

Supplemental Material for: Variation in preoperative stress testing by patient, physician, and surgical type

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1. Regression results, clustered by physician

Results have been edited/trimmed for clarity and brevity. Interaction terms have been replaced in the table below with exponents (^2) when applicable. All dichotomous variables (those prepended with "1." in the table) use a value of 0 as the referent.

Completed or cancelled test	Beta Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	

1.aortic_surgery	2.522167	.6078339	4.15	0.002	1.166378	3.877956
1.peripheral_vascular_surgery	1.531945	.1152814	13.29	0.000	1.285334	1.778556
1.urologic_surgery	1.5871	.0657605	24.13	0.000	1.446111	1.728088
documented_RCRI	.2135885	.03032	7.04	0.000	.1506825	.2764944
1.Gupta_greater_than_1pct	2.422218	.0472362	51.28	0.000	2.329492	2.514944
Estimated METs	-.1030793	.0128133	-8.04	0.000	-.1284818	-.0776767
functional_class	.1444786	.0214833	6.73	0.000	.1020898	.1868674
ADI_national	-.0141123	.0025089	-5.62	0.000	-.0190783	-.0091463
ADI_national^2	.0001325	.0000221	5.99	0.000	.0000888	.0001763
BMI	.0120129	.0016333	7.36	0.000	.0088076	.0152182
DBP	.0037949	.0011446	3.32	0.001	.0015493	.0060406
1.ischemic_heart_disease	.5187915	.0390133	13.30	0.000	.4412007	.5963823
predicted_prob_of_CAD	-.9799052	.1105385	-8.86	0.000	-1.198045	-.761765
1.congestive_heart_failure	-.1196815	.0476752	-2.51	0.014	-.2142709	-.0250922
date	.002128	.0004881	4.36	0.000	.0011708	.0030853
date^2	-6.15e-08	1.25e-08	-4.92	0.000	-8.61e-08	-3.70e-08
1.current_smoker	.1436825	.0424903	3.38	0.001	.0603125	.2270526
1.former_smoker	.1288456	.0290712	4.43	0.000	.0718283	.1858628
constant	-23.48573	4.748773	-4.95	0.000	-32.79838	-14.17308

/lnsig2u	-3.592461	.2658187			-4.113895	-3.071026

sigma_u	.1659232	.0220527			.1278436	.2153451
rho	.0082988	.0021877			.0049434	.0138999

2. Physician marginal rates of stress testing

Due to space constraints, only selected physician marginal results are displayed in Table 3. Here we present full marginal results by physician. These are also displayed visually in Figure 2.

Physician Rank	Marginal Rate	95% CI
1	0.58%	0.08% – 4.40%
2	1.00%	0.28% – 3.57%
3	1.07%	0.52% – 2.18%
4	1.20%	0.47% – 3.08%
5	1.22%	0.34% – 4.33%
6	1.25%	0.59% – 2.64%
7	1.39%	0.68% – 2.88%
8	1.50%	1.13% – 1.97%
9	1.52%	0.52% – 4.46%
10	1.55%	0.85% – 2.83%
11	1.56%	0.82% – 2.97%
12	1.60%	0.79% – 3.23%
13	1.64%	1.12% – 2.42%
14	1.67%	0.98% – 2.83%
15	1.68%	1.17% – 2.39%
16	1.68%	1.01% – 2.80%
17	1.70%	0.95% – 3.03%
18	1.73%	1.05% – 2.82%
19	1.78%	1.53% – 2.06%
20	1.80%	1.41% – 2.30%
21	1.87%	1.29% – 2.71%
22	1.89%	1.45% – 2.47%
23	1.93%	1.16% – 3.22%
24	1.95%	1.65% – 2.29%

