Published in final edited form as:

J Med Screen. 2014 December ; 21(4): 207–215. doi:10.1177/0969141314548055.

Geographic Variation in Radiologist Capacity and Widespread Implementation of Lung Cancer CT Screening

Fabrice Smieliauskas, PhD¹, Heber MacMahon, MB, BCh², Ravi Salgia, MD, PhD³, and Ya-Chen Tina Shih, PhD⁴

¹ Department of Health Studies, Program in the Economics of Cancer, University of Chicago, Chicago IL

² Section of Thoracic Radiology, Department of Radiology, University of Chicago, Chicago IL

³ Section of Hematology/Oncology, Department of Medicine, University of Chicago, Chicago IL

⁴ Section of Hospital Medicine, Department of Medicine, Program in the Economics of Cancer, University of Chicago, Chicago IL

Abstract

Background—Newly released United States Preventive Services Task Force (USPSTF) recommendations for lung cancer screening are expected to increase demand for low-dose computed tomography scanning, but health system capacity constraints might threaten the scale-up of screening.

Objectives—To estimate the prevalence of capacity constraints in the radiologist workforce and resulting potential disparities in access to lung cancer screening.

Methods—We combined information from health interview surveys to estimate the numbers of smokers who meet the USPSTF eligibility criteria, and information from administrative datasets to estimate the numbers of radiologists and the numbers of scans they currently interpret in Health Service Areas (HSAs) nationwide. We estimated and mapped the prevalence of capacity constrained HSAs – those having a greater than 5% or greater than 25% projected increase in scans over current levels from scaling up screening – and used descriptive statistics and logistic regressions to identify HSA characteristics associated with capacity constraints.

Results—Scaling up lung cancer screening would increase imaging procedures by an average of 4% across HSAs. Of the 9.6 million eligible smokers, 1,023,943 lived in HSAs with increases of at least 5%. HSAs that were rural, with many eligible smokers, and disproportionately Hispanic or low-income, smokers had significantly higher odds of facing capacity constraints.

Conclusions—Disparities in access to lung cancer screening appear likely unless policy makers target HSAs with few radiologists for additional resources. Radiologists should be able to absorb the workload imposed by lung cancer screening in most areas of the country.

Corresponding Author: Fabrice Smieliauskas, Ph.D., Assistant Professor, Department of Medicine, The University of Chicago. Mailing address: 5841 S Maryland Avenue, MC 2007, Room W249, Chicago IL 60637. TEL: (773) 834-2215. FAX: (773) 702-1979. fsmiel@uchicago.edu.

Financial disclosures: Dr. Shih reports serving on the International Advisory Board on Breast MRI for Bayer Pharma AG. No other potential conflicts of interest relevant to this article were reported.

Keywords

lung cancer; cancer screening; CT scan; health care capacity; radiologists

INTRODUCTION

Thousands of avoidable cancer deaths occur every year in the United States because evidence-based interventions become “lost in translation” between scientific discovery and clinical practice. For example, colorectal cancer screening can reduce colorectal cancer mortality by roughly 16%¹, but only 56% of adults aged 50 and over reported receiving guideline-concordant colorectal cancer screening in 2008, with racial and socioeconomic (SES) disparities in screening that have stubbornly persisted over time.^{2,3}

Lung cancer is the leading cause of cancer deaths in the United States, accounting for approximately 228,190 new cases and 159,480 deaths in 2013.⁴ For decades, prevention efforts have focused on tobacco use and control, owing to the lack of evidence on effective screening modalities for lung cancer. The Prostate, Lung, Colorectal, and Ovarian trial⁵ found no reduction in lung cancer mortality from screening with chest X-rays compared with usual care. However, based largely on the findings of a 20% relative reduction in lung cancer mortality following low-dose computed tomography (CT) screening for adults aged 55-74 with a history of heavy smoking in the National Lung Screening Trial⁶, several organizations now recommend low-dose CT screening.⁷⁻⁹ The United States Preventive Services Task Force (USPSTF) released a Grade B Recommendation for lung cancer screening in December 2013.⁷ Although early uptake has been slow¹⁰, under provisions of the Patient Protection and Affordable Care Act (ACA) of 2010, Medicare, and most Medicaid and private insurance plans must now provide coverage for USPSTF Grade A and B recommended services as early as 2015¹¹, in many cases with no patient cost-sharing. These provisions, and historical precedent regarding other USPSTF-recommended services, suggest that utilization of lung cancer screening may soon scale up nationwide.

