

Supplementary Online Content

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

eMethods 1. List of 29 AHRQ Risk Factors

We used 29 variables based on the AHRQ risk adjustment software to calculate comorbidity burden. These included acquired immune deficiency syndrome, alcohol abuse, deficiency anemias, rheumatoid arthritis/collagen vascular diseases, chronic blood loss anemia, congestive heart failure, chronic pulmonary disease, coagulopathy, depression, diabetes (uncomplicated), diabetes with chronic complications, drug abuse, hypertension (combine uncomplicated and complicated), hypothyroidism, liver disease, lymphoma, fluid and electrolyte disorders, metastatic cancer, other neurological disorders, obesity, paralysis, peripheral vascular disorders, psychoses, pulmonary circulation disorders, renal failure, solid tumor without metastasis, peptic ulcer disease excluding bleeding, valvular disease, and weight loss.

eMethods 2. Check Missingness on Hospital Characteristics

1. There are 3 hospitals with RSRR=.M D duo to missing on Race for WA State in year 2011-2013, so these hospitals were not included for analysis (2 for 2011, 2 for 2012 and 1 for 2013).
2. There are 402 hospitals with missing on ambulatory surgery center and/or availability of cardiac procedures for year 2011 - 2014. Since both are categorical variables, we would like to set up the missing as a new level to run the model (we won't lose these records).

eTable 1. Patient Level Characteristics for All 4 States During 4 Years (N = 1 252 505)

Variable	Description	Data
Age, mean	years	52.7 (18.1)
Age group	18-44	419,954 (34%)
	45-64	476,686 (38%)
	65-84	316,097 (25%)
	85 +	39,768 (3%)
	Sex	Male
	Female	648,085 (52%)
Race/ethnicity	White	826,424 (66%)
	Black	152,761 (12%)
	Hispanic	178,987 (14%)
	Other	94,333 (8%)
insurance	Medicare	401,918 (32%)
	Medicaid	200,726 (16%)
	Private	477,784 (38%)
	Self-pay	94,131 (8%)
	Other	77,945 (6%)
Patient location	1: Large metropolitan area	798,046 (64%)
	2: Small metropolitan area	330,053 (26%)
	3: Micropolitan areas	77,630 (6%)
	4: Not metropolitan or micropolitan	42,800 (3%)
Median income quartiles	1: First quartile	318,718 (26%)
	2: Second quartile	332,435 (27%)
	3: Third quartile	301772 (25%)
	4: Fourth quartile	261,788 (22%)

The surgical cohort consisted of 1,252,505 patients across all four years and states. The patient level characteristics of the entire cohort is presented in Table a. Table b depicts this data accounting for state and year.

eTable 2. Patient Level Characteristics by State and Year

State	Variable	Description	2011	2012	2013	2014	Overall
FL	Age, mean, years		53.3 (18.2%)	53.9 (18.0%)	54.3 (17.9%)	54.6 (17.9%)	54.0 (18.0%)
	Age group	18-44	44445 (32%)	45156 (31%)	43579 (30%)	43012 (29%)	176192 (31%)
		45-64	51427 (38%)	54777 (38%)	55213 (38%)	55787 (38%)	217204 (38%)
		65-84	36630 (27%)	40483 (28%)	41260 (28%)	42012 (29%)	160385 (28%)
		85 +	4380 (3%)	4776 (3%)	4918 (3%)	5226 (4%)	19300 (3%)
	Sex	0: Male	66026 (48%)	70446 (49%)	69979 (48%)	71290 (49%)	277741 (48%)
		1: Female	70856 (52%)	74746 (51%)	74991 (52%)	74747 (51%)	295340 (52%)
	Race	1: White	92547 (68%)	96434 (66%)	95313 (66%)	96373 (66%)	380667 (66%)
		2: Black	18226 (13%)	19342 (13%)	19624 (14%)	19873 (14%)	77065 (13%)
		3: Hispanic	22741 (17%)	25631 (18%)	26411 (18%)	25614 (18%)	100397 (18%)
		4: Other	3368 (2%)	3785 (3%)	3622 (2%)	4177 (3%)	14952 (3%)
	Insurance	1: Medicare	48641 (36%)	53062 (37%)	53715 (37%)	55237 (38%)	210655 (37%)
		2: Medicaid	16950 (12%)	18548 (13%)	19029 (13%)	18608 (13%)	73135 (13%)
		3: Private	46315 (34%)	46497 (32%)	45246 (31%)	47622 (33%)	185680 (32%)
		4: Self-pay	13079 (10%)	14643 (10%)	14824 (10%)	13366 (9%)	55912 (10%)
		5: Other	11897 (9%)	12442 (9%)	12156 (8%)	11204 (8%)	47699 (8%)
	Patient Location	1: Large metropolitan area	84260 (62%)	90299 (62%)	89618 (62%)	90539 (62%)	354716 (62%)
		2: Small metropolitan area	41401 (30%)	43018 (30%)	43538 (30%)	48283 (33%)	176240 (31%)
		3: Micropolitan areas	7213 (5%)	7701 (5%)	7781 (5%)	3677 (3%)	26372 (5%)

