

Online Supplement to the Paper “Using Patient-Specific Quality Information to Unlock Hidden Health Care Capabilities”

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Online Supplement A: Hausman Test Results

Table A1 Hausman Test Results				
	Fixed Effects (<i>F</i>)	Random Effects (<i>R</i>)	Difference (<i>F</i> - <i>R</i>)	Std. Err. $\sqrt{\text{diag}(V_F - V_R)}$
Surgical Volumes				
hosp_vol	0.56	0.21	0.35	0.52
surg_vol	-3.29	0.13	-3.42	7.80
Patient Characteristics				
age	-0.02	-0.02	0.00	0.00
female	-0.34	-0.31	-0.03	0.02
black	-0.09	-0.17	0.08	0.05
hispanic	-0.23	-0.32	0.09	0.06
asian	-0.26	-0.29	0.04	0.10
others	0.17	0.13	0.04	0.04
Comorbidities				
atrial fibrillation	-0.11	-0.12	0.01	0.02
alcohol abuse	0.38	0.28	0.09	0.09
deficiency anemias	0.07	0.09	-0.03	0.03
rheumatoid arthritis	-0.31	-0.27	-0.04	0.05
blood loss	0.16	0.08	0.08	0.13
heart failure	0.19	-0.09	0.28	0.21
lung disease	-0.25	-0.24	-0.01	0.02
coagulopathy	-0.11	-0.13	0.02	0.02
depression	0.08	0.07	0.01	0.04
diabetes	-0.10	-0.12	0.02	0.02
drug abuse	-0.17	-0.11	-0.06	0.08
hypertension	0.05	0.05	0.00	0.02
hypothyroidism	0.09	0.07	0.02	0.03
liver disease	-0.31	-0.15	-0.16	0.12
lymphoma	-0.22	-0.22	0.00	0.10
electrolyte disorders	0.07	0.04	0.03	0.02
metastatic cancer	-0.61	-0.53	-0.08	0.12
neurological disorders	0.11	0.10	0.02	0.05
obesity	-0.15	-0.20	0.05	0.03
paralysis	-0.12	-0.11	-0.01	0.07
vascular disorders	0.03	0.00	0.03	0.04
psychoses	-0.26	-0.31	0.05	0.10
pulmonary disorders	-0.47	-0.25	-0.22	0.25
renal failure	-0.33	-0.29	-0.04	0.03
solid tumor	-0.22	-0.19	-0.04	0.08
valvular disease	-0.52	-0.47	-0.05	0.30
weight loss	-0.01	-0.05	0.04	0.06
constant	0.01	0.79	-0.79	1.14

Note: H_o = difference in coefficients not systematic. F = consistent under H_o and H_a ; obtained from probit.

R = inconsistent under H_a , efficient under H_o ; obtained from multilevel probit.

Test results: $\chi^2(36) = (F - R)'[(V_F - V_R)^{-1}](F - R) = 33.78$, $Prob > \chi^2 = 0.5747$.