Little attention has focused on how health system capacity constraints might impede access to lung cancer screening. High smoking rates imply that 19.2% of Americans aged 55-74 (just over 11 million people) would be eligible for annual CT scans per NLST eligibility criteria.^{12,13} This number would grow under the USPSTF guidelines, which expand the eligible age range by six years to 55-80 on the basis of detailed modeling of the benefits and harms of screening when varying a range of programme parameters.¹³ While concerns have been expressed about the ability of the health system to scale up screening effectively¹⁴, no studies have addressed this issue systematically by estimating the prevalence of capacity constraints, geographic variations in screening capacity, and potential disparities in access to screening. In primary care, the maldistribution of primary care providers (PCPs) has led to access problems in areas with more low-income and minority populations.¹⁵ Huang et al¹⁶ estimated that insurance expansions under the ACA may lead to 7-44 million Americans living in areas with 5-10% increases in demand above current supply, and potential unmet need for primary care services.

In this study, we combined information from several national data sources to estimate total numbers of heavy smokers by geographic area, and capacity in the radiological workforce. We then estimated the proportion of USPSTF-eligible smokers living in areas where the scarcity of radiologists may threaten the implementation of lung cancer screening, and identified potential disparities in access to lung cancer screening that may emerge across demographic, socioeconomic, and rural/urban lines due to geographic variations in radiologist capacity.

METHODS

Data sources and construction of estimates for smoker counts, demographic, and socioeconomic status (SES) variables

We combined publicly accessible online data from the Behavioral Risk Factor Surveillance System survey (BRFSS) and the National Health Interview Survey (NHIS) to estimate the numbers of smokers who meet the USPSTF eligibility criteria. Data on county-level numbers of current daily, current occasional, and former smokers aged 55-80, as well as demographic and SES characteristics of smokers from the 2011 BRFSS, were obtained.

The 2010 NHIS, which collected more detailed data on smoker habits and history, was used to estimate how many of the smokers are eligible under the draft USPSTF recommendation. In each of the four Census regions, we estimated the proportions of current daily, current occasional, and former smokers, that met the USPSTF eligibility criteria in the recommended age range, including a 30 pack-year smoking history (for current and former smokers) and having quit less than 15 years ago (for former smokers), plus one NLST eligibility criterion: no history of lung cancer.⁶

County-level BRFSS data was aggregated to the level of Health Service Areas (HSAs) using publicly available crosswalks.¹⁷ There are 805 HSAs. For counties not surveyed in the BRFSS, representing 16.3% of the population across 329 HSAs, we imputed the proportion of smokers and composition of smoker demographics and SES using the HSA average. For an additional 70 HSAs not surveyed, we imputed the proportion of smokers and smoker characteristics using the state average.

We then estimated the proportion of the smokers estimated through the BRFSS who fully meet the eligibility criteria under the draft USPSTF lung cancer screening recommendation in each HSA from the NHIS, assuming that the eligibility proportions are the same for all HSAs within a Census Region, the lowest level geographic detail available in the public use NHIS.

Data sources and construction of estimates for numbers of radiologists and current scans

Online data from the 2012-13 Area Health Resource File (AHRF) and the 2010 Medicare Part B Carrier Summary Data File ('Carrier File') were combined to estimate the numbers of radiologists and the numbers of scans they currently interpret.

