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Determinants of the Overuse of Imaging in Low-Risk Prostate Cancer: a Systematic Review

Allison H Oakes, BA¹, Ritu Sharma, BSc¹, Madeline Jackson, MPH¹, and Jodi B Segal, MD, MPH^{1,2,3}

¹Johns Hopkins Bloomberg School of Public Health, Department of Health Policy and Management

²Johns Hopkins University School of Medicine, Department of Medicine

³Johns Hopkins University Center for Health Services and Outcomes Research

Abstract

Background—The overuse of radiologic services, where imaging tests are provided in circumstances where the propensity for harm exceeds the propensity for benefit, comprises a risk to patient safety and a burden on health care systems. Advanced imaging in the staging of low-risk prostate cancer is considered an overused procedure by many professional societies, yet the determinants that drive this phenomenon are not fully appreciated.

Methods—We systematically searched published literature within MEDLINE® and Embase® from January 1998 to March 2017. We searched for studies conducted in the United States that contain original data and describe determinants associated with the overuse of imaging in low-risk prostate cancer. Paired reviewers independently screened abstracts, assessed quality, and extracted data. We synthesized the identified determinants as a patient-level, clinician-level, or system-level factors of overuse.

Results—Fourteen articles were included; the 13 empirical studies defined overuse as being the use of imaging that was discordant with clinical guidelines. Patient- and system-related factors were most commonly described as being associated with overuse; clinician-level determinants were examined infrequently. Older patient age (n=5), more patient comorbidities (n=7), and characteristics related to geography (n=6), higher regional income (n=6) and less education (n=5) were the most consistently identified statistically significant determinants of overuse. Meaningful differences were detected between health care settings; large integrated health care systems provided less variable care and had lower rates of overuse. Clinical indicators related to prostate cancer were inconsistently associated with overuse.

Corresponding Author: Allison H Oakes, BA 624 North Broadway Hampton House 663 Baltimore, MD 21205 203-219-9194; aoakes2@jhu.edu.

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Conclusion—Many patient- and system-related determinants were identified as contributing to the overuse of advanced imaging to stage low-risk prostate cancer. Overuse may be the consequence of systematized clinician behavior and be relatively invariant of patient characteristics. The identified system-level determinants suggest that payment models that are not tied to volume or enhanced care coordination may curb overuse. We propose further examination of physician-level determinants and implore researchers to rank the relative importance of the identified factors and to test their influence through experimental and quasi-experimental methods.

Keywords

overuse; imaging; prostate cancer; quality measurement; health care costs

Introduction

Many health outcomes in the United States (US) lag behind those of other developed nations.¹⁻⁵ The prevailing explanation is that the overuse of healthcare services in the US harms patients, raises the cost of care, and diverts funding from necessary and beneficial services.⁴ Among the healthcare services with widespread overuse is radiologic imaging.⁶ From 1996 to 2010 imaging use increased significantly across all types of health systems.⁷

Several professional societies and policy organization have released guidelines and developed quality measures that aim to reduce the use of diagnostic imaging in diverse patient populations and care settings. Both the American Society of Clinical Oncology and the American Urological Association have listed the reduction of inappropriate imaging in men with prostate cancer as a priority and included this in their recommendations for the *Choosing Wisely* initiative of the American Board of Internal Medicine.⁸⁻¹⁰ While the literature on the overuse of imaging services has focused mostly on describing the prevalence of use of these services,¹¹ more recent scholarship has sought to learn what drives or determines overuse in this clinical setting. Why does imaging in men with early stage prostate cancer remain so prevalent? We aimed to synthesize the primary empirical literature describing the determinants of, or factors demonstrated to be associated positively or negatively with, the overuse of imaging in men with low-risk prostate cancer.

Materials and Methods

Data Sources and Searches

We searched MEDLINE® and Embase™ from January 1998 through March 2017 for English literature, of any study design. Our search broadly included terms reflecting overuse of imaging for low-risk prostate cancer: Low-risk prostate cancer: prostate[MeSH Terms] OR prostate [tiab] OR prostatic neoplasms[mesh] OR ((MUSIC [tiab] OR benign*[tiab] OR malign*[tiab] OR neoplasm*[tiab] OR carcinoma*[tiab] OR cancer*[tiab] OR tumor[tiab] OR tumors[tiab] OR tumoral*[tiab] OR tumori*[tiab] OR tumorlet*[tiab] OR tumour*[tiab] OR polyp[tiab] OR polyps[tiab] OR polypu*[tiab] OR polypi[tiab] OR adenom*[tiab]) AND prostat*[tiab]) AND “early stage” [ti] OR staging[ti] OR “low grade”[ti] OR “low risk”[ti]; with Overuse: “unnecessary procedures”[mh] OR overuse[tiab] OR inappropriate[ti] OR unnecessary[ti] OR “health services misuse”[MeSH Terms]

We handsearched the reference lists of each included article as well as related systematic reviews for additional articles. The protocol was registered in Prospero (#42015029482).

