Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

Supplemental Materials

Appendix 1: Choosing Wisely Recommendations; Low-value back pain and headache imaging claims algorithms

Appendix 2 and eTable 1: Sensitivity analyses, low-value headache predictors among clinicians who also saw back pain visits

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Appendix 1: Choosing Wisely Recommendations; Low-value back pain and headache imaging claims algorithms

Description	**Rationale**
Don't do imaging for low back pain within the first six weeks, unless red flags are present (American Academy of Family Physicians)	
	Red flags include, but are not limited to, severe or progressive neurological deficits or when serious underlying conditions such as osteomyelitis are suspected.
Don't obtain imaging studies in patients with non-specific low back pain (American College of Physicians)	Imaging of the lower spine before six weeks does not improve outcomes, but does increase costs. Low back pain is the fifth most common reason for all physician visits.
Don't do imaging for uncomplicated headaches (American College of Radiology)	Imaging headache patients absent specific risk factors for structural disease is not likely to change management or improve outcome. Those patients with a significant likelihood of structural disease requiring immediate attention are detected by clinical screens that have been validated in many settings. Many studies and clinical practice guidelines concur. Also, incidental findings lead to additional medical procedures and expense that do not improve patient well-being.
Description	**Claims Algorithm**
Don't do imaging for low back pain within the first six weeks, unless red flags are present (American Academy of Family Physicians)	Low back pain visit to a clinician for adults 18-64. We excluded patients with back pain visit in the prior 180 days (6 months). We excluded low back pain visits with red-flag diagnoses that would render imaging potentially appropriate, including neurologic deficits, constitutional symptoms, tuberculosis, septicemia, endocarditis, osteomyelitis, and trauma.

Don’t obtain imaging studies in patients with non-specific low back pain (American College of Physicians)	We further excluded visits if those same red-flag diagnoses occurred temporally proximal to low back pain visits (between 180 days prior to the index visit or after the index visit but prior to the date of image) and visits with certain chronic diagnoses, such as personal history of cancer, tuberculosis, or intravenous drug use were recorded between 365 days prior to the index visit.
	Among the remaining non red-flag visits, X-Ray, CT, or MRI of the back were counted as low-value is they occurred within 7 days after the index visit, with no other intervening visits to other providers.
Don’t do imaging for uncomplicated headaches (American College of Radiology)	Headache visits for adults 18-64, excluding those with a headache visit in the prior 90 days (3 months). We excluded headache visits with red-flag diagnoses that would render imaging potentially appropriate, including trauma, epilepsy/convulsions, neurologic deficits, giant cell arteritis.
	We further excluded visits if those red-flag diagnoses occurred proximal to the headache visit (between 90 days prior to the index visit or after the index visit but prior to the date of the image) and visits with certain chronic diagnoses, such as a personal history of cancer.
	Among the remaining non red-flag visits, CT or MRI of the head were counted as low-value if they occurred within 7 days after the index visit, with no other intervening visits to other providers.

Appendix 2, eTable 1: Sensitivity analyses, low-value headache predictors among clinicians who also saw back pain visits