We then extracted the number of radiologists and population from the AHRF for every county, and aggregated to the HSA level. We included diagnostic, interventional and 'other'

radiologists in our count, but excluded radiation oncologists. The Carrier File provided the current number of Medicare Fee-For-Service scans, and for each state we counted the sum of all imaging procedures *primarily* performed by diagnostic radiologists, including diagnostic imaging procedures (radiographs, ultrasound, CT, MRI, etc), but excluding imaging guidance of interventional procedures, nuclear medicine, and radiation oncology procedures.

To convert the Medicare scan numbers in each state to the current workload of all-payer scans by radiologists in each HSA, we first multiplied the state Medicare scan count by the proportion of a state's radiologists in each HSA (calculated from the AHRF) to obtain estimates of the number of Medicare scans in each HSA. Next, we estimated all-payer scans from Medicare scans with ratios calculated using survey-based estimates of the number of scans by all payers nationwide from *IMV Medical Information* (2010, 2011).^{18,19} *IMV Medical Information* only reports all-payer CT and MRI scans nationwide, not total scans of all modalities. We therefore assumed that the ratio of all-payer to Medicare total scans was equal to the ratio of all-payer to Medicare CT and MRI scans, following an approach similar to that in National Council on Radiation Protection (2009).²⁰

Construction of estimates of capacity constraints

Having estimated the number of current scans, we measured the degree to which *capacity* in the radiologist workforce in HSAs is *constrained* by the projected increase in scans. To estimate the potential need for scans by smokers meeting USPSTF eligibility criteria, we assumed that screening uptake rates would increase from the current 11.8% for former smokers and 7.6% for former smokers meeting NLST criteria²¹, to 75% for all smokers meeting NLST criteria. This is in the range of current breast and colorectal cancer screening rates.^{3,22} We assumed each smoker undergoing screening would receive an average of 1.13 scans per year (including initial and follow-up scans), as occurred in the NLST trial.⁶ We estimated the percentage increase in scans over current levels, and defined capacity constrained HSAs as those with a greater than 5% and (alternatively) greater than 25% projected increase in scans.

We explored the sensitivity of our estimates to varying the uptake rate from 50%-100%, and independently, to changing the proportion of smokers aged 55-80 meeting USPSTF eligibility by +/- 50%.

Statistical analysis

We tabulated HSA-level percentage increases in scans needed to meet demand for lung cancer screening driven by the USPSTF recommendations, and estimated the proportions of HSAs with capacity constraints. We also calculated the number of USPSTF-eligible smokers living in these HSAs. We used Geographic Information Systems (GIS) software to produce a coloured choropleth map to depict the geographic variation in the projected scan increases across HSAs, using three categories for the magnitude of increases: under 5%, 5-25%, and greater than 25%. All subsequent analyses used the assumptions of 75% uptake and NLST eligibility rates.

To study disparities in access to screening due to capacity constraints, we obtained descriptive statistics of the HSA-level numbers of radiologists, imaging procedures, populations, USPSTF-eligible smokers, and the composition of demographic and SES characteristics of smokers aged 55-80 in the HSAs, and used one-way ANOVA to test the differences in means of these variables across capacity categories. Three logistic regression models were used to determine which HSA characteristics were associated with being a capacity-constrained HSA: using the 5% threshold, the 25% threshold, and a 3-level ordinal outcome (<5%, 5-25%, > 25%). Stata 13 was used to perform statistical analyses, and the “robust” option was applied to ensure that all standard errors were robust to heteroskedasticity. All statistical tests were two-sided.

The University of Chicago Institutional Review Board exempted this study for approval, because all data were aggregated to HSA level.

RESULTS

Our results suggest that scaling up lung cancer screening was projected to lead to an average 4.0% (standard deviation 4.2%) increase in imaging procedures from their respective current levels across HSAs (Table 1). Of the 805 HSAs, 127 (16%) had no radiologists, so their percentage increase was undefined due to zero current scans. These HSAs were classified in the highest-threshold capacity constraint category (ie. >25% increase).

