprehensive Cancer Network (NCCN) guidelines' recommendation for

imaging to stage incident prostate cancer (National Comprehensive Cancer Network 2013). The NCCN risk stratification scheme is based on clinical stage, prostate biopsy Gleason grade, and PSA. Clinical stage is determined based on digital rectal exam (American Cancer Society 2013). Clinical stage T1 refers to nonpalpable tumors; T2 refers to palpable tumors appearing confined within the prostate; T3 tumors have begun to spread outside the prostatic capsule or into the seminal vesicles; and T4 tumors have spread to adjacent pelvic organs. Pathologists use the Gleason system to grade prostate tumors (American Cancer Society 2013). The Gleason system is based on the sum of the estimates of aggressiveness of the two most representative areas of a prostate cancer sample. The least-aggressive areas are graded as 1; the most-aggressive are graded 5; the scores range from 2 to 10. PSA is a protein produced by the prostate detectable in serum; higher PSA at diagnosis is associated with worse prostate cancer outcomes (Makarov et al. 2009). Bone scan was considered inappropriate unless a patient had any one of the following high-risk characteristics: clinical stage T3-4, Gleason score 8–10, or PSA >20 ng/mL. CT and MRI were considered inappropriate unless the patient had a 20 percent or higher risk of positive lymph nodes, estimated from the Partin tables (Makarov et al. 2007). CT was considered appropriate for low-risk patients undergoing radiation therapy because it may be used for treatment planning or for staging (Falchook, Hendrix, and Chen 2015). A bone scan in a low-risk patient was not considered inappropriate for patients diagnosed with fractures (ICD-9-CM: 733.10–733.19, 805.00–806.9, 905.1).

Classification as high-risk only required the presence of one high-risk feature; classification as low-risk required absence of high-risk features and nonmissing data for all three features: PSA, Gleason score, and clinical stage. Data are presented at the patient-level, stratified by indication. We analyze a composite measure of appropriateness: low-risk patients received “inappropriate imaging” if they received an inappropriate bone scan or axial imaging; and high-risk patients received “appropriate imaging” if they received all NCCN guideline-recommended imaging tests (Aus et al. 2001; Heidenreich et al. 2009). We did not measure inappropriate imaging among high-risk patients; utilization of extra medical imaging (such as PET scan) was “appropriate” for this study.

Records from all three data sources (VA, VA local contract, and Medicare) were reviewed for the 3-month period prior to diagnosis up to whichever came first: the time of cancer treatment initiation or 6 months following diagnosis.

Covariates. *Clinical covariates* included patient age at diagnosis (<55, 55–64, 65–69, 70–74, and 75+ years of age); serum PSA at diagnosis (0–4, 4–10, 10–20, and 20+ ng/mL); clinical tumor stage (T1, T2NOS, T2A, T2B, T2C, T3, and T4); and Gleason score (<7, 3 + 4, 4 + 3, and ≥8). Patient race was self-reported (black, white, other, or missing).

We identified a previously described set of 16 chronic medical conditions and a set of five mental health conditions common to veterans and of interest to VA policy makers. These conditions are a modified set of Elixhauser conditions including those potentially related to military service, including posttraumatic stress disorder (PTSD) and traumatic brain injury (Yu et al. 2003; Quan et al. 2005; Baldwin et al. 2006). The medical conditions include AIDS/HIV, arthritis, atrial fibrillation, acute myocardial infarction, congestive heart failure, chronic kidney disease, chronic obstructive pulmonary disease, diabetes, dyspepsia, ischemic heart disease, osteoporosis, peripheral vascular disease, traumatic brain injury, tuberculosis, spinal cord injury, and stroke. The mental health conditions include alcohol abuse, dementia, depression, psychoses, mental health conditions including PTSD, and substance abuse. Disease indicators were created using AHRQ's Clinical Classifications Software for each condition utilizing all available inpatient and outpatient ICD9 codes up to 12 months prior to diagnosis (Elixhauser, Steiner, and Palmer 2014). The medical comorbidities were added together and their sum categorized as 0, 1–2, 3, and 4+. A similar process was performed for mental health comorbidities, their sum categorized as 0, 1, or 2+.

Because the presence of back or bone pain may be an indication to perform advanced imaging among men with prostate cancer and because prostate cancer usually spreads first to the spine, we created a binary variable, “nonspecific back pain,” which was positive if the patient had any of the nonspecific back pain ICD-9-CM codes described in Appendix A.

Patient's treatment (radical prostatectomy, external beam radiation, and brachytherapy) was determined by ICD-9-CM and CPT codes from VA and Medicare claims data. Other treatments (primary androgen deprivation, watchful waiting, cryosurgery, etc.) were combined into a separate single category.

Demographics and Insurance Status. Marital status was analyzed as a binary variable: married versus single/divorced/widowed. VA priority status was grouped based on whether the patient had a service-connected disability, other severe disabilities, or had income below VHA means test; copays for

care are required of patients without these levels of disability (Liu et al. 2011). We created a binary indicator of whether the patient had evidence of Medicare claims totaling at least \$50 in the 6-month period prior to diagnosis. Median household income and proportion of the population with a college degree was identified for each patient's ZIP code based on 2010 Census data (United States Census Bureau 2014). Year of diagnosis was analyzed as a categorical variable. We adjusted the model for geographic region, operationalized as U.S. Census Region (New England, Mid-Atlantic, East North Central, West North Central, South Atlantic including Puerto Rico, East South Central, West South Central, Mountain, and Pacific).

Health System Covariates. VAMCs were categorized as having an academic affiliation versus not. VAMCs were categorized by the total number of prostate cancer patients diagnosed in the study period divided by the number of years studied: <60, 60–99, and >99 cases/year.

To avoid exclusion of study subjects with missing sociodemographic characteristics (i.e., VA priority status, median household income, proportion of the population with a college degree, and race), we classified men into a “missing” level within each categorical variable.

Statistical Analysis

We analyzed imaging utilization patterns stratified by imaging indication (high risk or low risk). We performed a bivariate analysis to determine the association between receipt of imaging and the described independent variables. We report p-values based on chi-squared tests for categorical variables. We next performed a multivariable-adjusted logistic regression model to determine the association between all described covariates and utilization of imaging, also stratified by imaging indication. All covariates remained in the model regardless of their statistical significance. We report odds ratios and 95 percent confidence intervals.