		4: Not metropolitan or micropolitan	3426 (3%)	3575 (2%)	3405 (2%)	2850 (2%)	13256 (2%)
	Median Income Quartiles	1: First quartile	41657 (31%)	46192 (32%)	55816 (39%)	57433 (40%)	201098 (36%)
		2: Second quartile	40857 (30%)	45377 (32%)	46957 (33%)	49994 (35%)	183185 (33%)
		3: Third quartile	37565 (28%)	36259 (25%)	29442 (21%)	26004 (18%)	129270 (23%)
		4: Fourth quartile	14144 (11%)	14630 (10%)	10024 (7%)	9712 (7%)	48510 (9%)
IA	Age, mean, years		55.0 (18.1%)	54.9 (17.6%)	54.7 (17.5%)	54.8 (17.7%)	54.8 (17.7%)
	Age group	18-44	2818 (28%)	3153 (28%)	3869 (28%)	3961 (28%)	13801 (28%)
		45-64	3882 (39%)	4623 (41%)	5720 (41%)	5569 (40%)	19794 (40%)
		65-84	2882 (29%)	3234 (28%)	3955 (28%)	3928 (28%)	13999 (28%)
		85 +	363 (4%)	377 (3%)	412 (3%)	490 (4%)	1642 (3%)
	Sex	0: Male	4681 (47%)	5565 (49%)	6950 (50%)	6971 (50%)	24167 (49%)
		1: Female	5264 (53%)	5822 (51%)	7006 (50%)	6977 (50%)	25069 (51%)
	Race	1: White	9333 (94%)	10629 (93%)	12932 (93%)	12848 (92%)	45742 (93%)
		2: Black	293 (3%)	378 (3%)	433 (3%)	459 (3%)	1563 (3%)
		3: Hispanic	146 (1%)	217 (2%)	388 (3%)	399 (3%)	1150 (2%)
		4: Other	173 (2%)	163 (1%)	203 (1%)	242 (2%)	781 (2%)
	Insurance	1: Medicare	3729 (37%)	4162 (37%)	5088 (36%)	5137 (37%)	18116 (37%)
		2: Medicaid	919 (9%)	1123 (10%)	1494 (11%)	1932 (14%)	5468 (11%)
		3: Private	4421 (44%)	5086 (45%)	6074 (44%)	5984 (43%)	21565 (44%)
		4: Self-pay	451 (5%)	543 (5%)	718 (5%)	439 (3%)	2151 (4%)
		5: Other	425 (4%)	472 (4%)	582 (4%)	456 (3%)	1935 (4%)
	Patient Location	1: Large metropolitan area	47 (0%)	62 (1%)	86 (1%)	86 (1%)	281 (1%)
		2: Small metropolitan area	5486 (55%)	6231 (55%)	7957 (57%)	8037 (58%)	27711 (56%)
		3: Micropolitan areas	1769 (18%)	2261 (20%)	2430 (17%)	2556 (18%)	9016 (18%)
		4: Not metropolitan or micropolitan	2641 (27%)	2831 (25%)	3477 (25%)	3265 (23%)	12214 (25%)