Online Supplement B: Population-Average Rates of Complication and Readmission

Figure B1 **Complication Rate by Surgeon**

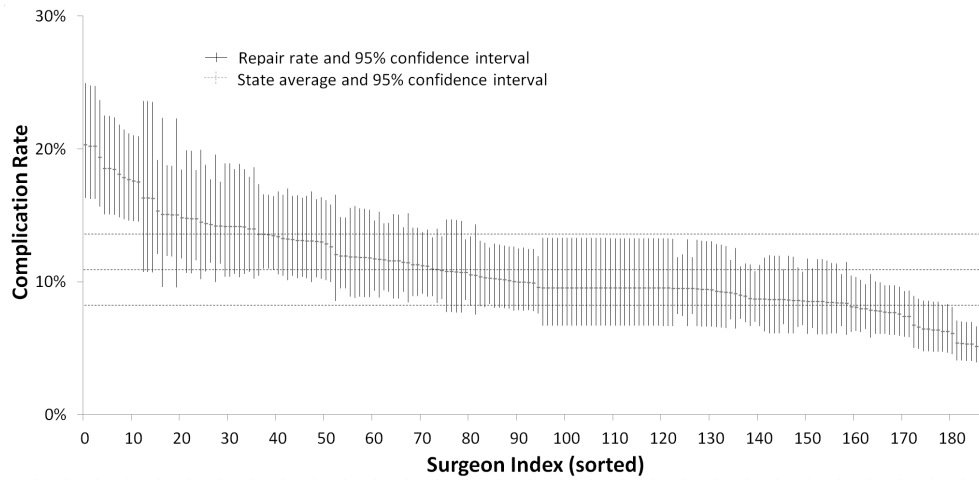
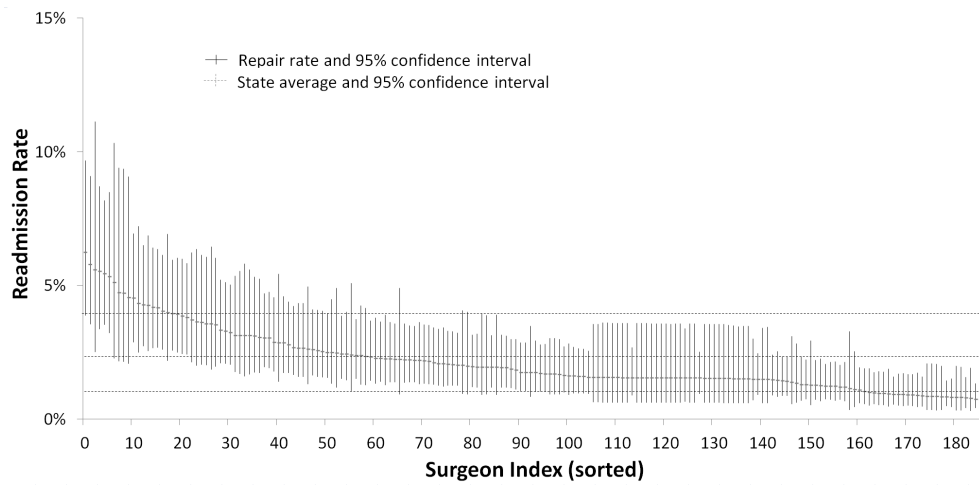


Figure B2 **Readmission Rate by Surgeon**



Online Supplement C: Patient-Specific Rates of Complication and Readmission

Figure C1 Complication Rate by Surgeon for Patients of Different Levels of Acuity

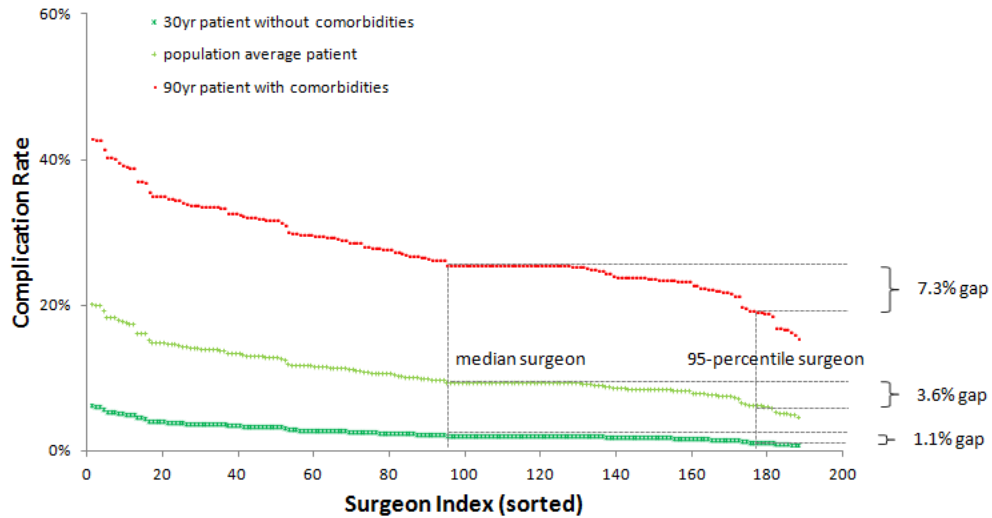
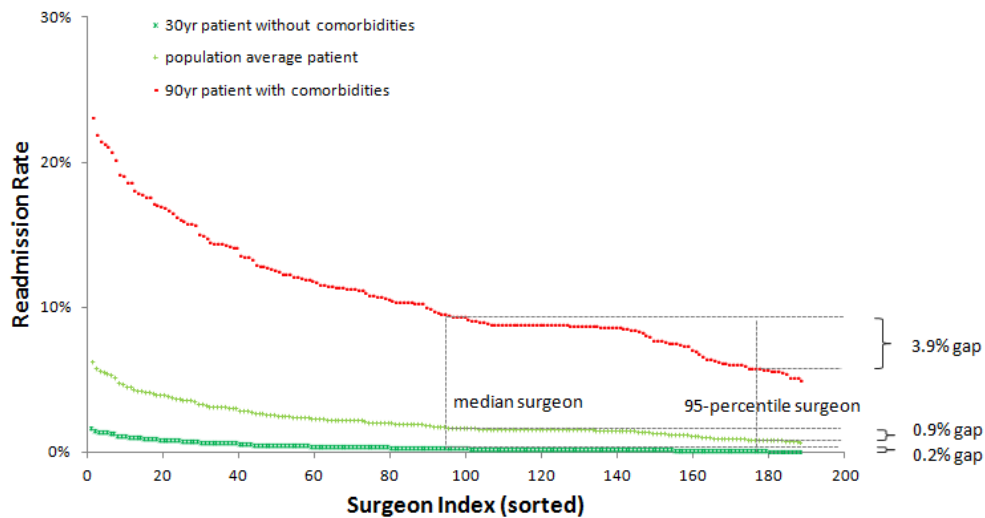