To determine the robustness of our analysis, we performed several sensitivity analyses: (1) we added back the 2,290 low-risk men, initially excluded for missing clinical stage, PSA, or Gleason grade. (2) we ran the model on the very lowest risk subgroup of patients, using the D'Amico criteria (PSA <10, Gleason score ≤6, and clinical stage ≤T2a) (D'Amico et al. 1998). (3) we ran the model changing the dependent variable from a composite representing appropriate imaging overall to one with axial

imaging (CT or MRI) as the dependent variable and a second sensitivity analysis with bone scan as the dependent variable. Because axial imaging may have been used for planning purposes among patients undergoing radiation therapy, we excluded low-risk patients undergoing radiation therapy from the axial imaging sensitivity analysis (final cohort $N = 13,452$). In addition, we excluded from the high-risk axial imaging sensitivity analysis any high-risk patient who did not require axial imaging (final cohort $N = 2,913$). (4) We ran the low-risk model excluding low-risk patients with evidence of fracture ($n = 84$), who many have been misclassified as low-risk patients.

Statistical analysis was performed using Stata 12.0 (StataCorp, College Station, TX, USA). All p -values were two-sided with statistical significance at $\alpha = 0.05$.

RESULTS

Our final cohort included 42,196 men. Regardless of risk group, men with incident prostate cancer were most likely to present with clinical stage T1 disease (low-risk 68 percent and high-risk 45 percent) (Table 1). Among low-risk patients, the most common Gleason grade was less than 7 (57 percent), while for high-risk patients it was Gleason grade 8 or greater (61 percent). PSA for low-risk patients most frequently was between 4 and 10 (67 percent), while for high-risk patients it was most likely to be greater than 20 (54 percent). The distributions of available data from a cohort of low-risk men with one or more missing staging variables (clinical stage, Gleason grade, PSA) is included in a third column and is qualitatively different from those of the low-risk cohort with complete staging information.

Overall, 12,167 (27 percent) men were determined to have high-risk prostate cancer based on either bone scan or CT imaging criteria and the rest were low risk. The distribution of race and marital status was similar across the risk groups, with roughly one quarter describing themselves as black and just over one half were married. Approximately one third of low-risk (30 percent) and high-risk (33 percent) patients with incident prostate cancer accessed medical services within the year prior to their diagnosis. The majority of low-risk and high-risk patients were diagnosed at facilities caring for high volumes of prostate cancer patients, 66 and 63 percent, respectively.

Table 1: Characteristics of Men with Incident Prostate Cancer Diagnosed in the VA, Stratified by Imaging Indication, Number (%)

	<i>Low Risk</i>	<i>High Risk</i>	<i>Unknown Risk</i>
Number of men	30,029	12,167	2,888
Clinical stage			
T1	21,011 (70.0)	5,432 (44.7)	1,380 (47.8)
T2NOS	1,354 (4.5)	630 (5.2)	125 (4.3)
T2A	3,596 (12.0)	1,042 (8.6)	296 (10.2)
T2B	1,159 (3.9)	840 (6.9)	85 (2.9)
T2C	2,909 (9.7)	2,592 (21.3)	182 (0.4)
T3		906 (7.5)	—
T4	—	309 (2.5)	—
Missing	—	416 (3.4)	820 (28.4)
Gleason grade			
Less than 7	17,154 (57.1)	1,854 (15.2)	1,532 (53.0)
3 + 4	9,531 (31.7)	1,561 (12.8)	709 (24.5)
4 + 3	3,344 (11.1)	1,063 (8.7)	314 (10.9)
Greater than or equal to 8	—	7,368 (60.6)	—
Missing	—	321 (2.6)	333 (11.5)
PSA level (ng/mL)			
0–4	4,071 (13.6)	644 (5.3)	173 (6.0)
4–10	21,221 (70.7)	2,959 (24.3)	683 (23.6)
10–20	4,737 (15.8)	1,720 (14.1)	195 (6.8)
Greater than 20	—	6,600 (54.3)	—
Missing	—	244 (2.0)	1,837 (63.6)
Medical comorbidities			
0	6,988 (23.3)	2,438 (20.0)	495 (17.1)
1–2	5,644 (18.8)	2,097 (17.2)	491 (17.0)
3+	5,306 (17.7)	2,092 (17.2)	500 (17.3)
4+	12,091 (40.3)	5,540 (45.5)	1,402 (48.5)
Mental health comorbidities			
0	14,308 (47.7)	5,729 (47.1)	1,199 (41.5)
1	7,013 (23.4)	3,167 (26.0)	750 (26.0)
2	8,708 (29.0)	3,271 (26.9)	939 (32.5)
Treatment			
Watchful-waiting/hormone therapy	11,352 (37.8)	5,903 (48.5)	1,043 (36.1)
Prostatectomy	8,041 (26.8)	2,518 (20.7)	1,277 (44.2)
Radiation therapy	10,636 (35.4)	3,746 (30.8)	568 (19.7)
Age in years			
<55	2,215 (7.4)	720 (5.9)	266 (9.2)
55–64	12,804 (42.6)	4,052 (33.3)	1,315 (45.5)
65–69	5,648 (18.8)	1,919 (15.8)	506 (17.5)
70–74	5,266 (17.5)	2,288 (18.8)	428 (14.8)
75+	4,096 (13.6)	3,188 (26.2)	373 (12.9)