	Median Income Quartiles	1: First quartile	1585 (16%)	1932 (17%)	1827 (13%)	1256 (9%)	6600 (14%)
		2: Second quartile	4489 (46%)	5108 (45%)	6242 (45%)	5970 (43%)	21809 (45%)
		3: Third quartile	3241 (33%)	3561 (32%)	4236 (31%)	4639 (34%)	15677 (32%)
		4: Fourth quartile	543 (6%)	682 (6%)	1533 (11%)	1970 (14%)	4728 (10%)
NY	Age, mean, years		50.3 (18.3%)	50.8 (18.3%)	51.4 (18.2%)	51.8 (18.1%)	51.1 (18.2%)
	Age group	18-44	49077 (39%)	47990 (38%)	44358 (37%)	41864 (36%)	183289 (37%)
		45-64	46125 (37%)	47048 (37%)	45754 (38%)	44511 (38%)	183438 (38%)
		65-84	25622 (21%)	27422 (22%)	27296 (23%)	27124 (23%)	107464 (22%)
		85 +	3604 (3%)	3760 (3%)	3867 (3%)	3668 (3%) 14	899 (3%)
	Sex	0: Male	59158 (48%)	59772 (47%)	58172 (48%)	56532 (48%)	233634 (48%)
		1: Female	65270 (52%)	66448 (53%)	63103 (52%)	60635 (52%)	255456 (52%)
	Race	1: White	74525 (60%)	70704 (56%)	68582 (57%)	67427 (58%)	281238 (58%)
		2: Black	17514 (14%)	17138 (14%)	17023 (14%)	16902 (14%)	68577 (14%)
		3: Hispanic	16782 (13%)	18360 (15%)	17955 (15%)	15582 (13%)	68679 (14%)
		4: Other	15607 (13%)	20018 (16%)	17715 (15%)	17256 (15%)	70596 (14%)
	Insurance	1: Medicare	32042 (26%)	33675 (27%)	33978 (28%)	33343 (28%)	133038 (27%)
		2: Medicaid	25716 (21%)	26033 (21%)	25131 (21%)	26558 (23%)	103438 (21%)
		3: Private	54495 (44%)	54595 (43%)	50902 (42%)	47219 (40%)	207211 (42%)
		4: Self-pay	6883 (6%)	6709 (5%)	6285 (5%)	5405 (5%)	25282 (5%)
		5: Other	5292 (4%)	5208 (4%)	4979 (4%)	4642 (4%)	20121 (4%)
	Patient Location	1: Large metropolitan area	92621 (75%)	94059 (75%)	90540 (75%)	91198 (78%)	368418 (76%)