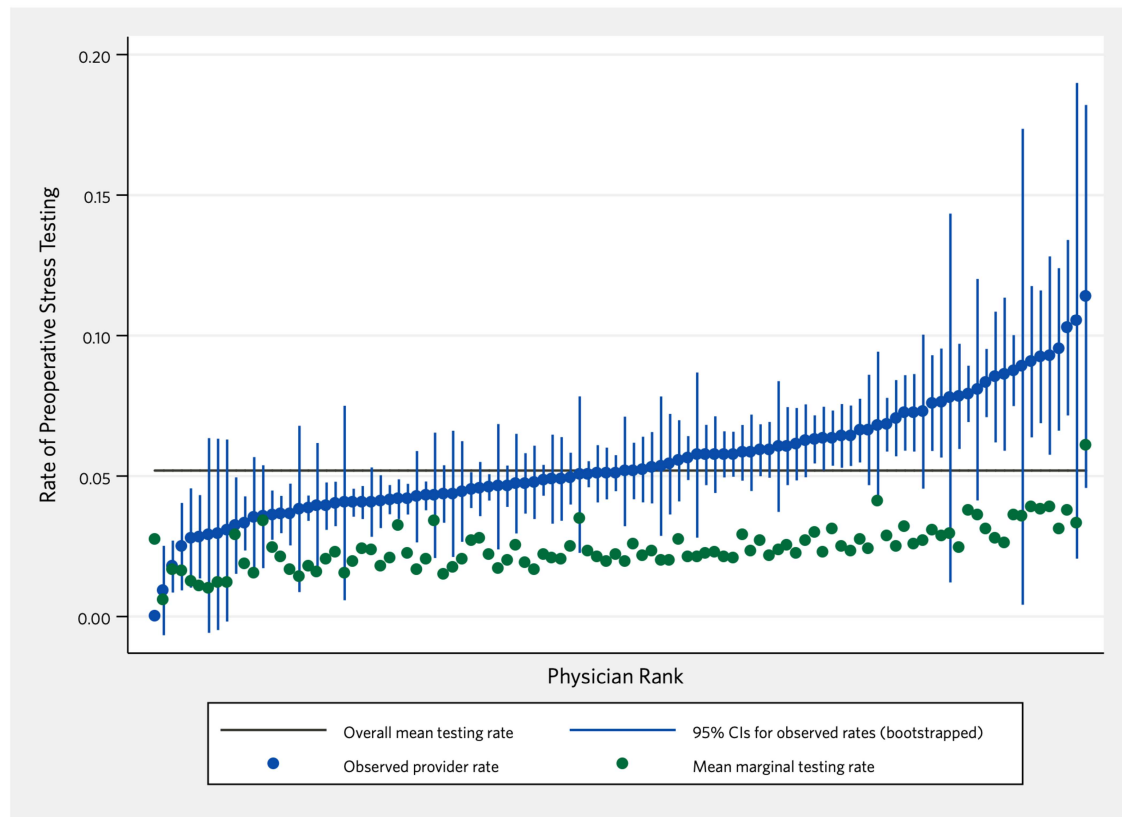
Physician Rank	Marginal Rate	95% CI
25	1.96%	1.56% – 2.45%
26	1.99%	1.63% – 2.42%
27	1.99%	1.17% – 3.38%
28	1.99%	1.42% – 2.80%
29	2.02%	1.62% – 2.52%
30	2.03%	1.71% – 2.42%
31	2.04%	1.45% – 2.89%
32	2.05%	1.20% – 3.48%
33	2.06%	1.70% – 2.48%
34	2.06%	1.48% – 2.87%
35	2.09%	1.77% – 2.46%
36	2.10%	1.64% – 2.69%
37	2.12%	1.75% – 2.57%
38	2.13%	1.75% – 2.60%
39	2.13%	1.67% – 2.73%
40	2.13%	1.20% – 3.80%
41	2.14%	1.75% – 2.62%
42	2.15%	1.68% – 2.76%
43	2.19%	1.86% – 2.58%
44	2.19%	1.87% – 2.56%
45	2.20%	1.89% – 2.55%
46	2.22%	1.93% – 2.56%
47	2.24%	1.76% – 2.84%
48	2.26%	1.74% – 2.93%
49	2.27%	1.76% – 2.93%
50	2.27%	1.75% – 2.95%
51	2.29%	1.70% – 3.08%