Study Selection

Two reviewers independently screened titles, abstracts, and full-text for inclusion. Differences between investigators were resolved through consensus adjudication. We included original, English-language studies, that were not exclusively describing populations of patients or clinicians outside of the United States. We further restricted the study to data collected after 1996 given the substantial changes in the U.S. healthcare system in the past two decades. We had no restrictions regarding study design.

Data Extraction, Quality, and Applicability Assessment

We created standardized forms for data extraction and pilot tested the forms prior to beginning the process of data extraction. Reviewers extracted information on the general study characteristics, study participant characteristics, the methods of data collection, the overuse event under investigation, the determinants evaluated and the determinants identified as significantly associated with the overuse event. We used the criteria for statistical significance as defined by each study. The determinants were classified during data abstraction as being related to the patient, the clinician, or the environment. One reviewer completed data abstraction and the second reviewer confirmed the first reviewer's data abstraction for completeness and accuracy.

Two reviewers independently assessed the risk of bias in included studies. The Critical Appraisal Checklist (from the Center for Evidence Based Management) was used for cohort studies and surveys.¹² The single qualitative study was assessed using the tool from the Joanna Briggs Institute.¹³

Data Synthesis and Analysis

We created a set of detailed evidence tables. We synthesized the results by determinants organized as patient-level, clinician-level, and environmental or systems level. The data were not amenable to quantitative pooling given the nature of the data and the heterogeneity across studies.

Role of the Funding Source

The funders had no role in this project.

Results

We identified 1920 titles meeting our inclusion criteria. From these, we identified 47 articles for full-text review. Fourteen studies examined the determinants of imaging overuse in the staging of low-risk prostate cancer. (Figure)

Characteristics of Included Studies

Among the included studies were thirteen cross-sectional studies¹⁴⁻²⁶ and one qualitative survey that used semi-structured interviews.²⁷ (Table I) Nine studies used Surveillance,

Epidemiology, and End Results (SEER)-Medicare linked data,^{15,18-23,25,26} four studies used data from the Veterans Health Administration (VA),^{14,21,24,27} and two studies used data from a single institution or system.^{16,17}

All of the included empirical studies defined overuse as being the use of imaging that was discordant with clinical guidelines regarding the initial evaluation of patients with low-risk prostate cancer. (Table I) The risk stratification was usually based on clinical stage, Gleason score, and prostate specific antigen (PSA) concentration. Although definitions of low-risk disease differed slightly across studies, the most inclusive definition was stage T1 or T2 disease with Gleason score ≤ 6 and PSA concentration ≤ 10 ng/mL. Similarly, the included qualitative study used semi-structured interviews to identify drivers of guideline-discordant use of imaging to stage incident prostate cancer.

Studies varied in the type and number of imaging modalities that were examined. All thirteen empirical studies evaluated the overuse of bone scan as an outcome. While two studies focused exclusively on bone scans, the remaining eleven studies considered bone scan in combination with up to three other imaging modalities; eleven studies examined computed tomography (CT),^{15-21,23-26} eight studies examined magnetic resonance imaging (MRI),^{15-17,20,21,24-26} five studies examined positron emission tomography (PET)^{18,19,21,24,26} and one study examined ultrasonography.¹⁵ (Table I) For example, an outcome may be defined as receipt of any imaging (bone scan, MRI, or PET) in an individual with early stage prostate cancer. On average, studies examined three types of imaging.

Twelve^{14,15,17-26} of the thirteen included quantitative studies used multivariate analyses, all of which controlled for key clinical and sociodemographic covariates and at least one environment-related covariate. Five of these studies contained two separate analyses; two studies subdivided the patient population into low- and intermediate-risk individuals,^{22,23} one study examined different imaging modalities separately,²⁰ and the other two studies asked separate but complementary research questions.^{18,25}

Risk of Bias

The risk of bias was low in 13^{14,15,17-27} of the 14 studies. One cross-sectional study had a moderate risk of bias¹⁶ because the statistical analysis did not adequately account for confounders.

Determinants of Imaging Overuse

Patient Factors

Eleven cross-sectional studies^{14-20,22-24,26} and one qualitative study²⁷ evaluated patient factors that contribute to the overuse of imaging in the staging of low-risk prostate cancer (Table II, Table III). All eleven empirical studies evaluated the effect of patient age, with six^{18,20,22-24,26} of the 11 reporting a significant relationship between age and overuse. Five articles, including six analyses, found that older age was associated with overuse,^{20,22-24,26} although two studies found that individuals in the oldest age category were subjected to less overuse than the youngest age group.^{18,20}

Race was investigated as a determinant of overuse in nine studies^{14,15,17,18,20,22-24,26} and was a significant determinant in seven.^{14,18,20,22-24,26} Five articles of Medicare beneficiaries, describing seven analyses, found that nonwhite or black race was associated with more overuse,^{18,20,22,23,26} while a study of veterans found that black race was associated with less overuse.¹⁴

Comorbid illness was evaluated in 10 studies. Seven articles, describing eight analyses, found that overuse was more likely to occur in patients with more comorbidities.^{17-20,22,24,26} The studies reporting a positive association measured comorbidity using the National Cancer Institute comorbidity index,^{20,22} the Deyo adaptation of the Charlson comorbidity index,¹⁷ or a simple count.^{18,19,24,26} In contrast, the three studies that relied upon the original Charlson comorbidity index^{14,23} or the Klabunde-Charlson comorbidity score¹⁵ did not find a significant association between comorbidity and overuse.