		2: Small metropolitan area	21170 (17%)	21443 (17%)	20729 (17%)	17149 (15%)	80491 (16%)
		3: Micropolitan areas	7300 (6%)	7346 (6%)	6887 (6%)	5906 (5%)	27439 (6%)
		4: Not metropolitan or micropolitan	3065 (2%)	3076 (2%)	2825 (2%)	2626 (2%)	11592 (2%)
	Median Income Quartiles	1: First quartile	25530 (22%)	25582 (21%)	20222 (17%)	20928 (19%)	92262 (20%)
		2: Second quartile	24545 (21%)	25407 (21%)	24302 (21%)	23557 (21%)	97811 (21%)
		3: Third quartile	27943 (24%)	25937 (22%)	26365 (23%)	24390 (22%)	104635 (22%)
		4: Fourth quartile	40539 (34%)	43404 (36%)	44671 (39%)	42586 (38%)	171200 (37%)
WA	Age, mean, years		51.7 (17.7%)	52.0 (17.7%)	52.8 (17.5%)	53.3 (17.5%)	52.4 (17.6%)
	Age group	18-44	12467 (35%)	12174 (34%)	11085 (33%)	10622 (31%)	46348 (33%)
		45-64	14524 (40%)	13923 (39%)	13493 (40%)	13432 (40%)	55372 (40%)
		65-84	7894 (22%)	8288 (23%)	8505 (25%)	8799 (26%)	33486 (24%)
		85 +	982 (3%)	967 (3%)	900 (3%)	957 (3%)	3806 (3%)
	Sex	0: Male	17227 (48%)	17107 (48%)	16682 (49%)	16734 (49%)	67750 (49%)
		1: Female	18640 (52%)	18245 (52%)	17301 (51%)	17076 (51%)	71262 (51%)
	Race	1: White	30067 (84%)	29875 (85%)	28662 (84%)	28338 (84%)	116942 (84%)
		2: Black	1369 (4%)	1412 (4%)	1265 (4%)	1264 (4%)	5310 (4%)
		3: Hispanic	2065 (6%)	2176 (6%)	2197 (6%)	2262 (7%)	8700 (6%)
		4: Other	2366 (7%)	1889 (5%)	1859 (5%)	1946 (6%)	8060 (6%)
	Insurance	1: Medicare	9262 (26%)	9620 (27%)	9939 (29%)	10316 (31%)	39137 (28%)
		2: Medicaid	4302 (12%)	3965 (11%)	3969 (12%)	6342 (19%)	18578 (13%)
		3: Private	16895 (47%)	16594 (47%)	14960 (44%)	14127 (42%)	62576 (45%)
		4: Self-pay	3058 (9%)	3124 (9%)	3193 (9%)	1294 (4%)	10669 (8%)
		5: Other	2350 (7%)	2049 (6%)	1922 (6%)	1731 (5%)	8052 (6%)

	Patient Location	1: Large metropolitan area	18633 (52%)	18563 (53%)	17641 (52%)	17902 (53%)	72739 (52%)
		2: Small metropolitan area	11755 (33%)	11546 (33%)	10906 (32%)	11246 (33%)	45453 (33%)
		3: Micropolitan areas	3848 (11%)	3561 (10%)	3783 (11%)	3584 (11%)	14776 (11%)
		4: Not metropolitan or micropolitan	1599 (4%)	1604 (5%)	1543 (5%)	988 (3%)	5734 (4%)
	Median Income Quartiles	1: First quartile	5103 (15%)	4625 (13%)	4305 (13%)	4256 (13%)	18289 (13%)
		2: Second quartile	7181 (20%)	7530 (22%)	7227 (22%)	7467 (23%)	29405 (22%)
		3: Third quartile	13199 (38%)	12802 (37%)	12695 (38%)	12638 (38%)	51334 (38%)
		4: Fourth quartile	9586 (27%)	9591 (28%)	8977 (27%)	8679 (26%)	36833 (27%)

eTable 3. Top 10 Clinical Condition Categories for Operations

We selected specific multi-level CCS procedure categories to define our surgical cohort. The 10 most frequent operations for the cohort are depicted in the table below.

Operation	Non-SNH		SNH		Overall	
	N	Percent	N	Percent	N	Percent
Cholecystectomy and common duct exploration	69,426	14.67	87,841	11.05	157,267	12.40
Appendectomy	48,875	10.32	63,827	8.03	112,702	8.89
Colorectal resection	24,698	5.22	30,079	3.78	54,777	4.32
Other OR upper GI therapeutic procedures	23,032	4.87	32,182	4.05	55,214	4.35
Transurethral excision; drainage; or removal urinary obstruction	20,827	4.40	26,537	3.34	47,364	3.73
Treatment; fracture or dislocation of lower extremity (other than hip or femur)	20,493	4.33	44,327	5.58	64,820	5.11
Other OR lower GI therapeutic procedures	20,318	4.29	32,713	4.11	53,031	4.18
Other therapeutic procedures on muscles and tendons	19,181	4.05	31,377	3.95	50,558	3.99
Excision; lysis peritoneal adhesions	12,375	2.61			27,731	2.19
Treatment; fracture or dislocation of hip and femur	11,498	2.43	19,457	2.45	30,955	2.44
Amputation of lower extremity	10,504	2.22	19,201	2.42	29,705	2.34

eTable 4. Check Linear Trend on Quartiles (Nurse to Bed Ratio and Surgical Volume)