Figure 1 shows the number of smokers and the proportion of HSAs affected by capacity constraints. Of the 9.6 million eligible smokers, 1,023,943 (over 10%) lived in HSAs with a projected increase in scans of at least 5%. Overall, 36% of HSAs fell into this category. There were 136,877 (1.4%) eligible smokers who lived in areas with a greater than 25% increase in scans, with 16% of all HSAs falling into this category. Table 1 and Figure 1 also display the sensitivity of these results to varying assumptions regarding the degree of uptake and eligibility criteria for a screening programme.

Figure 2 shows the nationwide geographic distribution of the implications of widespread implementation of lung cancer screening. While the majority of HSAs did not have high projected increases in scans, those that did were disproportionately in the Midwest – particularly the Great Plains states, which had most of the highest percentage increase areas.

We further explored both supply of radiologists and HSA characteristics by categories of capacity constraints (Table 2). Radiologists were nearly non-existent in HSAs with the largest projected increases in scans (>25%) (mean of 0.0155 radiologists), and much more numerous in non-capacity constrained HSAs (mean of 65.41; differences significant $p<0.0001$). There was also a two order of magnitude difference in the mean population between the most and the least capacity constrained HSAs (means of 27,626 v 549,374; $p<0.0001$).

Logistic regression (Table 3) allowed us to explore these predictors of capacity constraints. Population size, modelled as the logarithm of population in 100,000s, was significant and highly influential in the three regressions (Odds ratio [OR] 0.055-0.265; all $p<0.001$). HSAs in the Northeast, Midwest, and South had significantly higher odds of encountering capacity

constraints than HSAs in the West across the three models (OR 1.759-9.258 for the nine coefficients, all significant at the $p=0.05$ level, except Northeast in model (2)). This pattern was consistent with that observed in Figure 2. The proportion of the population made up of smokers aged 55-80 was a significant predictor of high scan increases in two out of three regressions (OR 1.141; $p<0.001$ in logistic $>5\%$ increase, and OR 1.079; $p<0.001$ in ordinal logistic 5%/25%).

HSAs with a higher proportion of smokers who were Hispanic significantly predicted capacity constraints defined as a $>5\%$ scan increase (OR 1.028; $p=0.005$) and in the ordinal logistic 5%/25% regression (OR 1.026; $p=0.009$). Low income among smoker households was a consistent predictor of capacity constraints across the three regressions, both at significant and marginally significant levels (OR 1.017, $p=0.054$; OR 1.032, $p=0.009$; OR 1.017, $p=0.030$). Weaker evidence suggested areas with higher proportions of Native American and low educational attainment smokers were more and less likely, respectively, to face capacity constraints.

DISCUSSION

The 2013 USPSTF recommendation is expected to dramatically change lung cancer screening, leading to an unprecedented increase in demand for low-dose CT scanning. Our study explores whether geographic variation in capacity in the radiologist workforce could lead to access barriers and disparities. We found that over 1 million ($>10\%$) of the 9.6 million smokers who met the eligibility criteria of the USPSTF recommendation resided in HSAs that would require a greater than 5% increase from the current volume of imaging procedures to scale up screening in response to the recommendation. Overall, this capacity constraint would be found in 36% of all HSAs. Using a more stringent definition of capacity constraints ($>25\%$ increase in imaging volumes) reduced the above estimates to 136,877 eligible smokers and 16% of HSAs. In addition, we found that the population size of an HSA (a proxy for the degree of rurality of the area) is by far the strongest predictor of capacity constraints, as this problem is concentrated in low population HSAs, with 127 HSAs lacking even a single radiologist. HSAs with higher percentages of smokers aged 55-80, and with higher proportions of Hispanics and low-income households among smokers aged 55-80, are consistently more likely to face capacity constraints, while HSAs in the West are less likely.