Figure C2 Readmission Rate by Surgeon for Patients of Different Levels of Acuity



Online Supplement D: Estimation Results of Each Type of Complication

Table D1 Estimation Results of Each Type of Complication

	Stroke		Wound Infection		Renal Failure		Reoperation		Ventilation	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Surgical Volumes										
hosp_vol	-0.21**	0.10	0.12	0.15	0.04	0.06	-0.24**	0.10	0.31***	0.11
surg_vol	0.16***	0.04	0.06	0.06	-0.05**	0.03	0.02	0.03	-0.08***	0.02
Patient Demographics										
age	0.02*	0.01	0.00	0.01	0.02***	0.00	0.02***	0.00	0.02***	0.01
female	0.17	0.22	0.20*	0.10	-0.12*	0.06	0.24**	0.11	0.18*	0.10
black	0.27	0.52	-0.43	0.47	0.35**	0.17	-0.07	0.25	0.16	0.20
hispanic	0.79**	0.34	-0.20	0.17	0.02	0.15	-0.06	0.24	0.11	0.21
asian	0.57	0.42	-5.07***	0.38	-0.19	0.18	0.05	0.39	-0.18	0.45
others	0.47**	0.24	-0.05	0.26	-0.16	0.13	-0.36	0.23	-0.20	0.26
Comorbidities										
atrial fibrillation	-0.02	0.17	-0.14	0.18	-0.07	0.08	0.04	0.16	-0.19	0.12
alcohol abuse	-5.23***	0.83	-4.35***	0.40	-0.09	0.23	-5.16***	0.33	-0.03	0.58
deficiency anemias	-0.09	0.33	-0.45**	0.22	-0.18	0.13	0.12	0.09	-0.46**	0.20
rheumatoid arthritis	-4.46	.	0.10	0.44	-0.23	0.24	-0.38	0.49	-4.91***	0.29
blood loss	-4.07	.	-4.44***	1.05	-5.10***	0.53	0.20	0.49	-4.08***	0.19
heart failure	0.44	0.34	0.32	0.82	0.29	0.67	-6.15***	0.51	3.03***	0.80
lung disease	0.03	0.23	0.12	0.22	0.02	0.10	0.01	0.12	-0.01	0.12
coagulopathy	-0.28	0.26	-0.12	0.15	0.32***	0.04	0.28**	0.12	0.28***	0.10
depression	-0.60	0.40	-0.05	0.42	-0.19	0.18	-0.32	0.33	-0.35	0.26
diabetes	-0.20	0.24	0.36**	0.14	0.07	0.12	-0.11	0.12	0.07	0.16
drug abuse	-3.49	.	-4.46***	0.66	-0.17	0.63	-4.71***	0.27	0.71*	0.39
hypertension	-0.54**	0.24	-0.21	0.15	-0.28**	0.09	-0.26***	0.08	-0.37***	0.13
hypothyroidism	0.05	0.25	-0.46	0.33	-0.08	0.13	0.10	0.14	-0.13	0.32
liver disease	-4.85***	0.76	0.41	0.67	0.66***	0.25	0.75**	0.32	-1.15**	0.48
lymphoma	-4.72	.	-4.81***	0.36	0.90**	0.39	0.19	0.49	-4.30***	0.23
electrolyte disorders	-0.15	0.25	-0.07	0.18	0.42***	0.12	0.14	0.15	0.14	0.10
metastatic cancer	-3.67	.	-4.36***	1.02	-4.58***	0.21	-4.90***	0.32	-4.13***	0.21
neurological disorders	0.71**	0.36	-4.79***	0.33	-0.44	0.33	0.05	0.33	0.25	0.20
obesity	0.37	0.36	0.03	0.27	0.15	0.18	-0.25*	0.15	-0.03	0.23
paralysis	2.09***	0.32	0.62	0.42	-0.18	0.33	0.61*	0.32	0.74***	0.25
vascular disorders	-0.55**	0.22	0.06	0.26	0.15	0.20	-0.39	0.29	0.42**	0.18
psychoses	-4.24	.	0.75	0.47	-0.31	0.48	-4.84***	0.14	0.03	0.40
pulmonary disorders	0.73	0.59	-5.43***	0.89	0.17	0.76	-6.16***	0.55	6.94***	0.26
renal failure	0.26	0.23	0.62***	0.18	1.11***	0.11	-0.09	0.15	0.35*	0.21
solid tumor	-3.98	.	0.73***	0.28	-0.06	0.41	-4.80***	0.37	-4.54***	0.12
valvular disease	0.14	0.42	0.83	0.94	0.50	0.46	1.37***	0.47	1.25***	0.44
weight loss	0.76***	0.29	0.62**	0.28	0.56***	0.12	0.69***	0.16	1.42***	0.18
Others										
repair	-0.20	0.21	-0.46**	0.24	-0.18*	0.09	-0.11	0.13	-0.24***	0.09
alpha	0.00	0.00	0.00	0.08	0.00	0.00	0.12	0.06	0.11	0.07
beta	0.00	0.00	0.02	0.05	0.00	0.00	0.02	0.05	0.00	0.00
constant	-3.32***	0.84	-3.21***	0.88	-3.08***	0.40	-2.22***	0.40	-4.45***	0.65
log likelihood	-74.37		-115.87		-594.03		-359.75		-244.36	