Adjusted by year and state					
Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
Nurse-bed ratio linear trend	1	41527.52151	41527.52151	17.23	<.0001
Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
Surgical volume linear trend	1	819.8559309	819.8559309	0.34	0.5592

There is linear trend based on surgical volume. We ran the final model with surgical volume as continuous variable and nurse-bed ratio as a categorical variable.

eTable 5. Final Full Model

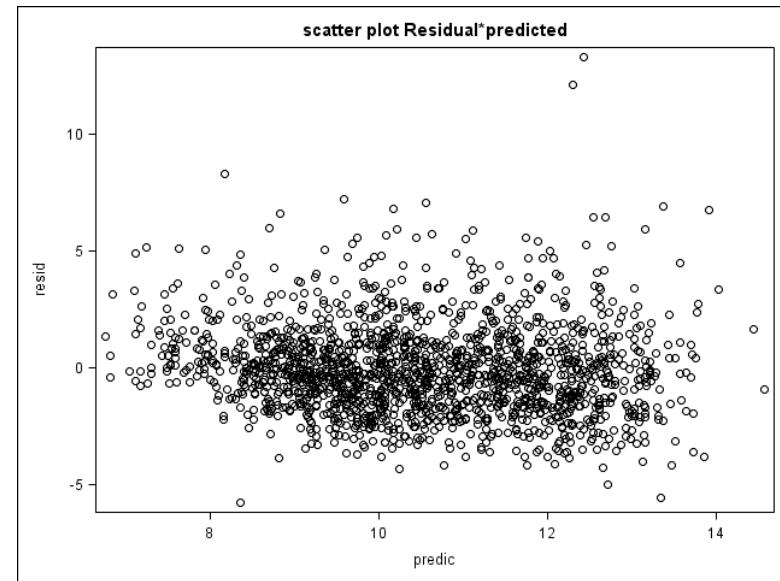
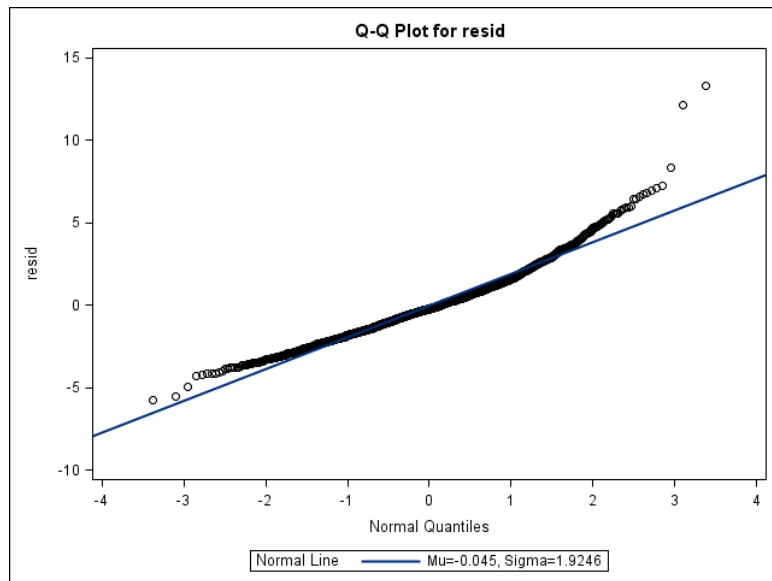
Overall p-value for each factor from the regression model