We chose 5% and 25% increases in scans as measures of radiologist capacity constraints. Proprietary surveys of radiologists have used measures such as desired workload change²³, vacancies, and placement rates²⁴ to measure tightness of radiology workforce capacity. However, we followed an approach similar to Huang et al¹⁶, calculating a percentage change measure based on estimates of the current radiologist workforce, radiologists' estimated workloads, and their anticipated workload increases following the USPSTF recommendations. All were calculated at the local health care market level using publicly available, nationally representative datasets. Radiologists' estimated current workloads included all scans they interpret, not just the CT scans performed in lung cancer screening. We employed a broad range of alternative percentage thresholds (5%-25%) to acknowledge

the lack of standards for measuring radiologist capacity and the flexibility in the radiologist workforce further described below.

Concerns have been raised over whether the health system can effectively scale up lung cancer screening, and there are projections of likely future shortages in the oncologist workforce.^{14,25} However, with a surplus of radiologists being reported as early as 2007²³ and continuing to increase through 2011²⁶, the radiologist workforce is probably not operating at full capacity. Additionally, the potential use of volumetric CT screening would result in fewer false positive screens than in the NLST trial, reducing the number of follow-up scans required.²⁷ Our results, which show that the average percentage increase in imaging is 4.0% (Table 1) in HSAs with current scans, suggest that radiologists will be able to absorb the workload imposed by the incremental scans from lung cancer screening in most areas of the country.

The projected disparities in access to lung cancer screening for rural, Hispanic, and low income smokers are cause for concern. Capacity constraints, distance, and lack of transportation are important barriers to many types of cancer screening in rural areas.²⁸ Hispanics are also less likely than Whites and Blacks to be screened for breast, cervical, and colorectal cancer.²⁹ In rural areas, with generally lower SES and education levels, and in some cases worse racial/ethnic segregation, demographic and SES disparities in access to cancer screening are common.²⁸

Our analysis identifies potential racial/ethnic and SES disparities resulting from inter-regional geographic disparities in radiologist capacity, where smokers in HSAs differ in their demographic and SES composition. Disparities across smokers within HSAs are also likely to emerge during scale-up, and should be explored in future research.

Teleradiology might mitigate access disparities, by allowing CT scans to be performed locally and delivered electronically for remote interpretation, but possibly insurmountable obstacles exist. None of the available lung cancer screening guidelines address the role of teleradiology, or provide any roadmap for its use. In fact, despite the technological viability of using telemammography and centralized interpretation to improve access to breast cancer screening in underserved communities³⁰, and advocacy for doing so³¹, the decentralized nature of the United States healthcare system has prevented this from becoming a common solution. Until lung cancer screening protocols are standardized^{32,33}, continuous communication and coordination between patients, PCPs, radiologists, and lung cancer specialists will be necessary to ensure quality control.³⁴ In addition, teleradiology companies frequently provide little more than arms-length scan interpretation³⁵, and PCPs who might step in to coordinate screening activities are not likely to be co-located with radiologists.

Policy makers intending to mitigate potential disparities identified in this study could target those HSAs with few or no radiologists. Subsidizing transportation for eligible smokers to HSAs with screening programmes, and financial incentives for radiologists to practice in underserved areas could also be considered.

A limitation of our study is its focus on the availability of radiologists, when other dimensions of health system capacity may also place important constraints on implementation of quality lung cancer screening. These constraints include availability of comprehensive screening facilities, CT imaging devices, and thoracic oncologists and surgeons. It should be noted that mammography device capacity constraints still constitute access barriers for breast cancer screening in some areas of the country.^{36–38} We plan to undertake future research to assess the impact of these other dimensions of capacity on the scale-up of lung cancer screening.

Acknowledgements

Funding: Dr. Shih is supported by grants from the Agency for Healthcare Research and Quality (R01 HS018535) and The University of Chicago Cancer Research Foundation Women's Board. Drs. Smieliauskas, Shih, and Salgia are supported by the National Cancer Institute (R03 CA184986).

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Figure 1.