Covariates	Defined High Back Imaging Rate Clinician at 95th Percentile	Removed High Back Imaging Clinician Predictor	Defined High Back Imaging Rate Clinician at 90th Percentile
Female patient	0.80 [0.78, 0.82]	0.80 [0.78, 0.82]	0.79 [0.77, 0.81]
Age distribution			
18-25 = ref			
26-35	1.04 [0.99, 1.09]	1.04 [0.99, 1.09]	1.04 [0.99, 1.09]
36-45	1.07 [1.03, 1.12]	1.07 [1.03, 1.12]	1.08 [1.04, 1.13]
46-55	1.12 [1.07, 1.16]	1.11 [1.07, 1.16]	1.13 [1.08, 1.18]
56-64	1.26 [1.21, 1.32]	1.26 [1.21, 1.32]	1.30 [1.24, 1.36]
Low Neighborhood Education Level[a]	0.98 [0.94, 1.01]	0.98 [0.94, 1.01]	0.98 [0.94, 1.01]
High Neighborhood Poverty Level[b]	0.93 [0.91, 0.96]	0.93 [0.91, 0.96]	0.94 [0.91, 0.96]
Quarter, continuous	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]
Race			
White = ref			
Black	0.87 [0.83, 0.90]	0.87 [0.83, 0.90]	0.86 [0.83, 0.90]
Hispanic	0.88 [0.85, 0.91]	0.88 [0.85, 0.91]	0.86 [0.83, 0.89]
Other	0.86 [0.82, 0.89]	0.85 [0.82, 0.89]	0.84 [0.80, 0.88]
US Region			
South = ref			
Northeast	0.94 [0.89, 0.99]	0.94 [0.90, 0.99]	0.94 [0.90, 0.99]
West	0.81 [0.78, 0.83]	0.80 [0.77, 0.83]	0.82 [0.79, 0.85]
Midwest	1.19 [1.16, 1.22]	1.18 [1.15, 1.21]	1.24 [1.21, 1.28]
Patient Out-of-pocket expenditure[c] for visit			
$0	1.03 [0.99, 1.08]	1.04 [1.00, 1.08]	0.95 [0.90, 0.99]
>$0, ≤ 25 = ref			

>$25, ≤ 35	0.98 [0.95, 1.01]	0.98 [0.95, 1.01]	0.82 [0.79, 0.85]
> $35	0.99 [0.96, 1.02]	0.99 [0.96, 1.02]	1.24 [1.21, 1.28]
Clinician's prior patient received imaging	1.80 [1.74, 1.86]	1.82 [1.76, 1.88]	1.66 [1.60, 1.72]
Ownership of imaging equipment			
Non-owner = ref			
Owner (billed for technical component)	1.65 [1.59, 1.72]	1.71 [1.65, 1.78]	1.41 [1.35, 1.47]
High rate of low-value back imaging	1.53 [1.45, 1.61]	N/A	1.39 [1.34, 1.45]

a Low neighborhood education: Census block groups with >25% below- high school education levels.
b High neighborhood poverty: Census block groups with ≥10% below-poverty levels.
c Out-of-pocket is the sum of deductible, co-pay, and co-insurance.

Appendix 3: Sensitivity analysis, accounting for the expected patient Out-Of-Pocket (OOP) expenditure for imaging

In our analysis, we also attempted to control for patient financial incentives to demand imaging, particularly those with no cost sharing for additional testing, and adjust for its impact on clinician image ordering behavior.

Our dataset did not have comprehensive benefit details for all members that could reveal the exact expected patient cost sharing for imaging. As a result, we calculated total patient out-of-pocket (OOP) expenditures for the clinician visit, expecting that patients' OOP obligations for the visit would be proportional to their obligations for imaging. We categorized non-zero visit OOP expenditures into tertiles, resulting in categories of $0, ≥$0 to $24.99, between $25 and $34.99, and ≥$35.

Stratifying by visit OOP expenditure allowed us to capture the varying financial incentives faced by patients in a heterogeneous set of plan structures. For instance, traditional plans charge $25 co-pays for visits with little cost sharing for subsequent imaging, while less generous plans charge higher co-pays and coinsurance. Other plans, notably high-deductible health plans where members are responsible for at least the first $1,000 of their care annually, generate the full charge for acute clinician visits as well as subsequent imaging. Finally, members with zero OOP expenditure for their visit either were in very generous plans with no cost sharing for visit or imaging, or were enrolled in high-deductible plans and had surpassed their deductible.

When we compared our expected OOP expenditure to the actual OOP expenditure for patients who ultimately received imaging, 92.8%, or 10,814 of 11,653 obtained images predicted to have zero OOP expenditure actually had zero OOP expenditure.