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	3	66328.4660	22109.4887	8.25	<.0001
State	3	692470.9336	230823.6445	86.12	<.0001
Safety Net Hospital	1	145785.7226	145785.7226	54.40	<.0001
Teaching Status	1	33128.0657	33128.0657	12.36	0.0005
Bedsize	3	15829.0962	5276.3654	1.97	0.1167
Ownership	2	168385.5631	84192.7816	31.41	<.0001
CBSATYPE	2	2490.3208	1245.1604	0.46	0.6285
Ambulatory Surgery	1	49644.4920	49644.4920	18.52	<.0001
Cardiac Capabilities	2	37549.0845	18774.5422	7.01	0.0009
Nurse-Bed Ratio	3	61605.3886	20535.1295	7.66	<.0001
Surgery Volume	1	78098.3587	78098.3587	29.14	<.0001
R-square					
R-Square	Coeff Var	Root MSE	RSRR Mean		
0.358457	480.4321	51.76970	10.77565		

eTable 6. Pairwise Comparisons

Effect	i	j	Difference	LowerCL	UpperCL	p-value
Year	2012	2013	-0.13	-0.47	0.20	0.74
Year	2012	2014	0.41	0.08	0.75	0.008
Year	2012	2011	0.35	0.02	0.69	0.036
Year	2013	2014	0.54	0.21	0.88	<0.001
Year	2013	2011	0.48	0.15	0.82	0.001
Year	2014	2011	-0.06	-0.40	0.28	0.97
State	FL	NY	1.21	0.88	1.54	<0.001
State	FL	WA	2.61	2.14	3.07	<0.001
State	FL	IA	2.65	1.93	3.36	<0.001
State	NY	WA	1.40	0.92	1.88	<0.001
State	NY	IA	1.44	0.72	2.16	<0.001
State	WA	IA	0.04	-0.67	0.75	0.99
Bedsizes	<200 beds	3:300-499 beds	-0.19	-0.68	0.29	0.73
Bedsizes	<200 beds	4:500 + beds	0.00	-0.62	0.62	1.000
Bedsizes	<200 beds	2:200-299 beds	-0.33	-0.78	0.11	0.21
Bedsizes	3:300-499 beds	4:500 + beds	0.19	-0.21	0.60	0.61
Bedsizes	3:300-499 beds	2:200-299 beds	-0.14	-0.56	0.28	0.83
Bedsizes	4:500 + beds	2:200-299 beds	-0.33	-0.87	0.20	0.38
Funding	2:Not-for-profit NonGov	3:Investor-owned	-1.26	-1.68	-0.84	<0.001
Funding	2:Not-for-profit NonGov	1: Nonfederal Gov	-0.61	-0.92	-0.30	<0.001
Funding	3:Investor-owned	1: Nonfederal Gov	0.65	0.17	1.13	0.004
Location	Micro	Rural	0.26	-1.61	2.13	0.94
Location	Micro	Metro	-0.23	-0.91	0.46	0.72
Location	Rural	Metro	-0.48	-2.27	1.30	0.80
Cardiac Capabilities	2:Catherization	3:Neither	-0.29	-0.73	0.15	0.28
Cardiac Capabilities	2:Catherization	1: Surgery	-0.59	-0.96	-0.22	0.001

Cardiac Capabilities	3:Neither	1: Surgery	-0.30	-0.73	0.13	0.24
Nurse-Bed Ratio	2nd quartile	3rd quartile	-0.01	-0.34	0.32	0.999
Nurse-Bed Ratio	2nd quartile	3rd quartile	-0.52	-0.91	-0.13	0.003
Nurse-Bed Ratio	2nd quartile	3rd quartile	-0.42	-0.79	-0.05	0.020
Nurse-Bed Ratio	3rd quartile	4th quartile	-0.51	-0.86	-0.16	0.011
Nurse-Bed Ratio	3rd quartile	1st quartile	-0.41	-0.79	-0.03	0.029
Nurse-Bed Ratio	4th quartile	1st quartile	0.10	-0.34	0.54	0.942

eFigure. Assumption of Normality

The above plots are from linear model of RSRR. We could see the qq-plot of raw residuals are approximately normal distributed with the upper tail slightly deviated from the normal, and there is no pattern on the scatter plot. The normal distribution and equal variance assumptions are not violated