continued

Table 1: *Continued*

	<i>Low Risk</i>	<i>High Risk</i>	<i>Unknown Risk</i>
Race			
Black	7,385 (24.6)	3,381 (27.8)	944 (32.7)
White	21,536 (71.7)	8,339 (68.5)	1,854 (64.2)
Other	305 (1.0)	120 (1.0)	21 (0.7)
Missing	803 (2.7)	327 (2.7)	69 (2.4)
Marital status			
Married	16,576 (55.2)	6,233 (51.2)	1,542 (53.4)
Single/divorced/widowed	13,453 (44.8)	5,934 (48.8)	1,346 (46.6)
Census tract per capita income			
<\$25,000	3,010 (10.0)	1,637 (13.5)	382 (13.2)
\$25,000–34,999	9,735 (32.4)	3,910 (32.1)	882 (30.5)
\$35,000–44,999	8,856 (29.5)	3,340 (27.5)	789 (27.3)
\$45,000–54,999	4,007 (13.3)	1,484 (12.2)	383 (13.3)
>\$55,000	3,324 (11.1)	1,279 (10.5)	340 (11.8)
Missing or unknown	1,097 (3.7)	517 (4.3)	112 (3.9)
Insurance in prediagnosis period			
No Medicare use	21,002 (69.9)	8,113 (66.7)	2,212 (76.6)
Some Medicare use	9,027 (30.1)	4,054 (33.3)	676 (23.4)
Priority status			
Catastrophically disabled	6,203 (20.7)	2,269 (18.7)	587 (20.3)
Moderate disability	4,568 (15.2)	1,714 (14.1)	459 (15.9)
Low income	13,633 (45.4)	6,333 (52.1)	1,360 (47.1)
No service-connected disability	5,525 (18.4)	1,798 (14.8)	473 (16.4)
Unknown	100 (0.3)	53 (0.4)	9 (0.3)
Hospital volume category			
<60 cases per year	3,221 (10.7)	1,537 (12.6)	285 (9.9)
60–99 cases per year	7,190 (23.9)	2,972 (24.4)	559 (19.4)
>99 cases per year	19,618 (65.3)	7,658 (62.9)	2,044 (70.8)
VAMC academic affiliation			
Yes	26,919 (89.6)	11,099 (91.2)	2,751 (95.3)
No	3,110 (10.4)	1,068 (8.8)	137 (4.7)
Percent of census tract population with at least 4 years of college			
<15%	12,758 (42.5)	5,250 (43.2)	1,233 (42.7)
≥15 to <20%	5,593 (18.6)	2,310 (19.0)	547 (18.9)
≥20 to <25%	3,397 (11.3)	1,313 (10.8)	333 (11.5)
≥25%	7,190 (23.9)	2,777 (22.8)	665 (23.0)
Missing	1,091 (3.6)	517 (4.3)	110 (3.8)
Year of diagnosis			
2004	6,382 (21.3)	2,916 (24.0)	1,006 (34.8)
2005	6,596 (22.0)	2,611 (21.5)	796 (27.6)
2006	7,086 (23.6)	2,871 (23.6)	517 (17.9)
2007	8,163 (27.2)	3,129 (25.7)	461 (16.0)
2008	1,802 (6.0)	640 (5.3)	108 (3.7)

continued

Table 1: *Continued*

	<i>Low Risk</i>	<i>High Risk</i>	<i>Unknown Risk</i>
U.S. census region			
Northeast	1,297 (4.3)	392 (3.2)	98 (3.4)
Mid-Atlantic	2,587 (8.6)	1,207 (9.9)	426 (14.6)
East North Central	3,180 (10.6)	1,365 (11.2)	590 (20.4)
West North Central	3,065 (10.2)	992 (8.2)	115 (4.0)
South Atlantic (+PR)	7,019 (23.4)	3,236 (26.6)	832 (28.8)
East South Central	2,309 (7.7)	755 (6.2)	166 (5.7)
West South Central	4,625 (15.4)	1,597 (13.1)	291 (10.1)
Mountain	2,606 (8.7)	1,164 (9.6)	188 (6.5)
Pacific	3,341 (11.1)	1,459 (12.0)	182 (6.3)

Low-Risk Patients

Forty-one percent of men with low-risk incident prostate cancer diagnosed in the VA underwent guideline inappropriate imaging (Table 2), while 43 percent of those low-risk patients with missing data underwent guideline inappropriate imaging. Among low-risk men, the following factors were independently associated with a higher likelihood of undergoing inappropriate imaging on multivariable analysis: higher clinical stage, higher Gleason score, presence of nonspecific back pain, greater medical or mental health comorbidity, older age, missing race, being unmarried, having lower income, having used Medicare insurance during the prediagnosis period, being treated at a lower prostate cancer volume hospital, being treated at a VAMC affiliated with an academic medical center, living in a census region where education is tracked, and being treated in 2006 or 2007 (Tables 3 and 4). A PSA in the 4–10 range was associated with a lower likelihood of inappropriate imaging, while a PSA above 10 but below 20 was associated with a higher likelihood of inappropriate imaging.

Table 2: Imaging Utilization among Men with Incident Prostate Cancer Diagnosed* in the VA, Stratified by Imaging indication, Number (%)

	<i>Low Risk</i>	<i>High Risk</i>	<i>Unknown Risk</i>
Received a bone scan	10,026 (33.4)	8,277 (68.0)	994 (34.4)
Pelvic or abdominal CT	10,463 (34.8)	7,068 (58.1)	917 (31.8)
Received a pelvic MRI	732 (2.4)	489 (4.0)	63 (2.2)
Received a PET scan	26 (0.09)	17 (0.14)	6 (0.2)
Received any imaging	12,248 (40.8)	9,327 (76.7)	1,354 (46.9)
Received guideline appropriate care	17,781 (59.2)	8,503 (69.9)	1,643 (56.9)

*Within 3 months prior to prostate cancer diagnosis and 6 months after diagnosis.

Table 3: Bivariate Association between Independent Variables and Receipt of Imaging among Men with Incident Prostate Cancer Diagnosed in the VA, Stratified by Imaging Indication

	Low Risk			High Risk		
	Inappropriate Imaging No. (%)	No Imaging No (%)	p-value	Appropriate Imaging No. (%)	No Imaging No. (%)	p-value
Number of men		30,029			12,167	
Clinical stage						
T1	8,172 (38.9)	12,839 (61.1)	<.001	3,445 (63.4)	1,987 (36.6)	<.001
T2NOS	530 (39.1)	824 (60.9)		400 (63.5)	230 (36.5)	
T2A	1,504 (41.8)	2,092 (58.2)		665 (63.8)	377 (36.2)	
T2B	611 (52.7)	548 (47.3)		655 (78.0)	185 (22.0)	
T2C	1,431 (49.2)	1,478 (50.8)		2,060 (79.5)	532 (20.5)	
T3	—	—		775 (85.5)	131 (14.5)	
T4	—	—		268 (86.7)	41 (13.3)	
Missing	—	—		235 (56.5)	181 (43.5)	
Gleason grade						
Less than 7	6,112 (35.6)	11,042 (64.4)	<.001	937 (50.5)	917 (49.5)	<.001
3 + 4	4,371 (45.9)	5,160 (54.1)		1,082 (69.3)	479 (30.7)	
4 + 3	1,765 (52.8)	1,579 (47.2)		773 (72.7)	290 (27.3)	
Greater than or equal to 8	—	—		5,550 (75.3)	1,818 (24.7)	
Missing	—	—		161 (50.2)	160 (49.8)	
PSA level (ng/mL)						
0–4	1,611 (39.6)	2,460 (60.4)	<.001	469 (72.8)	175 (27.2)	<.001
4–10	7,589 (35.8)	13,632 (64.2)		2,013 (68.0)	946 (32.0)	
10–20	3,048 (64.3)	1,689 (35.7)		1,381 (80.3)	339 (19.7)	
Greater than 20	—	—		4,504 (68.2)	2,096 (31.8)	
Missing	—	—		136 (55.7)	108 (44.3)	