Physician Rank	Marginal Rate	95% CI
52	2.32%	1.63% – 3.30%
53	2.32%	2.07% – 2.61%
54	2.33%	1.68% – 3.23%
55	2.34%	1.89% – 2.89%
56	2.35%	1.59% – 3.48%
57	2.36%	1.40% – 3.97%
58	2.39%	1.97% – 2.90%
59	2.40%	1.74% – 3.32%
60	2.43%	1.84% – 3.22%
61	2.46%	1.81% – 3.36%
62	2.48%	2.02% – 3.05%
63	2.49%	1.93% – 3.22%
64	2.50%	2.03% – 3.09%
65	2.51%	1.64% – 3.86%
66	2.53%	1.89% – 3.39%
67	2.56%	1.95% – 3.37%
68	2.58%	2.03% – 3.30%
69	2.62%	1.76% – 3.91%
70	2.68%	2.29% – 3.12%
71	2.68%	1.73% – 4.14%
72	2.70%	2.07% – 3.52%
73	2.71%	2.20% – 3.33%
74	2.75%	1.98% – 3.81%
75	2.75%	2.13% – 3.55%
76	2.75%	2.13% – 3.55%
77	2.76%	2.24% – 3.41%
78	2.76%	1.91% – 4.00%

Physician Rank	Marginal Rate	95% CI
79	2.86%	2.27% - 3.60%
80	2.87%	2.14% - 3.86%
81	2.89%	2.38% - 3.52%
82	2.92%	1.47% - 5.81%
83	2.94%	1.17% - 7.38%
84	2.99%	2.55% - 3.51%
85	3.09%	2.28% - 4.19%
86	3.09%	2.50% - 3.81%
87	3.09%	1.93% - 4.95%
88	3.09%	2.51% - 3.82%
89	3.17%	2.52% - 3.99%
90	3.22%	2.62% - 3.96%
91	3.33%	1.23% - 9.05%
92	3.39%	1.76% - 6.55%
93	3.40%	1.50% - 7.69%
94	3.50%	1.77% - 6.91%
95	3.57%	1.13% - 11.27%
96	3.59%	2.97% - 4.34%
97	3.60%	1.91% - 6.79%
98	3.77%	2.44% - 5.83%
99	3.79%	3.18% - 4.51%
100	3.80%	2.67% - 5.43%
101	3.89%	2.60% - 5.83%
102	3.91%	2.56% - 5.96%
103	4.11%	2.71% - 6.23%
104	6.08%	2.74% - 13.51%