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Robust standard errors are clustered by surgeon.

Online Supplement E: Model Elements and Sources for the Estimation of QALE

Since there is no single source or paper that provides the value of various parameters in our model, we draw from several sources in the medical literature to estimate long-term risks associated with mitral valve repair and replacement and quality of life associated with different risks. Below we discuss our estimates and sources of each model element for patients of different ages and different comorbidities.

Stroke: We estimate the risk of stroke based on Russo et al. (2008), who studied 1,344 patients that underwent mitral surgery at the Mayo Clinic from Jan 1980 to Dec 1995, and reported that (1) annual rate of stroke is 1.15% for mitral valve repair, 1.65% and 2.7% for biological and mechanical valve replacement, respectively, (2) risk ratio of age is 1.1 per 5 years, and (3) risk ratio of atrial fibrillation is 1.4 for both mitral valve repair and biological valve replacement. We estimate quality of life after stroke based on Shah and Gage (2011), who developed a decision-analysis model to compare the cost and quality-adjusted survival of various antithrombotic therapies on the basis of the results from Randomized Evaluation of Long Term Anticoagulation Therapy and other trials, and reported that quality of life after moderate to severe stroke is 0.39.

Bleeding: We estimate the risk of bleeding based on Russo et al. (2008), who reported that (1) annual rate of bleeding is 0.7% for mitral valve repair, 1.4% and 2.43% for biological and mechanical valve replacement, respectively, (2) risk ratio of age is 1.14 per 5 years, and (3) risk ratio of atrial fibrillation is 1.52 for both mitral valve repair and biological valve replacement. We estimate quality of life after stroke based on Shah and Gage (2011), who reported that quality of life after bleeding is 0.8.

Structural Valve Deterioration (SVD): We estimate the risk of structural valve deterioration based Bourguignon et al. (2014), who studied 450 patients that underwent biological valve replacement from 1984 to 2011, and reported that annual rate of structural valve deterioration is 2.75%, 1.5%, 0.6%, 0.4% for patients at their 50s, 60s, 70s and 80s, respectively. Because structural valve deterioration usually requires reoperation (Bourguignon et al., 2014), we assume that quality of life after structural valve deterioration is similar to that after reoperation.

Long-term Survival: We estimate long-term survival of patients with mitral valve repair based on the US Social Security database, assuming that mitral valve repair restores patients normal life expectancy (Ray et al., 2006). Long-term survival associated with mitral valve replacement is estimated based on Daneshmand et al. (2010), who studied 2,064 patients that underwent isolated primary mitral operations, and found that (1) annual mortality rates associated with biological and mechanical valve replacement are 1.8 and 1.3 times that associated with mitral valve repair, and (2) risk ratio is 1.4 for diabetes and 1.3 for lung disease. In a similar study, Daneshmand et al. (2009) found that risk ratio is 2.68 for renal disease and 1.37 for hypertension. Risk ratio of other

comorbidities is estimated to be 1.6 for heart failure (Gelsomino et al., 2011) and 2.3 for atrial fibrillation (Ruel et al., 2004).