We added this expected OOP expenditure for imaging into our main models and found it made nearly imperceptible changes to our results. See the table for a complete comparison of the results.

eTable 2: Sensitivity analyses, adding expected patient Out-Of-Pocket expenditure for imaging to the model

	Back Pain Visits Seen by Primary Care Physicians		**Back Pain Visits Seen by Chiropractors**		**Back Pain Visits Seen by Specialist Physicians[d]**	
Covariates	**Without OOP covariate**	**With OOP covariate**	**Without OOP covariate**	**With OOP covariate**	**Without OOP covariate**	**With OOP covariate**
Female patient	1.02 [1.00, 1.04]	1.02 [1.00, 1.04]	0.83 [0.81, 0.84]	0.83 [0.81, 0.84]	0.82 [0.80, 0.85]	0.82 [0.80, 0.85]

Age distribution						
18-25 = ref						
26-35	0.89 [0.86, 0.93]	0.89 [0.86, 0.93]	1.01 [0.98, 1.05]	1.02 [0.98, 1.05]	0.88 [0.82, 0.95]	0.88 [0.83, 0.95]
36-45	0.87 [0.84, 0.90]	0.87 [0.84, 0.90]	0.88 [0.85, 0.91]	0.89 [0.86, 0.93]	0.88 [0.82, 0.94]	0.88 [0.82, 0.94]
46-55	0.88 [0.85, 0.91]	0.88 [0.85, 0.91]	0.81 [0.79, 0.83]	0.82 [0.79, 0.85]	0.82 [0.76, 0.87]	0.81 [0.76, 0.87]
56-64	0.93 [0.90, 0.97]	0.93 [0.90, 0.97]	0.76 [0.74, 0.79]	0.78 [0.75, 0.81]	0.77 [0.72, 0.83]	0.77 [0.72 0.82]
Low Neighborhood Education Level[a]	0.99 [0.97, 1.01]	0.99 [0.97, 1.01]	1.09 [1.06, 1.13]	1.10 [1.07, 1.14]	0.90 [0.86, 0.94]	0.90 [0.85, 0.94]
High Neighborhood Poverty Level[b]	1.00 [0.98, 1.02]	1.00 [0.98, 1.02]	1.01 [0.98, 1.03]	1.01 [0.98, 1.03]	0.95 [0.91, 0.99]	0.95 [0.91, 0.99]
Quarter, continuous	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]
Race						
White = ref						
Black	1.00 [0.97, 1.03]	1.00 [0.97, 1.03]	1.25 [1.20, 1.30]	1.24 [1.19, 1.28]	1.02 [0.97, 1.07]	1.02 [0.97, 1.08]
Hispanic	1.18 [1.14, 1.21]	1.18 [1.15, 1.21]	1.30 [1.25, 1.34]	1.28 [1.24, 1.33]	1.12 [1.06, 1.19]	1.13 [1.07, 1.19]
Other	1.04 [1.00, 1.07]	1.04 [1.00, 1.07]	1.14 [1.10, 1.18]	1.13 [1.09, 1.17]	1.04 [0.98, 1.10]	1.04 [0.99, 1.11]
US Region						
South = ref						
Northeast	0.98 [0.94, 1.01]	0.98 [0.94, 1.01]	0.99 [0.95, 1.03]	0.94 [0.91, 0.98]	1.09 [1.03, 1.15]	1.12 [1.06, 1.18]
West	0.89 [0.87, 0.91]	0.89 [0.86, 0.91]	0.64 [0.63, 0.66]	0.64 [0.62, 0.65]	0.80 [0.76, 0.84]	0.80 [0.76, 0.84]
Midwest	0.96 [0.94, 0.98]	0.95 [0.93, 0.97]	0.71 [0.70, 0.73]	0.69 [0.68, 0.71]	0.84 [0.80, 0.87]	0.84 [0.81, 0.88]