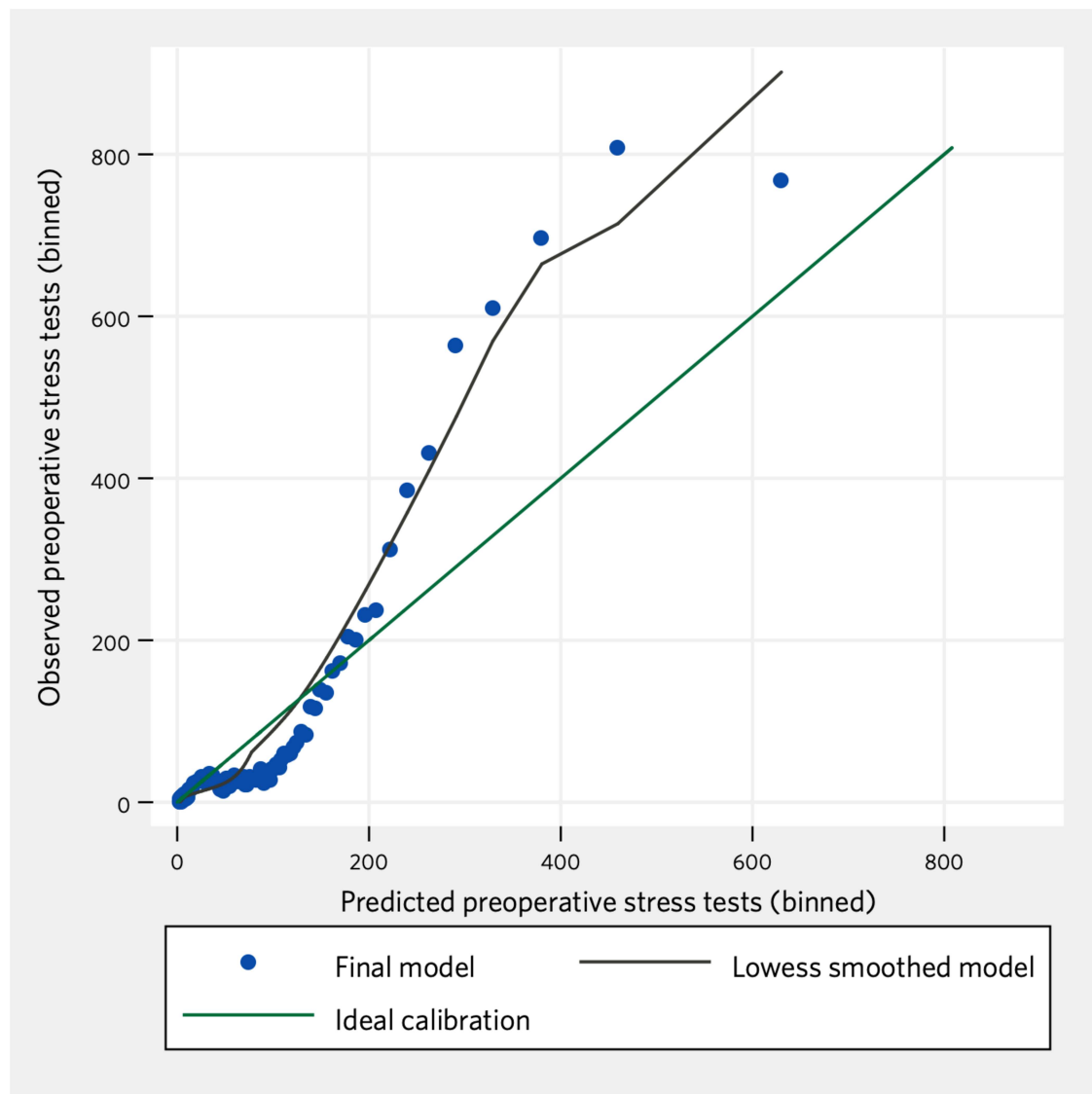
3. Physician rates of stress testing, unadjusted and marginal

Figure 1 demonstrates unadjusted rates of stress testing, and Figure 2 demonstrates marginal predictions for each physician, controlling for all other factors. Here we overlay the marginal results on the unadjusted results to demonstrate the effect of adjustment.