continued

Table 3: Continued

	Low Risk			High Risk		
	Inappropriate Imaging No. (%)	No Imaging No (%)	p-value	Appropriate Imaging No. (%)	No Imaging No. (%)	p-value
Nonspecific back pain						
No	9,865 (39.7)	15,016 (60.4)	<.001	6,781 (68.9)	3,060 (31.1)	<.001
Yes	2,383 (46.3)	2,765 (53.7)		1,722 (74.0)	604 (26.0)	
Medical comorbidities						
0	2,692 (38.5)	4,296 (61.5)	<.001	1,799 (73.8)	639 (26.2)	<.001
1–2	2,234 (39.6)	3,410 (60.4)		1,455 (69.4)	642 (30.6)	
3	2,135 (40.2)	3,171 (59.8)		1,399 (66.9)	693 (33.1)	
4+	5,187 (42.9)	6,904 (57.1)		3,850 (69.5)	1,690 (30.5)	
Mental health comorbidities						
0	5,672 (39.6)	8,636 (60.4)	<.001	4,017 (70.1)	1,712 (29.9)	.723
1	2,837 (40.5)	4,176 (59.6)		2,218 (70.0)	949 (30.0)	
2+	3,739 (42.9)	4,969 (57.1)		2,268 (69.3)	1,003 (30.7)	
Treatment						
Watchful-waiting/hormone therapy						
Prostatectomy	5,201 (45.8)	6,151 (54.2)	<.001	4,297 (72.8)	1,606 (27.2)	<.001
Radiation therapy	2,878 (35.8)	5,163 (64.2)		1,316 (52.3)	1,202 (47.7)	
Age in years	4,169 (39.2)	6,467 (60.8)		2,890 (77.2)	856 (22.9)	
<55	901 (40.7)	1,314 (59.3)	<.001	494 (68.6)	226 (31.4)	.089
55–64	4,990 (39.0)	7,814 (61.0)		2,789 (68.8)	1,263 (31.2)	
65–69	2,288 (40.5)	3,360 (59.5)		1,335 (69.6)	584 (30.4)	
70–74	2,240 (42.5)	3,026 (57.5)		1,649 (72.1)	639 (27.9)	
75+	1,829 (44.7)	2,267 (55.4)		2,236 (70.1)	952 (29.9)	
Race						

continued

Table 3: Continued

	Low Risk			High Risk		
	Inappropriate Imaging No. (%)	No Imaging No. (%)	p-value	Appropriate Imaging No. (%)	No Imaging No. (%)	p-value
Black	3,319 (44.9)	4,066 (55.06)	<.001	2,477 (73.3)	904 (26.7)	<.001
White	8,578 (39.8)	13,715 (60.6)		5,744 (68.9)	2,595 (31.1)	
Other	118 (38.7)	187 (61.3)		84 (70.0)	36 (30.0)	
Missing	233 (29.0)	570 (71.0)		198 (60.6)	129 (39.5)	
Marital status						
Married	6,528 (39.4)	10,048 (60.6)	<.001	4,235 (67.9)	1,998 (32.1)	<.001
Single/divorced/widowed	5,720 (42.5)	7,733 (57.5)		4,268 (71.9)	1,666 (28.1)	
Census tract per capita income						
<\$25,000	1,483 (49.3)	1,527 (50.7)	<.001	1,194 (72.9)	443 (27.1)	.059
\$25,000–34,999	3,812 (39.2)	5,923 (60.8)		2,682 (68.6)	1,228 (31.4)	
\$35,000–44,999	3,586 (40.5)	5,270 (59.5)		2,334 (69.9)	1,006 (30.1)	
\$45,000–54,999	1,556 (38.8)	2,451 (61.2)		1,044 (70.4)	440 (29.7)	
>\$55,000	1,325 (39.9)	1,999 (60.1)		888 (69.4)	391 (30.6)	
Missing or unknown	486 (44.3)	611 (55.7)		361 (69.8)	156 (30.2)	
Insurance in prediagnosis period						
No Medicare use	8,365 (39.8)	12,637 (60.1)	<.001	5,602 (69.1)	2,511 (31.0)	.004
Some Medicare use	3,883 (43.0)	5,144 (57.0)		2,901 (71.6)	1,153 (28.4)	
Priority status						