a Low neighborhood education: Census block groups with >25% below- high school education levels.						
b High neighborhood poverty: Census block groups with ≥10% below-poverty levels.						
c Out-of-pocket is the sum of deductible, co-pay, and co-insurance.						
d The most common specialties (accounting for 2/3 of all specialist visits) were orthopedic surgery, neurosurgery, back and spine surgery, physical medicine, rheumatology						
	Back Pain Visits Seen by Primary Care Physicians		**Back Pain Visits Seen by Chiropractors**		**Back Pain Visits Seen by Specialist Physicians[d]**	
Covariates	**Without OOP covariate**	**With OOP covariate**	**Without OOP covariate**	**With OOP covariate**	**Without OOP covariate**	**With OOP covariate**
Patient Out-of-pocket expenditure[c] for visit						
$0		1.06 [1.03, 1.10]		1.59 [1.52, 1.66]		1.08 [1.01, 1.16]
>$0, ≤ 25 = ref						
>$25, ≤ 35		0.97 [0.95, 0.99]		0.80 [0.78, 0.82]		1.09 [1.03, 1.14]
> $35		1.09 [1.07, 1.11]		2.10 [2.05, 2.14]		1.23 [1.19, 1.28]
Clinician's prior patient received imaging	1.81 [1.77, 1.85]	1.81 [1.77, 1.85]	2.82 [2.76, 2.88]	2.80 [2.74, 2.86]	2.98 [2.89, 3.08]	2.98 [2.88, 3.07]
Ownership of imaging equipment						
Non-owner = ref						
Owner (billed for technical component)	2.07 [2.04, 2.11]	2.06 [2.03, 2.10]	7.70 [7.46, 7.96]	7.76 [7.51, 8.01]	4.99 [4.81, 5.18]	4.96 [4.78, 5.15]
High rate of low-value back imaging	N/A	N/A	N/A	N/A	N/A	N/A
a Low neighborhood education: Census block groups with >25% below- high school education						

levels.					
b High neighborhood poverty: Census block groups with ≥10% below-poverty levels.					
c Out-of-pocket is the sum of deductible, co-pay, and co-insurance.					
d The most common specialties (accounting for 2/3 of all specialist visits) were orthopedic surgery, neurosurgery, back and spine surgery, physical medicine, rheumatology					

eTable 2 (Continued): Sensitivity analyses, adding expected patient Out-Of-Pocket expenditure for imaging to the model

	Headache Visits Seen by Primary Care Physicians		**Headache Visits Seen by Primary Care Physicians Who Also Saw ≥4 Back Pain visits**	
Covariates	**Without OOP covariate**	**With OOP covariate**	**Without OOP covariate**	**With OOP covariate**
Female patient	0.81 [0.80, 0.83]	0.81 [0.80, 0.83]	0.79 [0.77, 0.81]	0.79 [0.77, 0.81]
Age distribution				
18-25 = ref				
26-35	1.03 [0.99, 1.07]	1.03 [1.00, 1.07]	1.04 [0.99, 1.09]	1.04 [0.99, 1.09]
36-45	1.06 [1.03, 1.10]	1.06 [1.03, 1.10]	1.08 [1.04, 1.13]	1.08 [1.04, 1.13]
46-55	1.08 [1.04, 1.12]	1.08 [1.04, 1.12]	1.13 [1.08, 1.18]	1.13 [1.08, 1.18]
56-64	1.19 [1.15, 1.24]	1.19 [1.14, 1.24]	1.30 [1.24, 1.36]	1.30 [1.24, 1.36]
Low Neighborhood Education Level[a]	0.97 [0.94, 1.00]	0.97 [0.94, 1.00]	0.98 [0.94, 1.01]	0.98 [0.94, 1.01]
High Neighborhood Poverty Level[b]	0.95 [0.93, 0.98]	0.95 [0.93, 0.98]	0.93 [0.91, 0.96]	0.93 [0.91, 0.96]
Quarter, continuous	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]
Race				
White = ref				
Black	0.91 [0.88, 0.93]	0.91 [0.88, 0.94]	0.86 [0.83, 0.90]	0.86 [0.83, 0.99]
Hispanic	0.93 [0.90, 0.96]	0.93 [0.90, 0.96]	0.86 [0.83, 0.89]	0.86 [0.83, 0.89]
Other	0.87 [0.84, 0.90]	0.87 [0.84, 0.90]	0.84 [0.80, 0.88]	0.84 [0.80, 0.88]
US Region				