The effect of clinical features specific to prostate cancer were examined in six studies.^{14,16-18,24,26} These studies varied markedly in what was included in the models. While one study included only clinical stage in the model,¹⁷ another study included nine prostate cancer related factors.¹⁶ Clinical stage was the most frequently evaluated, the impact of which was assessed in all six studies. Higher clinical stage, generally T2 versus T1 disease, was found to be a significant predictor of overuse in three studies.^{16,24,26} PSA level was examined in four studies^{14,16,24,26}; a higher level was only found to be a significant predictor of overuse in one study.²⁴ Gleason score was evaluated in three studies,^{16,24,26} two of which found that individuals with scores greater than or equal to 7 were subjected to imaging overuse.^{24,26} Although examined by only one study, the other clinical feature that positively predicted overuse was nonspecific back pain.²⁴

Five articles, with eight analyses, assessed treatment intensity as a potential determinant of overuse. Three of these articles,^{15,20,23} described in five analyses, found that individuals who were planning less invasive treatment or planning active surveillance had less imaging overuse compared to individuals planning for surgery or intensive therapies. The qualitative study reported that patients did not recall or discuss the relationship between their imaging results and subsequent choice of treatment. Additionally, the interviewed patients demonstrated limited knowledge about imaging or clinical guidelines and none of the patients reported that he had specifically requested any type of imaging.²⁷

Clinician Factors

One empirical study¹⁸ and one qualitative study²⁷ evaluated provider-level factors that contribute to the overuse of imaging in the staging of low-risk prostate cancer (Table II, Table III). The empirical study primarily focused on physician-driven variation in the ordering of non-recommended services; the authors found that a physician's inappropriate use of imaging for a given patient significantly predicted inappropriate imaging in subsequent patients. This study also found that ownership of a CT scanner positively and significantly contributed to the likelihood of a patient experiencing unneeded imaging. The qualitative study found that patients trusted their doctor to make decisions about their care, especially related to imaging. This study also found that physicians from a high utilizing site relied more heavily on their own intuition or professional experience rather than guidelines,

as compared to their low utilizing counterparts. Other identified physician-level drivers of overuse included personal concern about missing a clinically significant diagnosis and fear of litigation.

System or Environmental Factors

Twelve cross-sectional studies^{14,15,17-26} evaluated system or environmental factors as determinants of unnecessary imaging in prostate cancer (Table II, Table III).

Eight studies assessed the impact of neighborhood wealth on utilization. Four articles, describing seven analyses, found that among populations insured by Medicare, patients living in higher income census tracts had more overuse.^{15,20,22,23} Two other studies in this population did not find a significant relationship.^{18,26} Two studies that focused on populations receiving care in integrated health care delivery systems found that higher income census tracts were protected from overuse.^{17,24} Seven of the studies that evaluated the effect of income also measured the association between education and overuse; all five studies of Medicare beneficiaries found that men living in areas with a less educated population were more often subjected to imaging overuse than men living in more highly educated areas.^{15,20,22-24} Neither study that focused on patients in integrated health care delivery systems found a significant relationship between education and utilization.^{17,24}

Geographic differences were evaluated in 10 studies using diverse measures.^{14,15,17,18,20-25} Four of these studies examined population density, with three reporting that patients in non-urban or rural areas experienced more overuse.^{20,22,23} Six out of the ten studies assessed the impact of region on overuse;^{15,18,20-22,25} three articles, describing five analyses, found significantly more overuse in the Northeastern US.^{18,20,22} The three other studies investigated smaller geographic units and all found significant variation in unnecessary imaging.^{15,21,25} The three studies that focused on integrated delivery systems and looked for an effect of geography did not find a significant relationship with overuse.^{14,17,24}

Two studies directly studied the effect of insurance type on overuse, with both finding that imaging was significantly lower in veterans than in Medicare beneficiaries.^{21,24} One of these studies also found that VA medical centers having academic affiliation were more likely to overuse than those without.²⁴

Three studies examined the relationship between the overuse of imaging in low-risk prostate cancer and other measures of utilization or resource supply;^{19,24,25} overuse was positively associated with appropriate imaging in high-risk prostate cancer,²⁵ inappropriate imaging in low-risk breast cancer,¹⁹ low overall hospital volume,²⁴ and hospital bed count per 1000 regional residents.¹⁹

Discussion

We identified fourteen studies that examined the determinants of imaging overuse in the staging of low-risk prostate cancer. This literature was very consistent in defining overuse as care that was discordant with clinical practice guidelines.