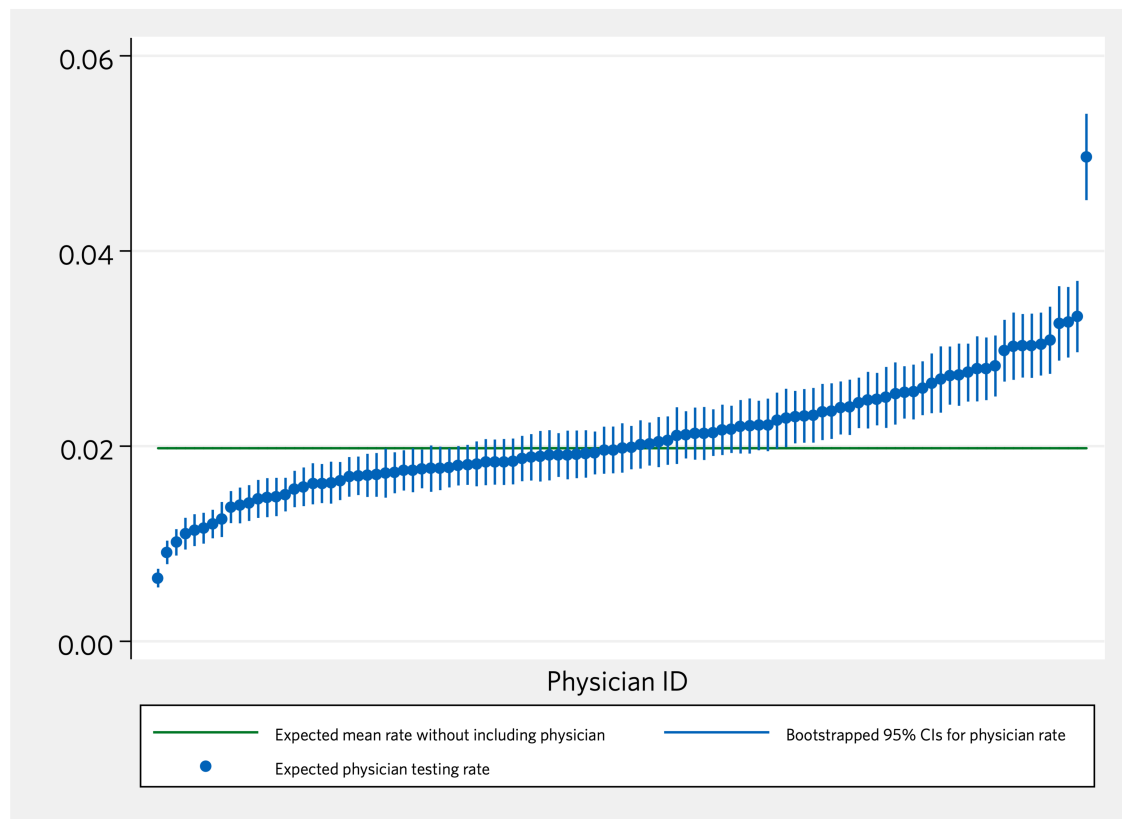
4. Calibration of final model

Based on the plot above, we suspected less-than-ideal calibration of our final model. We do not know of a universally accepted method to assess the calibration of a multilevel model on multiply-imputed data, but in most of our assessments this model fails Hosmer-Lemeshow Goodness-of-Fit testing, and the calibration plot shown here (binned into centiles) indeed suggests poor calibration. We emphasize again that our goal here is to explain variance in testing, not to guide future physicians in who should be referred for stress testing or to enable individual physician profiling.



5. Expected testing rates with an identical population

One way to contextualize provider effects is to imagine that each provider sees an identical panel of patients and estimate the consequent differences in outcomes. Here, we sampled 1,000 patients from our original population and estimated rates of stress testing if that same cohort were seen by each physician in our dataset. The overall mean is the expected rate for this small cohort without controlling for physician ID.



6. Sensitivity analysis excluding patients planned for aortic or vascular surgery

We repeated our analysis while excluding patients who were considered for aortic or vascular surgery. As in all models with dichotomous outcomes, the fixed variance leads to different effect sizes when using a different list of predictors. All effects are in the same direction as in our base-case analysis, as shown below. All changes in effect size are smaller than the smallest effect size in our base-case model (congestive heart failure). We have highlighted results where marginal rates differ from the base case by 0.02% or greater. This is an arbitrary threshold based on the intuition that a difference of less than 1 test per 500 visits is small. Due to rounding, some cells with less than a 0.2% absolute difference are displayed as differences of 0.2% in the cells below.

This analysis includes a total of 151,213 visits.

Predictor	Value	Mean marginal rate, base case	95% CI	Mean marginal rate with aortic and vascular surgery patients excluded	95% CI
MICA > 1%	0	0.6%	(0.6% - 0.7%)	0.6%	(0.5% - 0.7%)
	1	7.1%	(6.7% - 7.5%)	6.8%	(6.4% - 7.1%)
Documented RCRI	0	2.2%	(2.0% - 2.3%)	2.1%	(1.9% - 2.2%)
	1	2.7%	(2.5% - 2.9%)	2.6%	(2.4% - 2.8%)
	2	3.4%	(3.0% - 3.8%)	3.2%	(2.8% - 3.6%)
	3	4.2%	(3.5% - 5.0%)	3.9%	(3.3% - 4.7%)
	4	5.1%	(4.0% - 6.5%)	4.9%	(3.8% - 6.2%)
	5	6.4%	(4.7% - 8.6%)	6.0%	(4.4% - 8.2%)
Functional class	1	2.1%	(1.9% - 2.2%)	2.0%	(1.8% - 2.1%)
	2	2.4%	(2.2% - 2.5%)	2.2%	(2.1% - 2.4%)
	3	2.8%	(2.6% - 3.0%)	2.6%	(2.4% - 2.8%)
	4	3.2%	(2.9% - 3.5%)	2.9%	(2.6% - 3.3%)
Estimated metabolic equivalents	2	3.3%	(2.9% - 3.7%)	3.0%	(2.7% - 3.4%)
	4	2.7%	(2.5% - 2.9%)	2.5%	(2.3% - 2.7%)
	8	1.8%	(1.6% - 1.9%)	1.7%	(1.5% - 1.9%)
Body mass index	20	2.1%	(1.9% - 2.3%)	2.0%	(1.8% - 2.1%)
	30	2.4%	(2.2% - 2.5%)	2.2%	(2.1% - 2.4%)
	40	2.7%	(2.5% - 2.9%)	2.5%	(2.3% - 2.7%)