Lastly, quality of life is estimated to be 0.6 for readmission (Cox et al., 2007), 0.45 for reoperation (Regier et al., 2006), 0.7 for ventilation (Windisch et al., 2003) and 0.85 for wound infection (Jidus et al., 2009). Quality of life for patients with comorbidities is estimated to be 0.751 for diabetes, 0.636 for heart failure, 0.714 for lung disease, 0.651 for renal failure, 0.789 for hypertension and 0.774 for atrial fibrillation (Sullivan and Ghushchyan, 2006).

Online Supplement F: Numerical Analysis Results with Heterogeneous Weights on Travel Distance

Table F1 Comparison of the Effectiveness of Patient-Specific Information and Capacity Increase

Weight on Distance	Weight on Waiting Time	Expected Number of Repairs	Average Distance (miles)	Average Waiting (months)	Convenience Adjusted QALE*(days)	Expected Number of Repairs	Average Distance (miles)	Average Waiting (months)	Convenience Adjusted QALE*(days)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)			
			Patient-Specific (current capacity)			Population-Average (current capacity)						
Low	Low	2,174	26	5.7	258	2,104	26	5.8	243			
	Medium	2,163	28	1.1	257	2,090	28	1.1	240			
	High	2,153	30	0.5	256	2,099	30	0.5	243			
Medium	Low	2,163	22	5.6	246	2,099	22	5.7	232			
	Medium	2,152	23	1.1	244	2,095	24	1.1	231			
	High	2,147	24	0.5	245	2,088	24	0.5	232			
High	Low	2,115	17	5.2	171	2,064	17	5.3	158			
	Medium	2,101	17	1.0	168	2,054	17	1.1	155			
	High	2,087	17	0.5	168	2,044	17	0.5	156			
			Population-Average (10% capacity increase)			Population-Average (20% capacity increase)						
Low	Low	2,122	26	5.8	248	2,131	26	5.4	255			
	Medium	2,115	28	1.1	249	2,133	29	1.1	254			
	High	2,116	30	0.5	249	2,135	30	0.5	256			
Medium	Low	2,116	22	5.4	240	2,129	23	5.3	245			
	Medium	2,111	24	1.1	238	2,131	24	1.1	244			
	High	2,108	25	0.5	238	2,127	25	0.5	245			
High	Low	2,082	17	4.9	167	2,102	17	4.6	175			
	Medium	2,074	17	1.0	164	2,095	17	0.9	171			
	High	2,063	17	0.5	163	2,088	18	0.5	170			
Actual		1,557	19									

Note: This table compares scenarios when patients choose surgeons based on patient-specific information (with current capacity) and population-average information (with 0-20% capacity increases). We consider Low, Medium and High weights patients place on travelling and waiting. Equivalent quality-adjusted life days per mile for Low, Medium and High weights on travelling are 0.5, 1, 5. Equivalent quality-adjusted life days per month for Low, Medium and High weights on waiting are 10, 50, 100. *For the ease of comparison, a fixed amount of one quality-adjusted life year has been subtracted from Convenience Adjusted QALE for both patient-specific and population-average cases.

Table F2 Comparison of the Values from Using Patient-Specific and Population-Average Information

Weight on Distance	Diff. in Num. of Repairs			Diff. in Total QALE (year)			Diff. in Average Travel Dist.(mile)			Diff. in Average Wait Time(month)		
	Weight on Waiting			Weight on Waiting			Weight on Waiting			Weight on Waiting		
	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Low	71	74	55	108	120	81	0	0	0	-0.1	0.0	0.0
Medium	64	57	59	93	84	89	0	0	0	-0.2	0.0	0.0
High	51	47	43	70	65	59	0	0	0	-0.2	-0.1	0.0

Note: This table summarizes the changes in total number of repairs, quality-adjusted life years, average travel distance and waiting time per patient when information is switched from population-average to patient-specific. We consider Low, Medium and High weights patients place on travelling and waiting. Equivalent quality-adjusted life days per mile for Low, Medium and High weights on travelling are 0.5, 1, 5. Equivalent quality-adjusted life days per month for Low, Medium and High weights on waiting are 10, 50, 100.