Significant patterns were identified between key patient factors and imaging overuse. A complex association between age and overuse emerged suggesting that increasing patient age is associated with overuse, but only up to a certain point. In some instances, the oldest patients are protected from overuse as compared to the youngest individuals. A more homogenous pattern was seen for more comorbidities and for black or nonwhite race, all of which were associated with overuse. Interestingly, clinical indicators that are specifically related to prostate cancer and disease severity were inconsistently associated with overuse. This finding may indicate that overuse is the consequence of a systematized behavior of the clinician, rather than the application of personalized care decisions to patients who might fall into a clinical grey area or on the higher end of the of low-risk disease spectrum. This claim is further supported by the one study that examined physician-level determinants, which found that physician utilization of a non-recommended service for a prior patient predicts subsequent non-recommended service use.¹⁸

In 2017, The Lancet launched a “Right Care” series that focused on the appropriateness of medical care around the world. As was extensively discussed in this series, treatment decisions are initiated at the individual level, the locus of which is the interaction between a provider and a patient. It is unsurprising, then, that this literature consistently identified patient level variables that are drivers of overuse.²⁸ Notably however, only one empirical study examined provider-level determinants. Because physician recommendation for a service has been identified as a contributor to the uptake of other kinds of services, notably cancer screening, this topic requires further study.

Individual treatment decisions are also influenced by the environment and system in which they take place. Nearly all of the included studies evaluated the relationship between system-level factors and overuse. Within the Medicare population, a consistent pattern of environmental determinants emerged, in which individuals in census tracts with higher education were less likely to experience overuse. This suggests that these individuals may be better able to evaluate the tradeoffs between the benefits and harms of low-value care, although there certainly may be confounders of this relationship. Significant patterns of geographic variation were also repeatedly identified within the Medicare population, with a tendency for overuse in rural and non-urban areas and the Northeast. Notably, far fewer regional patterns were found in the studies that focused on populations that received their care in integrated health care systems, suggesting that the care delivered within these settings might be more consistent and less susceptible to outside influence. Although the rates of imaging overuse in these systems were still high, there was less overuse relative to what was observed in the general Medicare population, suggesting that payment models that are not tied to volume or that improved information sharing may prevent overuse.

Despite the relative consistency of these findings, the identified associations cannot be interpreted as being causal. Moreover, the relationship between the identified factors and overutilization is complex; overutilization can be correlated with rates of appropriate utilization within the same disease,²⁵ rates of overutilization in other diseases,¹⁹ and with low volume of overall service delivery.²⁴ Researchers should aim to understand the relative importance of these factors through experimental and quasi-experimental methods that assess changes in overuse in response to new policies or guidelines. Such empirical work

could guide the development of interventions that reduce overuse while avoiding unintended consequences like the denial of care to those who could benefit.

This systematic review is not without limitations. We did not search the grey literature; therefore, publication bias is a possibility. The studies identified by our literature search overwhelmingly utilized claims data for their analyses. The largest majority, nine studies, used SEER-Medicare linked data. It is unclear if the overreliance on claims data in this research area biases estimates of overuse.²⁹ Relatedly, without a critical mass of qualitative studies or surveys, we are unable to examine the association between putative determinants and patients or clinicians perceptions of overuse or any features of the actual medical decision making process. Finally, while the studies were consistent in defining overuse as guideline discordant care, various types of imaging were included in the outcome. Based on the paucity of studies and the heterogeneous distribution of the different definitions, it is impossible to say if the determinants of overuse vary by imaging modality. As new imaging technologies are introduced, it is also important to regularly reevaluate how overuse should be defined, and the extent to which trends across years can really be compared.

In 2015, an article in the BMJ put forward a plan for a coordinated research effort to improve our understanding of this complex problem.³⁰ Additionally, the four-part Lancet series on “Right Care” highlighted that identification of the most important drivers of overuse is a top research priority.^{6,28,31,32} Our systematic review contributes to this larger coordinated research agenda by focusing on a specific and prevalent type of overuse, imaging in the staging of low-risk prostate cancer, and synthesizing the empirical literature to describe its determinants. Understanding the drivers of this phenomenon is particularly important as the US Preventative Services Task Force changed the PSA Screening recommendation from a grade D to grade C, which will likely lead to many more men undergoing screening, being diagnosed with early stage prostate cancer, and thus becoming at risk for unnecessary imaging procedures.³³ The drivers identified in our review might inform the development of novel interventions to curb unnecessary imaging in this clinical scenario.