continued

Table 3: *Continued*

	Low Risk			High Risk		
	Inappropriate Imaging No. (%)	No Imaging No (%)	p-value	Appropriate Imaging No. (%)	No Imaging No. (%)	p-value
Catastrophically disabled	2,479 (40.0)	3,724 (60.0)	<.001	1,555 (68.5)	714 (31.5)	<.001
Moderate disability	1,823 (39.9)	2,745 (60.1)		1,157 (32.5)	557 (32.5)	
Low income	5,865 (43.0)	7,768 (57.0)		4,539 (71.7)	1,794 (28.3)	
No service-connected disability	2,043 (37.0)	3,482 (63.0)	<.001	1,219 (67.8)	579 (32.2)	<.001
Unknown	38 (38.0)	62 (62.0)		33 (62.3)	20 (37.7)	
Hospital volume category						
<60 cases per year	1,741 (54.1)	1,480 (46.0)	<.001	1,070 (69.6)	467 (30.4)	.210
60–99 cases per year	2,617 (36.4)	4,573 (63.6)		2,041 (68.7)	931 (31.3)	
>99 cases per year	7,890 (40.2)	11,728 (59.8)		5,392 (70.4)	2,266 (29.6)	
VAMC academic affiliation			<.001			<.001
Yes	11,170 (41.5)	15,749 (58.5)		7,830 (70.6)	3,269 (29.5)	
No	1,078 (34.7)	2,032 (65.3)		673 (63.0)	395 (37.0)	
Percent of census tract population with at least 4 years of college			.003			.884
<15%	5,277 (41.4)	7,481 (58.6)		3,664 (69.8)	1,586 (30.2)	
≥15 to <20%	2,314 (41.4)	3,279 (58.6)		1,623 (70.3)	687 (29.7)	
≥20 to <25%	1,367 (40.2)	2,030 (59.8)		903 (68.8)	410 (31.2)	
≥25%	2,809 (39.1)	4,381 (60.9)		1,952 (70.3)	825 (29.7)	
Missing	481 (44.1)	610 (55.91)		361 (69.8)	156 (30.2)	
Year of diagnosis			<.001			<.001
2004	2,521 (39.5)	3,861 (60.5)		1,787 (61.3)	1,129 (38.7)	
2005	2,642 (40.1)	3,954 (60.0)		1,790 (68.6)	821 (31.4)	
2006	2,950 (41.6)	4,136 (58.4)		2,055 (71.6)	816 (28.4)	
2007	3,452 (42.3)	4,711 (57.7)		2,379 (76.0)	750 (24.0)	
2008	683 (37.9)	1,119 (62.0)		492 (76.9)	148 (23.1)	

Table 4: Multivariable-Adjusted Logistic Regression Modeling the Association between Imaging and Clinico-Demographic Factors among Men with Incident Prostate Cancer Diagnosed in the VA, Stratified by Imaging Indication and Adjusted for Region, Odds Ratio (95% Confidence Interval)

	Low Risk		High Risk	
	OR (95% CI)	Predicted Probability OR (95% CI)	OR (95% CI)	Predicted Probability OR (95% CI)
Clinical stage				
T1	1.00 (Reference)	0.39 (0.39–0.40)	1.00 (Reference)	0.65 (0.64–0.66)
T2NOS	1.07 (0.95–1.21)	0.41 (0.38–0.44)	1.02 (0.85–1.22)	0.65 (0.62–0.69)
T2A	1.12* (1.04–1.21)	0.42 (0.40–0.43)	1.00 (0.86–1.15)	0.65 (0.62–0.67)
T2B	1.49* (1.31–1.69)	0.48 (0.45–0.51)	1.88* (1.57–2.25)	0.77 (0.74–0.78)
T2C	1.41* (1.30–1.53)	0.47 (0.45–0.49)	1.83* (1.63–2.06)	0.76 (0.75–0.78)
T3	–	–	4.05* (3.30–5.01)	0.87 (0.85–0.89)
T4	–	–	3.60* (2.53–5.13)	0.86 (0.82–0.90)
Missing	–	–	0.79* (0.63–0.99)	0.60 (0.55–0.65)
Gleason grade				
Less than 7	1.00 (Reference)	0.36 (0.36–0.37)	1.00 (Reference)	0.49 (0.46–0.51)
3 + 4	1.48* (1.40–1.56)	0.45 (0.44–0.46)	2.04* (1.76–2.36)	0.65 (0.62–0.67)
4 + 3	2.01* (1.86–2.18)	0.52 (0.50–0.53)	2.21* (1.86–2.63)	0.66 (0.63–0.69)
Greater than or equal to 8	–	–	4.20* (3.64–4.84)	0.78 (0.77–0.79)
Missing	–	–	1.08 (0.83–1.41)	0.51 (0.45–0.56)
PSA level (ng/mL)				
0–4	1.00 (Reference)	0.39 (0.38–0.41)	1.00 (Reference)	0.64 (0.60–0.68)
4–10	0.86* (0.80–0.93)	0.36 (0.36–0.37)	0.85 (0.70–1.04)	0.60 (0.59–0.62)
10–20	2.75* (2.51–3.01)	0.63 (0.61–0.64)	1.67* (1.34–2.07)	0.73 (0.71–0.75)
Greater than 20	–	–	1.74* (1.41–2.14)	0.74 (0.73–0.75)
Missing	–	–	0.46* (0.34–0.64)	0.48 (0.42–0.53)

continued

Table 4: Continued

	Low Risk		High Risk	
	OR (95% CI)	Predicted Probability OR (95% CI)	OR (95% CI)	Predicted Probability OR (95% CI)
Nonspecific back pain				
No	1.00 (Reference)	0.40 (0.39–0.41)	1.00 (Reference)	0.72 (0.71–0.74)
Yes	1.33* (1.25–1.42)	0.40 (0.39–0.42)	1.29* (1.16–1.44)	0.70 (0.68–0.71)
Medical comorbidities				
0	1.00 (Reference)	0.40 (0.39–0.41)	1.00 (Reference)	0.72 (0.71–0.74)
1–2	1.03 (0.95–1.11)	0.40 (0.39–0.42)	0.85* (0.7–0.98)	0.70 (0.68–0.71)
3	1.01 (0.94–1.10)	0.40 (0.39–0.42)	0.78* (0.68–0.89)	0.68 (0.66–0.70)
4+	1.07* (1.00–1.15)	0.42 (0.41–0.43)	0.85* (0.75–0.96)	0.70 (0.69–0.71)
Mental health comorbidities				
0	1.00 (Reference)	0.40 (0.39–0.41)	1.00 (Reference)	0.70 (0.69–0.71)
1	1.01 (0.95–1.08)	0.40 (0.39–0.41)	0.98 (0.88–1.08)	0.70 (0.68–0.71)
2+	1.11* (1.04–1.18)	0.43 (0.42–0.44)	0.98 (0.88–1.09)	0.70 (0.68–0.71)
Age in years				
<55	1.00 (Reference)	0.40 (0.38–0.42)	1.00 (Reference)	0.69 (0.65–0.72)
55–64	1.02 (0.92–1.13)	0.40 (0.39–0.41)	1.07 (0.89–1.28)	0.69 (0.68–0.71)
65–69	1.12* (1.00–1.25)	0.42 (0.41–0.43)	1.16 (0.95–1.43)	0.71 (0.69–0.73)
70–74	1.10 (0.98–1.24)	0.42 (0.40–0.43)	1.27* (1.03–1.56)	0.73 (0.71–0.74)
75+	1.00 (0.89–1.13)	0.40 (0.38–0.41)	0.99 (0.81–1.21)	0.68 (0.66–0.70)
Race				
Black	1.00 (Reference)	0.42 (0.40–0.43)	1.00 (Reference)	0.71 (0.70–0.73)
White	0.97 (0.91–1.03)	0.41 (0.40–0.41)	0.91 (0.82–1.01)	0.70 (0.69–0.70)
Other	0.99 (0.77–1.27)	0.41 (0.36–0.47)	1.06 (0.69–1.63)	0.72 (0.65–0.80)
Missing	0.74* (0.62–0.88)	0.35 (0.32–0.38)	0.70* (0.54–0.91)	0.64 (0.60–0.69)