Proportion of HSAs with projected radiologist capacity constraints. >5% and >25% estimated increases in scans are alternative definitions of HSAs projected to have capacity constraints. '-/+50% Eligible' - 50% lower or higher number of eligible smokers.

Figure 2. Geographic distribution of HSAs with projected radiologist capacity constraints. >5% and >25% estimated increases in scans are alternative definitions of HSAs projected to have capacity constraints.

Table 1

Percentage Increases in Imaging Procedures per Year from Scaling-Up Lung Cancer Screening, including Sensitivity Analyses for Uptake and Eligibility Rates, by HSA

	Mean (%)	SD (%)	Min (%)	Max (%)
Base case	4.0	4.2	0.0	61.4
Uptake 50%	2.4	2.6	0.0	38.3
Uptake 100%	5.5	5.7	0.0	84.5
50% lower number of eligible smokers	2.0	2.1	0.0	30.7
50% higher number of eligible smokers	5.9	6.2	0.0	92.1

Notes: Abbreviations: HSA - Health Service Area. SD - Standard Deviation. Min - Minimum. Max - Maximum. Number of observations is 678 HSAs for all statistics, and does not include 127 HSAs without scans prior to scale-up, for which the percentage increase is undefined.

Table 2**HSA Descriptive Statistics, by Projected Capacity Constraints**

	Total	>25% increase	5-25% increase	<5% increase	Significant Difference
SUPPLY VARIABLES					
Radiologists	42.86 (119.3)	0.0155 (0.124)	4.669 (5.309)	65.41 (144.2)	***
Current scans	567023.1 (1504946.1)	240.8 (1930.8)	58856.3 (56310.1)	866289.8 (1812295.7)	***
Current scans per radiologist per day	56.51 (12.59)	62.13 (5.847)	54.23 (12.74)	57.20 (12.49)	**
SMOKERS					
Total USPSTF-eligible smokers	11864.4 (21854.8)	1061.1 (1306.3)	5544.2 (4332.1)	16525.0 (26000.7)	***
Smokers aged 55-80 (as % of population)	17.02 (4.491)	16.92 (4.985)	19.51 (5.297)	16.28 (3.762)	***
% Current Daily Smokers	3.715 (2.158)	3.775 (3.085)	4.756 (2.675)	3.378 (1.499)	***
% Current Occasional Smokers	1.230 (1.004)	1.142 (1.080)	1.371 (1.223)	1.208 (0.901)	
% Former Smokers	12.08 (3.617)	12.00 (4.365)	13.39 (4.327)	11.69 (3.037)	***
HSA CHARACTERISTICS					
Population	383534.8 (840675.6)	27625.8 (22514.3)	135656.1 (109464.5)	549373.7 (1010510.1)	***
Northeast	0.0894 (0.286)	0.00775 (0.0880)	0.131 (0.339)	0.0969 (0.296)	***
Midwest	0.337 (0.473)	0.512 (0.502)	0.394 (0.490)	0.275 (0.447)	***
South	0.409 (0.492)	0.357 (0.481)	0.362 (0.482)	0.436 (0.496)	
West	0.165 (0.372)	0.124 (0.331)	0.113 (0.317)	0.192 (0.394)	**
SOCIOECONOMIC/DEMOGRAPHIC COMPOSITION					
White (as % of smokers aged 55-80)	84.56 (15.05)	85.13 (17.33)	86.68 (14.99)	83.75 (14.40)	*
% Black	7.010 (11.03)	6.550 (14.17)	5.678 (10.46)	7.539 (10.26)	
% Hispanic	4.633 (9.921)	4.509 (10.82)	3.997 (9.244)	4.862 (9.901)	
% Asian	0.592 (2.792)	0.210 (0.514)	0.116 (0.617)	0.836 (3.440)	***
% Native American	1.484 (3.784)	1.784 (5.562)	1.947 (5.441)	1.266 (2.317)	*
% Female	44.26 (11.24)	43.52 (15.20)	43.95 (12.45)	44.54 (9.577)	
% Uninsured	9.231 (7.670)	9.058 (11.26)	9.551 (8.835)	9.174 (6.013)	