Conclusions

The overuse of medical services is likely to harm patients physically, psychologically, and financially, and simultaneously threatens the sustainability of the health care system by increasing costs and poorly allocating resources. In order to curb overuse, it is necessary to develop conceptually and empirically accurate and reliable ways to identify and measure it. Through simultaneous improvements in study design and measurement, the continued identification of determinants will highlight targets for intervention. This review exposed relatively consistent patient- and system-level determinants that contribute to the overuse of imaging to stage low-risk prostate cancer and highlights a need for more research into provider-level variation.

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Revisions_Highlights

Highlights for “Determinants of the Overuse of Imaging in Low-Risk Prostate Cancer: A Systematic Review”

- Fourteen articles were identified
- All empirical articles defined overuse as care that was discordant with guidelines
- Many patient- and system-related factors were identified as contributing to overuse
- Overuse may be driven by clinician behavior and be invariant of patient characteristics
- More research is needed on the physician-level determinants of overuse

Figure. Summary of the literature search

* Reviewers did not need to agree on reason for exclusion

Table 1

Characteristics of Included Studies

Author, Year Design	Population	Overuse definition used in this population	Imaging Modalities					Guideline(s) Referenced
			MRI	PET	CT	Bone Scan	Ultrasound	
Studies Using SEER-Medicare Data								
Choi, 2011 ¹⁵ , 523 Retrospective cohort	65 years old or older diagnosed with prostate cancer in 2004 and 2005	<ul style="list-style-type: none">• PSA<10ng/ml• Clinical stage T1c-T2a• Gleason score 6	X		X	X	X	American College of Radiologists-2009; National Comprehensive Cancer Network-2009
Makarov, 2012 ²⁶ Cross-sectional	66 to 85 year old diagnosed with prostate cancer in 2004 and 2005	<ul style="list-style-type: none">• PSA 10ng/ml• Clinical stage <T3• Gleason score 6• No symptoms suggesting high risk disease	X	X	X	X		National Comprehensive Cancer Network-2002
Makarov, 2012 ²⁵ Cross-sectional	66-85 years old diagnosed with prostate cancer in 2004 or 2005	<ul style="list-style-type: none">• PSA 10ng/ml• Clinical stage <T3• Gleason score 6• No symptoms suggesting high risk disease	X		X	X		National Comprehensive Cancer Network-2002
Prasad, 2012 ²³ Retrospective cohort	65 years or older diagnosed with prostate cancer between 2004-2005 and followed through Dec 31, 2007	Low-risk: <ul style="list-style-type: none">• PSA 10ng/ml• Clinical stage T1-T2a• Gleason score 6 Intermediate-risk: <ul style="list-style-type: none">• PSA>10toand 20ng/ml• Clinical stage T2b-T2c• Gleason score = 7			X	X		American Urological Association-2000; National Comprehensive Cancer Network-2010
Falchook, 2014 ²² Retrospective cohort	65 years and older diagnosed with prostate cancer between 2004-2007	Low-risk: <ul style="list-style-type: none">• PSA 10 ng/ml• Clinical stage T1-T2a• Gleason score 6				X		National Comprehensive Cancer Network

Author, Year Design	Population	Overuse definition used in this population	Imaging Modalities					Guideline(s) Referenced
			MRI	PET	CT	Bone Scan	Ultrasound	
		Intermediate risk: <ul style="list-style-type: none"> PSA > 10 to and 20 ng/ml Clinical stage T2b Gleason score = 7 						
Falchook, 2015 ²⁰ Retrospective cohort	Older than 65 years, diagnosed with prostate cancer between 2004 and 2007	Bone scan evaluation: <ul style="list-style-type: none"> Clinical stage < T3 Gleason score 7 No symptoms of bony metastasis NOT clinical stage T1-T2 and PSA > 20 ng/ml CT/MRI evaluation: <ul style="list-style-type: none"> Clinical stage T1-T2 and nomogram 20 % probability of lymph node involvement 	X		X	X		National Comprehensive Cancer Network-2004
Makarov, 2015 ¹⁹ Retrospective cohort	67 to 94 years old diagnosed with low-risk prostate cancer from 2004 to 2007	<ul style="list-style-type: none"> PSA 10ng/ml Clinical stage T1c/T2a Gleason score 6 		X	X	X		American Society of Clinical Oncology Choosing Wisely-2012
Lipitz-Snyderman, 2016 ¹⁸ Retrospective cohort	66 years and older diagnosed with cancer between 2004 and 2011, with follow-up through 2012	<ul style="list-style-type: none"> Clinical stage T1c/T2a Gleason score < 7 First or only low-grade prostate cancer 		X	X	X		American Society of Clinical Oncology Choosing Wisely-2012
Studies Using VA Data								
Palvolgyi, 2010 ¹⁴ Retrospective cohort	Newly diagnosed with prostate cancer from 1998 and 2004	<ul style="list-style-type: none"> PSA < 10ng/ml, Clinical stage T2a Gleason score 6 				X		American Urological Association Clinical Practice Guidelines-2009
Makarov, 2016 ²⁴ Retrospective cohort	Under age 85 years newly diagnosed with prostate cancer between 2004 and 2008	Bone scan evaluation: <ul style="list-style-type: none"> PSA 20ng/ml Clinical stage < T3 Gleason score < 8 	X	X	X	X		National Comprehensive Cancer Network-2013