continued

Table 4: Continued

	Low Risk		High Risk	
	OR (95% CI)	Predicted Probability OR (95% CI)	OR (95% CI)	Predicted Probability OR (95% CI)
Marital status				
Married				
Single/divorced/widowed	1.00 (Reference)	0.40 (0.39–0.41)	1.00 (Reference)	0.69 (0.68–0.70)
Census tract per capita income	1.09* (1.03–1.14)	0.42 (0.41–0.43)	1.15* (1.05–1.25)	0.71 (0.70–0.72)
<\$25,000	1.00 (Reference)	0.44 (0.42–0.46)	1.00 (Reference)	0.71 (0.68–0.74)
\$25,000–34,999	0.72* (0.66–0.79)	0.37 (0.36–0.38)	0.87 (0.75–1.00)	0.69 (0.66–0.71)
\$35,000–44,999	0.81* (0.74–0.89)	0.39 (0.38–0.40)	0.97 (0.83–1.12)	0.71 (0.68–0.73)
\$45,000–54,999	0.82* (0.73–0.92)	0.40 (0.38–0.41)	1.05 (0.87–1.26)	0.72 (0.69–0.75)
>\$55,000	0.93 (0.82–1.06)	0.42 (0.40–0.44)	0.99 (0.80–1.21)	0.71 (0.68–0.74)
Missing or unknown	10.9* (1.21–98.2)	0.86 (0.64–1.08)	0.53 (0.03–9.43)	0.59 (0.001–1.17)
Insurance in prediagnosis period				
No Medicare use	1.00 (Reference)	0.40 (0.39–0.41)	1.00 (Reference)	0.70 (0.69–0.70)
Some Medicare use	1.09* (1.03–1.16)	0.42 (0.41–0.43)	1.05 (0.95–1.17)	0.71 (0.69–0.72)
Priority status				
Catastrophically disabled	1.00 (Reference)	0.40 (0.39–0.41)	1.00 (Reference)	0.69 (0.67–0.70)
Moderate disability	1.04 (0.96–1.13)	0.41 (0.39–0.42)	1.00 (0.87–1.16)	0.69 (0.67–0.71)
Low income	1.09* (1.02–1.17)	0.42 (0.41–0.42)	1.14* (1.01–1.28)	0.71 (0.70–0.72)
No service-connected disability	0.98 (0.90–1.07)	0.39 (0.38–0.41)	1.05 (0.90–1.22)	0.69 (0.67–0.71)
Unknown	0.85 (0.55–1.31)	0.36 (0.27–0.45)	0.72 (0.39–1.34)	0.62 (0.49–0.74)
Hospital volume category				
<60 cases per year	1.00 (Reference)	0.54 (0.53–0.56)	1.00 (Reference)	0.72 (0.70–0.74)
60–99 cases per year	0.51* (0.47–0.56)	0.39 (0.38–0.41)	0.92 (0.79–1.08)	0.70 (0.69–0.72)
>99 cases per year	0.50* (0.46–0.55)	0.39 (0.38–0.40)	0.86* (0.75–0.99)	0.69 (0.68–0.70)

continued

Table 4: *Continued*

	<i>Low Risk</i>		<i>High Risk</i>	
	<i>OR (95% CI)</i>	<i>Predicted Probability OR (95% CI)</i>	<i>OR (95% CI)</i>	<i>Predicted Probability OR (95% CI)</i>
VAMC academic affiliation				
Yes	1.33* (1.22–1.45)	0.41 (0.41–0.42)	1.19* (1.02–1.38)	0.67 (0.64–0.70)
No	1.00 (Reference)	0.35 (0.34–0.37)	1.00 (Reference)	0.70 (0.69–0.71)
Percent of census track population with at least 4 years of college				
<15%	1.00 (Reference)	0.42 (0.41–0.44)	1.00 (Reference)	0.69 (0.66–0.72)
≥15 to <20%	1.05 (0.98–1.13)	0.43 (0.42–0.45)	1.01 (0.90–1.14)	0.69 (0.66–0.73)
≥20 to <25%	1.00 (0.92–1.09)	0.42 (0.41–0.44)	0.97 (0.83–1.12)	0.69 (0.65–0.72)
≥25%	0.96 (0.88–1.03)	0.41 (0.40–0.43)	1.04 (0.91–1.19)	0.70 (0.67–0.73)
Missing	0.09* (0.01–0.77)	0.08 (–0.05–0.21)	1.75 (0.10–31.2)	0.79 (0.37–1.20)
Year of diagnosis				
2004	1.00 (Reference)	0.39 (0.38–0.40)	1.00 (Reference)	0.62 (0.61–0.64)
2005	1.05 (0.97–1.13)	0.40 (0.39–0.41)	1.34* (1.19–1.51)	0.68 (0.66–0.70)
2006	1.11* (1.03–1.19)	0.41 (0.40–0.43)	1.59* (1.41–1.79)	0.71 (0.70–0.73)
2007	1.16* (1.08–1.24)	0.42 (0.41–0.43)	2.05* (1.81–2.31)	0.75 (0.74–0.77)
2008	0.97 (0.86–1.09)	0.39 (0.37–0.41)	2.05* (1.66–2.54)	0.76 (0.73–0.79)

* $p < .05$.