South = ref				
Northeast	0.96 [0.93, 1.00]	0.96 [0.93, 0.99]	0.95 [0.90, 1.00]	0.94 [0.90, 0.99]
West	0.81 [0.78, 0.83]	0.81 [0.78, 0.83]	0.82 [0.79, 0.85]	0.82 [0.79, 0.85]
Midwest	1.15 [1.13, 1.18]	1.15 [1.12, 1.17]	1.24 [1.20, 1.27]	1.24 [1.21, 1.28]
c Out-of-pocket is the sum of deductible, co-pay, and co-insurance.				
	Headache Visits Seen by Primary Care Physicians		**Headache Visits Seen by Primary Care Physicians Who Also Saw ≥4 Back Pain visits**	
Covariates	**Without OOP covariate**	**With OOP covariate**	**Without OOP covariate**	**With OOP covariate**
Patient Out-of-pocket expenditure[c] for visit				
$0		1.16 [1.12, 1.20]		0.95 [0.91, 1.00]
>$0, ≤ 25 = ref				
>$25, ≤ 35		1.00 [0.97, 1.02]		0.97 [0.94, 1.00]
> $35		0.99 [0.97, 1.02]		0.94 [0.91, 0.97]
Clinician's prior patient received imaging	2.01 [1.95, 2.06]	2.00 [1.95, 2.06]	1.66 [1.60, 1.72]	1.66 [1.60, 1.72]
Ownership of imaging equipment				
Non-owner = ref				
Owner (billed for technical component)	1.88 [1.83, 1.94]	1.88 [1.82, 1.94]	1.40 [1.34, 1.46]	1.41 [1.35, 1.47]
High rate of low-value back imaging	N/A	N/A	1.39 [1.34, 1.45]	1.39 [1.34, 1.45]
c Out-of-pocket is the sum of deductible, co-pay, and co-insurance.				

Appendix 4: Sensitivity analyses, accounting for patients who contribute multiple visits

Although the vast majority of patients contribute only one episode of either acute headache or back pain to our samples, some patients do contribute multiple episodes over the 5-year study span.

We conducted a series of sensitivity analyses here to determine whether this difference in accounting for variation between visits impacted our results.

First, we re-ran analyses including only a patient's first episode in each sample. Second, we then re-ran analyses including a random episode for any patient with more than one episode. Finally, although patient and clinician are not perfectly nested levels, we used mixed-effects modeling using random clinician as the first level and random patient as the second level.

Running analyses on only a patient's first episode or on a random episode for patients with multiple episodes did not meaningfully alter our results.

Results of the analyses are in the following eTable 3.