Author, Year Design	Population	Overuse definition used in this population	Imaging Modalities					Guideline(s) Referenced
			MRI	PET	CT	Bone Scan	Ultrasound	
		<ul style="list-style-type: none"> • Patient not diagnosed with fractures • <20 % probability of lymph node involvement estimate d from the Partin tables 						
Makarov, 2016 ²⁷ Qualitative study *	Patients diagnosed with prostate cancer within last 6 months Physicians who reported caring for prostate cancer patients within last 6 months							American Society of Clinical Oncology Choosing Wisely-2012; National Comprehensive Cancer Network-2013; American Urological Association Choosing Wisely-2013
Other Data Sources								
Lavery, 2011 ¹⁶ Retrospective cohort Institutional database	Low-risk patients undergoing robotic-assisted laparoscopic prostatectomy between May 2005 and Jan 2010	<ul style="list-style-type: none"> • PSA 10ng/ml • Gleason score 6 	X		X	X		American College of Radiology-2000
McWilliams, 2014 ²¹ Retrospective cohort \Both VA and SEER-Medicare data	Older than 65 years old with lung, rectal or prostate cancer that was first diagnosed in 2003-2004	<ul style="list-style-type: none"> • Clinical stage T1/T2 • Gleason score <7 	X	X	X	X		American Society of Clinical Oncology Choosing Wisely
Salloum, 2017 ¹⁷ Retrospective cohort Health system database	18 years old and older with low-risk incident prostate cancer between 2004 and 2011	<ul style="list-style-type: none"> • Gleason score 6 	X		X	X		National Comprehensive Cancer Network-2002

CT = computerized tomography, MRI = magnetic resonance imaging, PET = positron emission tomography, PSA = prostate specific antigen,

SEER = Surveillance, Epidemiology and End Results, T = tumor, VA = Veterans Affairs

* Study did not examine instances of actual overuse

Table II
Determinants of Imaging Overuse in Low or Intermediate Risk Prostate Cancer*

Author, year	Outcome	Patient factors**	Environmental or System factors**
Studies Using SEER-Medicare Data			
Choi, 2011 ¹⁵ ,	Bone scan, ultrasound, or CT/MRI in low-risk patients	Treatment (ref surgery): radiation, active surveillance [less overuse], watchful waiting, hormone ablation only, cryotherapy Age, race, marital status, year, Klabunde-Charlson comorbidity score	Median household income (ref < \$35,000): >\$60,000 Percent high school education (ref <75): >90 [less overuse] Geography SEER region (ref San Francisco): New Jersey, Hawaii, Los Angeles, Seattle [less overuse] Population density
Makarov, 2012 ²⁶	Bone scan, CT/MRI, or PET in low-risk patients	Age (ref 66-69): 70-74, 75-79, 80-85 Comorbidities (ref 0): 1-2, 3+ Race (ref white): other/missing, black Clinical stage (ref T1): T2, missing Gleason score (ref <7): 7, missing Marital status, PSA	Census tract education (ref fraction adults 25 or older with 4+ years college): fraction adults 25 or older with less than 4 years college Census tract per capita income
Makarov ^a , 2012 ²⁵	Bone scan in low-risk patients	None	Geography SEER region: significant variation; high of 62 percent probability of inappropriate imaging in New Jersey registry, low of 22 percent probability of inappropriate imaging in Utah registry
	Regional rate of inappropriate imaging in low-risk patients	None	Regional rate of appropriate imaging in high-risk patients: significant correlation
Prasad, 2012 ²³	Bone scan or CT in low-risk patients	Age (ref 65-69): 70-74, >=75 Treatment (ref radical prostatectomy): cryotherapy, standard radiation therapy, active surveillance [less overuse], ADT only, proton beam therapy Charlson comorbidity score, race, marital status	Median household income (ref < \$35,000): \$35-44,999, \$45-59,999, > \$60,000 Percent high school education (ref <75): 75-84.9, 85-89.9, >=90 [less overuse] Population density (ref urban): rural
	Bone scan or CT in intermediate-risk patients	Age (ref 65-69): 70-74, >=75 Race (ref white): black, Hispanic, Asian Treatment (ref radical prostatectomy): cryotherapy, proton beam therapy, standard radiation therapy, active surveillance [less overuse], ADT only Charlson comorbidity score, marital status	Median household income (ref < \$35,000): \$35-44,999, \$45-59,999, > \$60,000; Percent high school education (ref: <75): 75-84.9, 85-89.9, >=90 [less overuse] Population density (ref urban): rural
Falchook, 2014 ²²	Bone scan in low-risk patients	Race (ref white): nonwhite Marital status (ref married): not married/unknown [less overuse] NCI comorbidity index (ref 0): >0 Age, year	Median household income (ref quartile 1): quartile 2, quartile 3, quartile 4 Region (ref northeast): central [less overuse], south [less overuse], west less overuse] Percent non-high school graduates in census tract, population density
	Bone scan in intermediate-risk patients	Race (ref white): nonwhite NCI comorbidity index (ref 0): >0 Age (ref 66-69): 70-74, 75-79, 80-84, 85+ Marital status, year	Median household income (ref quartile 1): quartile 2, quartile 3, quartile 4- highest Region (ref northeast): central [less overuse], south [less overuse], west less overuse] Percent non-high school graduates in census tract (ref quartile 1): quartile 2, quartile 3, quartile 4 Population density (ref urban): rural
Falchook, 2015 ²⁰	Bone scan in low-risk patients	Age (ref 66-69): 70-74, 75-79, >79 Race (ref white): nonwhite NCI comorbidity (ref 0): >0	Median household income in census tract (ref 0-25 quartile): 25-50 quartile, 50-75 quartile, 75-100 quartile