High-Risk Patients

Seventy percent of men with high-risk incident prostate cancer underwent guideline appropriate imaging (Table 2). Among high-risk men, the following factors were independently associated with a higher likelihood of undergoing an appropriate imaging work-up on multivariable analysis: higher clinical stage, higher Gleason score, higher PSA, presence of nonspecific back pain, fewer medical comorbidities, older age, missing race, being unmarried, having low income, being treated at a lower prostate cancer volume hospital or at a VAMC affiliated with an academic medical center, and being diagnosed in a later year (Tables 3 and 4). Number of mental health comorbidities, use of Medicare in the prediagnosis period, and census tract-level fraction of adults having attended 4 or more years of college, were not significantly associated with appropriate imaging.

Sensitivity Analyses

Performing the sensitivity analysis in the D'Amico low-risk subgroup made the following variables no longer significant compared to the base case model: PSA level, priority status, and Medicare utilization. The direction of the ORs, however, remained largely unchanged (Appendix B). This lowest risk subgroup had a 32 percent overall rate of inappropriate imaging. The sensitivity analysis comparing the low-risk cohort with unknown risk excluded to the base case low-risk men demonstrated no significant changes (Appendix C). The sensitivity analysis excluding 84 patients with fractures from the low-risk group demonstrated no significant changes in any of the variables, as compared to the base model (Appendix D).

The sensitivity analysis using bone scan as the dependent variable generated the following changes as compared to the base case model (Appendix E). In the low-risk analysis, medical comorbidity, insurance in the prediagnosis period, and age were no longer statistically significant. Several other variables underwent minor changes without affecting overall statistical significance. In the high-risk analysis, VAMC academic affiliation was no longer statistically significant. The sensitivity analysis using axial imaging as the dependent variable of interest had the following changes as compared to the base case model (Appendix F). In the low-risk analysis, priority status went from being statistically significant in the base case to no longer significant in the sensitivity analysis. Several other variables underwent minor changes without affecting overall statistical significance. There was no notable change in the significance of the

variable measuring Medicare use in the prediagnosis period. In the high-risk analysis, VAMC academic affiliation was no longer statistically significant.

DISCUSSION

This study is the first complete, national-level effort to assess the prevalence and correlates of imaging to stage incident prostate cancer in the VA. We found high rates of inappropriate imaging among men with low-risk prostate cancer (41 percent) as well as lower than optimal rates of appropriate imaging (i.e., the use of all indicated imaging tests among all patients in whom imaging is indicated by the NCCN guidelines) among men with high-risk prostate cancer (70 percent). These patterns of utilization are similar to those observed among a cohort of men treated in a fee-for-service Medicare setting, a nonoverlapping cohort of patients (Makarov et al. 2012a,b). The Medicare population has a 46 percent frequency of inappropriate imaging among low-risk men and a 67 percent rate of appropriate imaging among high-risk men. Men utilizing health care services funded through Medicare had a higher odds ratio for inappropriate imaging among low-risk disease [1.09 (1.03–1.16)] but not necessarily for appropriate imaging for high-risk disease [1.05 (0.95–1.17)], though the statistical significance of the low-risk odds ratio is sensitive to the definition of the low-risk cohort and the particular imaging endpoint selected. While this finding suggests that there is a dampening of overuse among men who receive care in the VA without affecting appropriate use, this study did not include a cohort of men treated exclusively outside of the VA and therefore cannot directly assess the association between imaging and treatment within the VA versus treatment in a fee-for-service Medicare setting.

Our study is also the first to suggest that care at a higher volume medical center is associated with more guideline-concordant care. Low-risk patients treated in middle and higher prostate cancer volume medical centers were half as likely to undergo inappropriate imaging [ORs 0.51 (0.34–0.78) and 0.50 (0.35–0.73)], respectively] as those treated in low-volume facilities. High-risk patients were less likely to undergo appropriate imaging at the highest volume medical centers, though the effect was small 0.86* (0.75–0.99) and appeared to be driven by use of bone scan, rather than axial imaging. The positive association between hospital volume and outcomes has been demonstrated in numerous publications across many settings (Begg et al. 1998; Thiemann et al. 1999; Birkmeyer, Finlayson, and Birkmeyer 2001; Birkmeyer et al. 2002). Though the focus of this study is on a process endpoint, it is still

remarkable to observe a lower utilization of health care resources at higher volume medical centers. Future research should determine whether this relationship is specific to the VA or whether it may also exist in a fee-for-service setting.

Consistent with previous research, clinical disease characteristics were significantly associated with imaging patterns. Previous studies demonstrated clinical stage T2 prostate cancer had a 1.35 (1.27–1.44) odds ratio of inappropriate imaging compared to T1 disease; higher clinical stage in our VACCR cohort was also associated with higher rates of inappropriate imaging [1.40 (1.29–1.52)] for T2c compared to T1 disease (Makarov et al. 2012b). In contrast to previous studies, where moderately elevated clinical stage was associated with decreased rates of appropriate imaging, our study revealed an increased odds ratio for appropriate imaging among high-risk men with higher clinical stage prostate cancer (Makarov et al. 2012b), suggesting physicians are more likely to recommend imaging with the perception of higher risk. The pattern of increased imaging utilization with higher disease characteristics is evident with PSA. While previous analyses have not demonstrated an association between PSA and imaging utilization (Kindrick et al. 1998; Cooperberg et al. 2002; Makarov et al. 2012b), this study demonstrates a positive association between elevated PSA and increased imaging, both appropriate and inappropriate. Higher Gleason scores, even though they should not guide imaging decisions for men with low-risk prostate cancer (National Comprehensive Cancer Network 2013), were associated with increased rates of both appropriate and inappropriate imaging, similar to prior studies (Makarov et al. 2012b). Finally, we found higher imaging rates among both low- and high-risk patients with nonspecific back pain ICD-9-CM codes. To our knowledge, this association has not been previously described in the literature, though it makes intuitive sense, as back complaints in the setting of prostate cancer are likely to trigger concern for metastatic disease and may warrant an imaging evaluation. The sensitivity analyses highlight that regardless of how restrictively one defines the levels of risk or how stringent the imaging criteria, there appears always to be inappropriate imaging and variation within the practice of various providers.