eTable 3: Accounting for patients who contribute multiple visits

	Back Pain Visits Seen by Primary Care Physicians			**Back Pain Visits Seen by Chiropractors**		
Covariates	**all patient visits**	**1st patient visit only**	**random patient visit[d]**	**all patient visits**	**1st patient visit only**	**random patient visit[d]**
Female patient	1.02 [1.00, 1.04]	1.00 [0.98, 1.02]	1.00 [0.98, 1.02]	0.83 [0.81, 0.84]	0.81 [0.80, 0.83]	0.81 [0.80, 0.83]
Age distribution (18-25 = ref)						
26-35	0.89 [0.86, 0.93]	0.90 [0.87, 0.94]	0.90 [0.87, 0.94]	1.01 [0.98, 1.05]	1.01 [0.97, 1.05]	1.02 [0.98, 1.06]
36-45	0.87 [0.84, 0.90]	0.89 [0.86, 0.92]	0.89 [0.86, 0.92]	0.88 [0.85, 0.91]	0.89[0.86, 0.92]	0.91 [0.88, 0.94]
46-55	0.88 [0.85, 0.91]	0.90 [0.87, 0.94]	0.91 [0.88, 0.94]	0.81 [0.79, 0.83]	0.83 [0.80, 0.86]	0.85 [0.82, 0.88]
56-64	0.93 [0.90, 0.97]	0.98 [0.94, 1.01]	0.98 [0.94, 1.01]	0.76 [0.74, 0.79]	0.78 [0.75, 0.82]	0.80 [0.77, 0.84]
Low Neighborhood	0.99	1.00	1.00	1.09	1.10	1.11

Education Level[a]	[0.97, 1.01]	[0.97, 1.02]	[0.97, 1.02]	[1.06, 1.13]	[1.07, 1.14]	[1.07, 1.14]
High Neighborhood Poverty Level[b]	1.00 [0.98, 1.02]	1.00 [0.98, 1.03]	1.01 [0.98, 1.03]	1.01 [0.98, 1.03]	1.01 [0.98, 1.04]	1.01 [0.98, 1.04]
Quarter, continuous	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]
Race (White = ref)						
Black	1.00 [0.97, 1.03]	0.99 [0.96, 1.02]	1.00 [0.97, 1.03]	1.25 [1.20, 1.30]	1.24 [1.19, 1.29]	1.25 [1.20, 1.30]
Hispanic	1.18 [1.14, 1.21]	1.16 [1.13, 1.19]	1.16 [1.13, 1.19]	1.30 [1.25, 1.34]	1.27 [1.23, 1.32]	1.28 [1.23, 1.33]
Other	1.04 [1.00, 1.07]	1.03 [0.99, 1.06]	1.03 [0.99, 1.06]	1.14 [1.10, 1.18]	1.13 [1.08, 1.17]	1.13 [1.08, 1.17]
US Region (South = ref)						
Northeast	0.98 [0.94, 1.01]	0.98 [0.95, 1.02]	0.97 [0.94, 1.01]	0.99 [0.95, 1.03]	0.99 [0.95, 1.03]	0.99 [0.95, 1.03]
West	0.89 [0.87, 0.91]	0.89 [0.87, 0.91]	0.89 [0.87, 0.91]	0.64 [0.63, 0.66]	0.65 [0.63, 0.67]	0.65 [0.63, 0.67]
Midwest	0.96 [0.94, 0.98]	0.96 [0.94, 0.98]	0.96 [0.94, 0.98]	0.71 [0.70, 0.73]	0.72 [0.70, 0.74]	0.72 [0.70, 0.74]
Clinician's prior patient received imaging	1.81 [1.77, 1.85]	1.80 [1.76, 1.84]	1.81 [1.77, 1.85]	2.82 [2.76, 2.88]	2.81 [2.75 [2.87]	2.83 [2.77, 2.89]
Ownership of imaging equipment (non-owner = ref)						
Owner (billed for technical component)	2.07 [2.04, 2.11]	2.05 [2.02, 2.09]	2.06 [2.02, 2.10]	7.70 [7.46, 7.96]	7.62 [7.37, 7.88]	7.74 [7.48, 8.00]
High rate of low-value back imaging	N/A	N/A	N/A	N/A	N/A	N/A
a Low neighborhood education: Census block groups with >25% below- high school education levels.						
b High neighborhood poverty: Census block groups with ≥10% below-poverty levels.						
c The most common specialties (accounting for 2/3 of all specialist visits) were orthopedic surgery, neurosurgery, back and spine surgery, physical medicine,						