Author, year	Outcome	Patient factors**	Environmental or System factors**
		First treatment (ref EBRT): non-EBRT [less overuse], observation [less overuse] marital status, year	Percent non-high school graduates in census tract (ref 0-25 quartile): 25-50 quartile, 50-75 quartile, 75-100 quartile Geographic region (ref northeast): central [less overuse], south [less overuse], west [less overuse] Population density (ref urban): not urban/unknown, metropolitan
	CT/MRI in low-risk patients	Age (ref 66-69): 70-74, 75-79, >79 [less overuse] Race (ref white): nonwhite race NCI comorbidity (ref 0): >0 Year of diagnosis (ref 2004): 2005, 2006, 2007 First treatment (ref EBRT): non-EBRT [less overuse], observation [less overuse] Marital status	Median household income in census tract (ref 0-25 quartile): 25-50 quartile, 50-75 quartile, 75-100 quartile Percent non-high school graduates in census tract (ref 0-25 quartile): 25-50 quartile, 50-75 quartile, 75-100 quartile Geographic region (ref northeast): central [less overuse], south [less overuse], west [less overuse] Population density
Makarov, 2015 ¹⁹	Bone scan, PET, or CT in low-risk patients	Comorbidities (ref 0): 1-2, 3+ Age	Acute care regional hospital beds per 1000 HRR residents (continuous variable): increased odds with number of beds Quartile of inappropriate breast cancer imaging rate (ref quartile 1): quartile 2, quartile 3, quartile 4
Lipitz-Snyderman, 2016 ¹⁸	Bone scan, PET, or CT in low-risk patients	Age (ref 66-69): 70-74, 75-79, 80-84, 85+ [less overuse] Race (ref white): black, other Modified Charlson comorbidity index (ref 0): 1, 2+ Marital status, clinical stage, year, treatment, tumor characteristics	Region (ref northeast): south [less overuse], Midwest [less overuse], west [less overuse] Median census tract income, metropolitan location
	CT in low-risk patients	Age, Race, modified Charlson comorbidity index, marital status, stage, year of diagnosis, treatment, tumor characteristics *Significance NR	Region, median census tract income, metropolitan location *Significance NR
Studies Using VA Data			
Palvolgyi, 2010 ¹⁴	Bone scan in low-risk patients	Race (ref white): black [less overuse], Hispanic, other Year (continuous variable): lower odds with time Age, PSA, clinical stage, Charlson comorbidity score	VA location
Makarov, 2016 ²⁴	Bone scan, CT/MRI, or PET in low-risk patients	Clinical stage (ref T1): T2NOS, T2A, T2B, T2C Gleason grade (ref <7): 3+4, 4+3 PSA (ref 0-4): 4-10 [less overuse], 10-20 Medical comorbidities (ref 0): 1-2, 3, 4+ Mental health comorbidities (ref 0): 1, 2+ Age (ref <55): 55-64, 65-69, 70-74, 75+ Race (ref black): missing [less overuse], white, other Marital status (ref married): (single/divorced/widow ed Insurance in prediagnosis period (ref no Medicare use): some Medicare use Priority status (ref catastrophically disabled): low income, moderate disability, no service-connected disability, unknown Nonspecific back pain (ref no): yes Year (ref 2004): 2005, 2006, 2007, 2008	Census tract per capita income (ref < \$25,000): \$25-34999 [less overuse], 35-44999 [less overuse], 45-54999 [less overuse], >55000, missing/unknown Hospital volume (ref <60 cases): (60-99 cases [less overuse], >99 cases [less overuse] VAMC academic affiliation (ref no): yes Percent census tract education (ref <15): 15-20, 20-25, >25, missing [less overuse] US census region NR
Makarov ^b , 2016 ²⁷	Patient and provider knowledge and behaviors relating to	Goals, knowledge, beliefs about capabilities, emotion	Environmental context and resources, social influences/norms