	Total	>25% increase	5-25% increase	<5% increase	Significant Difference
% Unemployed	12.56 (11.55)	11.59 (13.25)	11.88 (13.48)	13.02 (10.39)	
% Less than High School Education	17.65 (11.34)	14.98 (12.20)	20.62 (13.73)	17.40 (10.04)	***
% Household Income less than \$25,000	36.59 (13.56)	37.81 (16.87)	39.86 (13.58)	35.27 (12.41)	***
Observations	805	129	160	516	

mean coefficients; standard deviation in parentheses

*
p<0.10,

**
p<0.05,

p<0.01. Columns provide means and standard deviations for all HSAs combined, HSAs with greater than 25% increase in scans, HSAs with 5-25% increase in scans, and HSAs with under 5% increase in scans. Greater than 5% increase and greater than 25% increase in scans are alternative definitions of capacity constraints.

Table 3

Categorical Variable Regressions: HSA-level Odds of Projected Capacity Constraints

	(1) Logistic >5%	(2) Logistic >25%	(3) Ordinal Logistic 5% and 25%
HSA CHARACTERISTICS			
Log(Population/100,000)	0.265*** [0.217,0.324]	0.055*** [0.032,0.093]	0.190*** [0.154,0.234]
Census Region (reference group = West)			
Northeast	9.258*** [3.985,21.508]	1.759 [0.219,14.164]	7.850*** [3.624,17.002]
Midwest	4.771*** [2.483,9.169]	5.271*** [1.758,15.808]	4.660*** [2.437,8.912]
South	2.203*** [1.139,4.260]	8.583*** [2.575,28.606]	2.644*** [1.384,5.052]
Smokers aged 55-80 (as % of population)	1.141*** [1.086,1.199]	1.013 [0.962,1.066]	1.079*** [1.036,1.123]
SOCIOECONOMIC/DEMOGRAPHIC COMPOSITION			
Black (as % of smokers aged 55-80)	1.004 [0.987,1.022]	0.996 [0.975,1.018]	1.005 [0.990,1.021]
% Hispanic	1.028*** [1.008,1.048]	1.025 [0.985,1.067]	1.026*** [1.007,1.046]
% Asian	0.880 [0.724,1.070]	0.875 [0.497,1.543]	0.910 [0.784,1.055]
% Native	1.044 [0.983,1.109]	1.011 [0.922,1.109]	1.036* [0.994,1.080]
% Female	1.008 [0.992,1.026]	1.011 [0.993,1.030]	1.006 [0.991,1.022]
% Uninsured	0.988 [0.960,1.017]	1.001 [0.970,1.033]	0.986 [0.964,1.009]
% Unemployed	1.005 [0.990,1.019]	1.017 [0.994,1.040]	1.009 [0.996,1.021]
% Less than High School Education	1.004 [0.985,1.024]	0.964** [0.937,0.992]	0.995 [0.978,1.012]
% Household Income less than \$25,000	1.017* [1.000,1.034]	1.032*** [1.008,1.057]	1.017** [1.002,1.032]
<i>N</i>	804	804	804
pseudo <i>R</i> ²	0.351	0.606	0.337
Log Likelihood	-340.835	-139.674	-480.111
Hosmer-Lemeshow	0.204	0.942	

Results presented as odds ratios; 95% confidence intervals in brackets.

Notes: First/second column displays results of logistic regression predicting odds of HSA having a greater than 5%/25% projected increase in scans, respectively. Third column displays results of ordinal logistic regression predicting odds of a higher projected increase in scans relative to a lower projected increase in scans, using 25% and 5% as thresholds. 'Hosmer-Lemeshow' presents p-value on Hosmer-Lemeshow statistic of model fit -- it is estimated for logistic regressions but is not defined for ordinal logistic regression.

*
p<0.10,

**
p<0.05,

p<0.01.

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