rheumatology						
d For patients with multiple visits we selected a random visit to include with visits from patients with only one visit						

eTable 3 (continued): Accounting for patients who contribute multiple visits

	Back Pain Visits Seen by Specialist Physicians[c]			Headache Visits Seen by Primary Care Physicians		
Covariates	**all patient visits**	**1st patient visit only**	**random patient visit[d]**	**all patient visits**	**1st patient visit only**	**random patient visit[d]**
Female patient	0.82 [0.80, 0.85]	0.82 [0.79, 0.84]	0.82 [0.79, 0.85]	0.81 [0.80, 0.83]	0.82 [0.80, 0.84]	0.82 [0.80, 0.84]
Age distribution (18-25 = ref)						
26-35	0.88 [0.82, 0.95]	0.89 [0.83, 0.96]	0.89 [0.83, 0.96]	1.03 [0.99, 1.07]	1.06 [1.02, 1.10]	1.07 [1.02, 1.11]
36-45	0.88 [0.82, 0.94]	0.90 [0.84, 0.96]	0.90 [0.84, 0.97]	1.06 [1.03, 1.10]	1.11 [1.06, 1.15]	1.12 [1.08, 1.16]
46-55	0.82 [0.76, 0.87]	0.85 [0.80, 0.91]	0.86 [0.80, 0.92]	1.08 [1.04, 1.12]	1.15 [1.11, 1.20]	1.16 [1.12, 1.21]
56-64	0.77 [0.72, 0.83]	0.81 [0.76, 0.87]	0.82 [0.77, 0.88]	1.19 [1.15, 1.24]	1.28 [1.23, 1.34]	1.30 [1.25, 1.35]
Low Neighborhood Education Level[a]	0.90 [0.86, 0.94]	0.90 [0.85, 0.94]	0.90 [0.85, 0.94]	0.97 [0.94, 1.00]	0.97 [0.94, 1.00]	0.97 [0.94, 1.00]
High Neighborhood Poverty Level[b]	0.95 [0.91, 0.99]	0.95 [0.91, 0.99]	0.96 [0.92, 1.01]	0.95 [0.93, 0.98]	0.95 [0.93, 0.98]	0.96 [0.93, 0.99]
Quarter, continuous	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 1.00]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]
Race (White = ref)						
Black	1.02 [0.97, 1.07]	1.01 [0.96, 1.07]	1.01 [0.95, 1.06]	0.91 [0.88, 0.93]	0.88 [0.85, 0.91]	0.89 [0.86, 0.92]
Hispanic	1.12 [1.06, 1.19]	1.12 [1.06, 1.19]	1.11 [1.05, 1.18]	0.93 [0.90, 0.96]	0.89 [0.86, 0.92]	0.90 [0.87, 0.93]
Other	1.04	1.04	1.04	0.87	0.86	0.86

	[0.98, 1.10]	[0.98, 1.11]	[0.99, 1.11]	[0.84, 0.90]	[0.82, 0.89]	[0.83, 0.90]
US Region (South = ref)						
Northeast	1.09 [1.03, 1.15]	1.09 [1.03, 1.15]	1.10 [1.04, 1.16]	0.96 [0.93, 1.00]	0.97 [0.93, 1.01]	0.98 [0.94, 1.02]
West	0.80 [0.76, 0.84]	0.79 [0.75, 0.83]	0.79 [0.75, 0.84]	0.81 [0.78, 0.83]	0.81 [0.78, 0.84]	0.81 [0.78, 0.83]
Midwest	0.84 [0.80, 0.87]	0.84 [0.81, 0.88]	0.84 [0.81, 0.88]	1.15 [1.13, 1.18]	1.15 [1.12, 1.18]	1.16 [1.13, 1.19]
Clinician's prior patient received imaging	2.98 [2.89, 3.08]	2.93 [2.83, 3.03]	2.93 [2.83, 3.03]	2.01 [1.95, 2.06]	1.99 [1.93, 2.05]	1.99 [1.93, 2.05]
Ownership of imaging equipment (non-owner = ref)						
Owner (billed for technical component)	4.99 [4.81, 5.18]	5.02 [4.82, 5.22]	5.04 [4.85, 5.23]	1.88 [1.83, 1.94]	1.92 [1.85, 1.98]	1.91 [1.84, 1.97]
High rate of low-value back imaging	N/A	N/A	N/A	N/A	N/A	N/A
a Low neighborhood education: Census block groups with >25% below- high school education levels.						
b High neighborhood poverty: Census block groups with ≥10% below-poverty levels.						
c The most common specialties (accounting for 2/3 of all specialist visits) were orthopedic surgery, neurosurgery, back and spine surgery, physical medicine, rheumatology						
d For patients with multiple visits we selected a random visit to include with visits from patients with only one visit						