Author, year	Outcome	Patient factors**	Environmental or System factors**
	the use of imaging in low-risk patients		
Other Data Sources			
Lavery, 2011 ¹⁶	Bone scan or CT/MRI in low-risk patients	Clinical stage (ref T1c): T2a Age, PSA, prostate weight, path staging, Gleason score, extracapsular extension, seminal vesicle invasion, positive surgical margin, biochemical recurrence, median follow-up	None
McWilliams, 2014 ^{c 21}	Bone scan, CT/MRI, or PET in low-risk patients	None	Geography HRRs: significant variation Health system (ref Medicare): VA [less overuse]
Salloum, 2017 ¹⁷		Deyo-Charlson comorbidity index (ref 0): ≥1 Year (ref 2005): 2006-2011 [each year less overuse] Age, race, clinical stage	Census tract median household income (ref <\$60,000): >\$60,000 [less overuse] Site

* Bold =Significant factors defined in the studies

* Analyses controlled for all listed variables unless otherwise noted

^a Article did not study patient factors but the model was adjusted for Gleason grade, PSA, clinical stage, education, race, comorbidity, age, income

^b Qualitative study that did not examine instances of actual overuse, statistical tests of significance were not conducted

^c Coefficients for patient-level factors not presented or discussed, but model was adjusted for “patient- and area-level sociodemographic” characteristics

ADT= androgen deprivation therapy, CT = computerized tomography, EBRT =external-beam radiation therapy, HRRs = hospital referral regions, MRI = magnetic resonance imaging, NR= not reported, NCI =National Cancer Institute, PET = positron emission tomography, PSA = prostate specific antigen, SEER = Surveillance, Epidemiology and End Results, T = tumor, VA = Veterans Affairs, VAMC = VA Medical Centers

Table III
Summary of Determinants Associated with Overuse of Imaging

Factors (Number of Studies)	Determinant	Studies Reporting Significance / Studies Evaluating the Association	Significant associations with overuse of imaging
Patient Factors (11 studies)	Age	••••••••••	↑ Older age was positively associated with overuse in 5 studies. ↓ Oldest age category had less overuse than the youngest age group in 2 studies.
	Race	••••••••••	Results vary by data source. ↑ Nonwhite or black race positively associated with overuse in 5 studies of Medicare beneficiaries. ↓ Black race was associated with less overuse in 1 study in the VA
	Comorbid illness	••••••••••	↑ More comorbidities positively associated with overuse.
	Treatment intensity	•••••	↑ Plans for less intensive treatment or active surveillance associated with less overuse.
	Clinical stage	•••••	↑ Higher clinical stage positively associated with overuse.
	PSA level	•••••	↑ Higher PSA level positively associated with overuse.
	Gleason score	•••	↑ Gleason score greater than or equal to 7 positively associated with overuse.
	Nonspecific back pain	•	↑ Nonspecific back pain positively associated with overuse.
Clinician Factors (1 study)	Previous use of non-recommended services	•	↑ Physician utilization of a non-recommended service positively associated with overuse in subsequent patients.
	Ownership of a CT scanner	•	↑ Ownership of a CT scanner positively associated with overuse.
Factors (Number of Studies)	Determinant	Studies Reporting Significance / Studies Evaluating the Association	Significant associations with overuse of imaging
System or Environmental Factors (12 studies)	Neighborhood income	••••••••••	Results vary by data source. ↑ Living in a higher income census tract positively associated with overuse in 4 studies of Medicare beneficiaries. ↓ Living in a higher income census tract was associated with less overuse in 2 integrated health care systems.
	Neighborhood education	••••••••••	Results vary by data source. ↑ Living in a less educated census tract positively associated with overuse in 5 studies of Medicare beneficiaries. — 2 studies of integrated health care systems did not find a significant relationship.
	Geographic region	••••••~••••••	Results vary by data source. ↑ Significant regional differences were identified in 6 studies of Medicare beneficiaries (3 studies identified Northeastern US region). — 3 studies of integrated health care systems did not find a significant relationship.
	Population density	•••••	↑ Non-urban and rural areas positively associated with overuse.

Factors (Number of Studies)	Determinant	Studies Reporting Significance / Studies Evaluating the Association	Significant associations with overuse of imaging
	Insurance type	• •	Overuse of imaging was significantly lower in veterans than in Medicare beneficiaries.
	Center with academic affiliation	•	↑ Academic affiliation was positively associated with overuse in the VA setting.
	Other measures of utilization or resource supply	• • •	↑ Appropriate imaging in high-risk prostate cancer, inappropriate imaging in low-risk breast cancer, low overall hospital volume (Makarov), and hospital beds per 1000 regional residents were all positively associated with overuse of imaging.