Our study has some strengths and limitations. An important strength is our large population-based cohort, which includes a wide variety of clinical and demographic covariates. This cohort is predominately under the care of salaried physicians without financial incentive to provide unnecessary care. An additional benefit is our ability to study health care utilization outside of this integrated delivery system and determine whether such utilization affects

the appropriateness of care. In contrast to previous studies, we assessed clinical symptoms such as fracture and nonspecific back pain determined from claims data. While studies of VA patients have sometimes been criticized for being difficult to generalize outside the VA, this study confirms previous observations from a cohort of men treated in a fee-for-service setting.

It remains possible that some patients in the cohort obtained imaging outside the VA using commercial insurance. We suspect this phenomenon is likely to be limited as patients in our cohort relied on VA for their diagnosis and treatment. Previous studies have demonstrated that utilization of commercial insurance among veterans is low and veterans tend not to leave VA for their cancer care (e.g., only 8 percent of veterans with elevated PSAs sought care outside of VA after their diagnosis [Zeliadt et al. 2010]). Our assessment of clinical stage is limited because it can be based on findings from imaging studies; an inappropriate bone scan obtained in a clinically low-risk patient might fortuitously reveal a metastatic lesion, upgrading the patient's clinical stage to T4 and making the test appear to have been ordered appropriately for a patient now reclassified as high risk. As previously noted, the frequency of such upgrading is likely to be low and would bias the results of our study to the null (Chybowski et al. 1991; Makarov et al. 2012b). This limitation applies to all imaging analyses which use clinical stage as a covariate. There is some controversy regarding whether providers routinely use the Partin tables to decide about pelvic imaging (Makarov et al. 2007). As compared to other widely available nomograms which either had not yet been developed at the time of patient registry into the VACCR (Nguyen et al. 2009) or require pathological factors not routinely collected in this dataset (Memorial Sloan Kettering Cancer Center 2015; Prostate Cancer Research Foundation 2015), the Partin tables were widely available, require minimum data for use, and have been used in previous publications to determine the appropriateness of axial imaging (Makarov et al. 2012a,b, 2013, 2014a,b).

Analyses of electronic medical records data limit our ability to know a clinician's intent when ordering an imaging test because there is no associated ICD-9-CM code associated with an imaging order; however, the high rates of inappropriate imaging are unlikely to be explained completely by other indications and the low rate of appropriate imaging would only be further decreased if a portion of these scans were for indications other than prostate cancer staging. Use of VA's electronic EMR data and Medicare claims preclude our ability to integrate the results of an imaging study. We acknowledge the age of our data. The selection by Choosing Wisely of inappropriate prostate cancer imaging was made based primarily on the opinion of thought lead-

ers, and our data provide confirmation of the extent of inappropriate use historically, even in a setting without fee-for-service financial incentives. These data provide an appropriate baseline for evaluating the impact of diffusion of Choosing Wisely. Future efforts will be needed to repeat this analysis to assess the effects of PQRS and Choosing Wisely. While it will be important to repeat this analysis to assess the effects of PQRS and Choosing Wisely, establishing a benchmark at this time for future studies remains a worthwhile endeavor.

We found high rates of inappropriate imaging among low-risk prostate cancer patients and low rates of appropriate imaging among high-risk patients in this VACCR cohort. Despite providing a centralized organizational structure, facilitating the efficient flow of information and policy, and providing a compensation structure which dissociates payment from the volume of services delivered, VA imaging rates were similar to those observed among patients treated in a fee-for-service Medicare setting. Interestingly, VA imaging rates are also similar to prostate cancer imaging rates among low-risk (46 percent) and high-risk (63 percent). Swedish prostate cancer patients prior to the initiation of a highly successful, nationwide effort to lower inappropriate prostate cancer imaging (Makarov et al. 2013). The results of the Swedish effort suggest that a similar, coordinated intervention might have success in the VA. In addition, we believe that observing the behavior of patients enrolled in an integrated health care system with additional access to care in the fee-for-service system elucidates a fundamental principle of health care delivery. Our findings should interest VA patients and policy makers implementing the Veterans Access, Choice and Accountability Act of 2014 (United States Congress 2014), allowing access to fee-for-service health care. Our data suggest such patients are at risk of receiving more unnecessary care without change in appropriate care, though validation of this finding is still necessary. Future research should explore the association between region and appropriateness of imaging in the VA (Makarov et al. 2012a) so that specific interventions may be designed to improve guideline-concordant prostate cancer imaging.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.

Appendix A. ICD-9-CM Codes for the Identification of Nonspecific Back Pain.

Appendix B. Sensitivity Analysis of Low-Risk Group Compared to D'Amico Low-Risk Group. Multivariable-adjusted logistic regression modeling the association between imaging and clinical demographic factors among men with incident prostate cancer diagnosed in the VA, stratified by patient risk group and adjusted for region, odds ratio (95 percent confidence interval).

Appendix C. Sensitivity Analysis Comparing Low-Risk Cohort with Unknown Risk Excluded to Low-Risk Men without Exclusions for Unknown Risk. Multivariable-adjusted logistic regression modeling the association between imaging and clinic-demographic factors among men with incident prostate cancer diagnosed in the VA, stratified by patient risk group and adjusted for region, odds ratio (95 percent confidence interval).

Appendix D. Sensitivity Analysis Comparing Low-Risk Cohort to Low-Risk Cohort Excluding Those with Vertebral Fracture. Multivariable-adjusted logistic regression modeling the association between imaging and clinic-demographic factors among men with incident prostate cancer diagnosed in the VA, stratified by patient risk group and adjusted for region, odds ratio (95 percent confidence interval).

Appendix E. Sensitivity Analysis Comparing Results When Using Two Different Dependent Variables: A Composite Measure of Appropriate Imaging or Bone Scan Only. Multivariable-adjusted logistic regression modeling the association between receipt of bone scan and clinic-demo-

graphic factors among men with incident prostate cancer diagnosed in the VA, stratified by guideline indication for bone scan, adjusted for region.

Appendix F. Sensitivity Analysis Comparing Results When Using Two Different Dependent Variables: A Composite Measure of Appropriate Imaging or Axial Imaging Only. Multivariable-adjusted logistic regression modeling the association between imaging with CT or MRI and clinical demographic factors among men with incident prostate cancer diagnosed in the VA, stratified by guideline indication for axial imaging (CT or MRI), adjusted for region—and excluding radiation patients from low-risk group.