eTable 3 (continued): Accounting for patients who contribute multiple visits

	Headache Visits Seen by Primary Care Physicians Who Also Saw ≥4 Back Pain visits			
Covariates	**all patient visits**	**1st patient visit only**	**random patient visit[d]**	
Female patient	0.79 [0.77, 0.81]	0.80 [0.78, 0.82]	0.80 [0.78, 0.82]	
Age distribution (18-25 = ref)				

26-35	1.04 [0.99, 1.09]	1.06 [1.01, 1.12]	1.06 [1.01, 1.12]	
36-45	1.08 [1.04, 1.13]	1.14 [1.09, 1.19]	1.13 [1.08, 1.18]	
46-55	1.13 [1.08, 1.18]	1.21 [1.15, 1.27]	1.20 [1.15, 1.26]	
56-64	1.30 [1.24, 1.36]	1.40 [1.33, 1.47]	1.38 [1.31, 1.45]	
Low Neighborhood Education Level[a]	0.98 [0.94, 1.01]	0.98 [0.94, 1.01]	0.98 [0.94, 1.01]	
High Neighborhood Poverty Level[b]	0.93 [0.91, 0.96]	0.94 [0.91, 0.98]	0.94 [0.91, 0.97]	
Quarter, continuous	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	0.99 [0.99, 0.99]	
Race (White = ref)				
Black	0.86 [0.83, 0.90]	0.85 [0.82, 0.89]	0.85 [0.82, 0.88]	
Hispanic	0.86 [0.83, 0.89]	0.83 [0.80, 0.87]	0.84 [0.81, 0.88]	
Other	0.84 [0.80, 0.88]	0.82 [0.78, 0.86]	0.83 [0.79, 0.87]	
US Region (South = ref)				
Northeast	0.95 [0.90, 1.00]	0.95 [0.90, 1.00]	0.95 [0.90, 1.00]	
West	0.82 [0.79, 0.85]	0.81 [0.78, 0.84]	0.81 [0.78, 0.85]	
Midwest	1.24 [1.20, 1.27]	1.24 [1.20, 1.28]	1.24 [1.21, 1.28]	
Clinician's prior patient received imaging	1.66 [1.60, 1.72]	1.63 [1.57, 1.70]	1.63 [1.56, 1.69]	
Ownership of imaging equipment (non-owner = ref)				

Owner (billed for technical component)	1.40 [1.34, 1.46]	1.40 [1.34, 1.46]	1.40 [1.34, 1.47]	
High rate of low-value back imaging	1.39 [1.34, 1.45]	1.37 [1.32, 1.43]	1.38 [1.32, 1.43]	
a Low neighborhood education: Census block groups with >25% below-high school education levels.				
b High neighborhood poverty: Census block groups with ≥10% below-poverty levels.				
c The most common specialties (accounting for 2/3 of all specialist visits) were orthopedic surgery, neurosurgery, back and spine surgery, physical medicine, rheumatology				
d For patients with multiple visits we selected a random visit to include with visits from patients with only one visit				