Predictor	Value	Mean marginal rate, base case	95% CI	Mean marginal rate with aortic and vascular surgery patients excluded	95% CI
Diastolic blood pressure	70	2.3%	(2.2% - 2.5%)	2.2%	(2.1% - 2.4%)
	90	2.5%	(2.3% - 2.7%)	2.4%	(2.2% - 2.6%)
	110	2.7%	(2.4% - 3.0%)	2.6%	(2.3% - 2.9%)
Ischemic heart disease	0	2.1%	(2.0% - 2.3%)	2.0%	(1.9% - 2.2%)
	1	3.6%	(3.3% - 3.9%)	3.3%	(3.1% - 3.7%)
Congestive heart failure	0	2.4%	(2.2% - 2.5%)	2.3%	(2.1% - 2.4%)
	1	2.1%	(1.9% - 2.3%)	2.0%	(1.8% - 2.2%)
Area deprivation index	10	2.8%	(2.5% - 3.1%)	2.6%	(2.4% - 2.9%)
	50	2.2%	(2.0% - 2.3%)	2.1%	(1.9% - 2.2%)
	90	2.6%	(2.4% - 2.8%)	2.4%	(2.2% - 2.7%)
Predicted probability of obstructive coronary artery disease	5%	2.6%	(2.4% - 2.7%)	2.4%	(2.3% - 2.6%)
	10%	2.4%	(2.3% - 2.6%)	2.3%	(2.2% - 2.5%)
	20%	2.2%	(2.1% - 2.4%)	2.1%	(1.9% - 2.2%)
Tobacco use	Current smoker	2.6%	(2.3% - 2.8%)	2.4%	(2.2% - 2.7%)
	Former smoker	2.5%	(2.3% - 2.7%)	2.4%	(2.2% - 2.6%)
	Neither	2.2%	(2.1% - 2.4%)	2.1%	(1.9% - 2.2%)
Date	2008.06.30	3.5%	(3.2% - 3.8%)	3.3%	(3.0% - 3.6%)
	2013.06.30	2.6%	(2.4% - 2.8%)	2.5%	(2.3% - 2.7%)
	2018.06.30	1.3%	(1.2% - 1.4%)	1.2%	(1.1% - 1.3%)
Surgical category	Aortic	23.4%	(6.0% -91.1%)	-	
	Peripheral vascular	8.7%	(6.7% -11.3%)	-	
	Urologic	9.2%	(8.3% -10.2%)	8.8%	(7.9% - 9.9%)
	Other	1.9%	(1.7% - 2.0%)	1.8%	(1.7% - 2.0%)
Physician (summary)	Lowest	1.0%	(0.1% - 4.4%)	0.5%	(0.1% - 3.6%)
	5th percentile	1.2%	(0.6% - 2.6%)	0.8%	(0.3% - 1.8%)
	Median	2.3%	(2.1% - 2.6%)	1.6%	(1.2% - 2.0%)

Predictor	Value	Mean marginal rate, base case	95% CI	Mean marginal rate with aortic and vascular surgery patients excluded	95% CI
	95th percentile	3.8%	(3.2% - 4.5%)	2.7%	(1.8% - 4.1%)
	Highest	6.1%	(2.7% -13.5%)	4.5%	(1.8% -11.3%)

7. Marginal testing rate as a function of physician experience

As with all datasets, our conclusions are a product of many decisions. For example, although we rejected physician experience as a predictor of testing rate in favor of date and a physician-specific random effect, reasonable investigators could disagree. To generate the graph below, we replaced date in our model with the number of visits each physician had completed between the beginning of our dataset and the visit in question (a proxy for preoperative clinic experience). We then computed and graphed marginal probabilities as described in our primary results.

