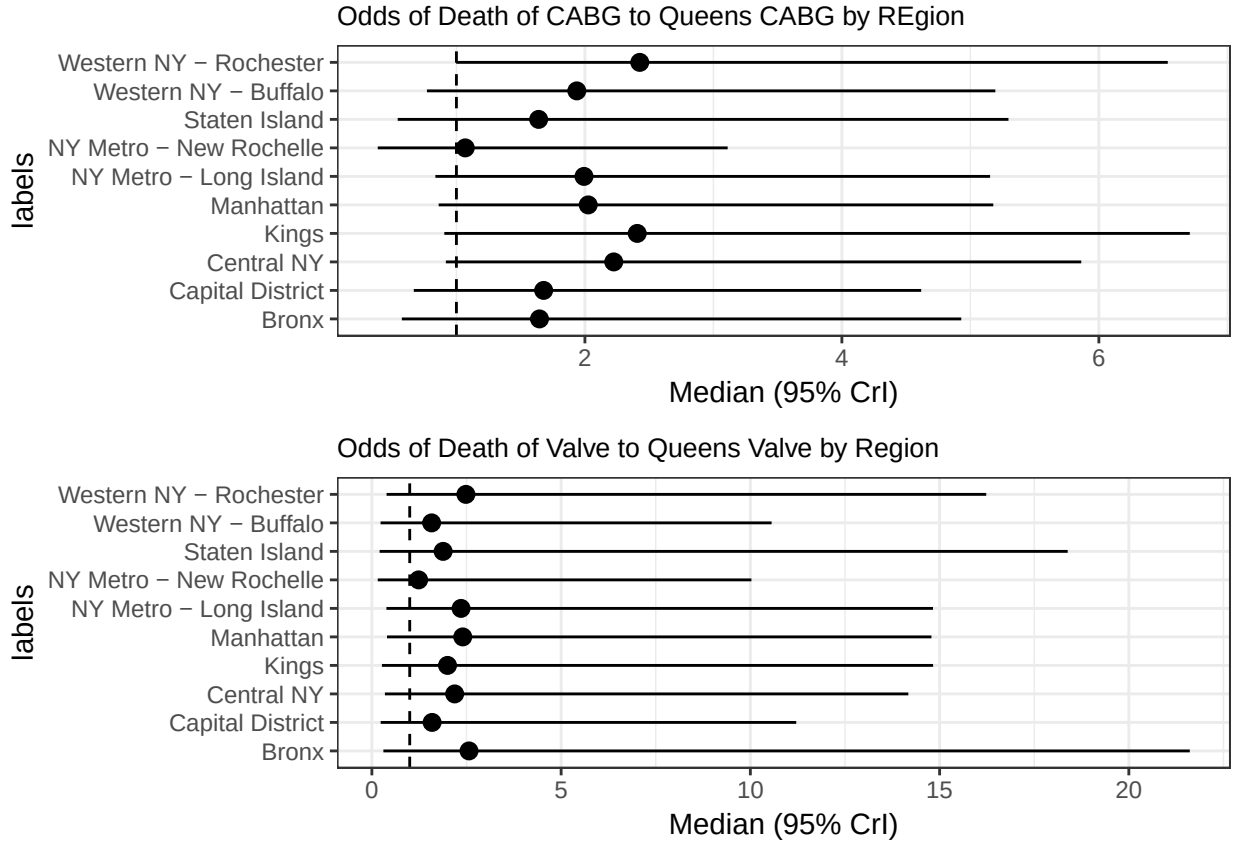
Case Study 2

Zach White

November 15, 2017

Objective 1



The model form of the binomial generalized linear mixed model is the following:

$$\log\left(\frac{Pr(Y_{ijk}=y|N,\boldsymbol{\beta},\mathbf{X})}{1-Pr(Y_{ijk}=y|N,\boldsymbol{\beta},\mathbf{X})}\right)=\beta_0+\beta_{\text{region}}\text{R}_{ijk}+\beta_{\text{procedure}}\text{P}_{ijk}+\beta_{\text{region:procedure}}\text{R}_{ijk}\text{P}_{ijk}+\text{h}_i+\text{d}_j$$

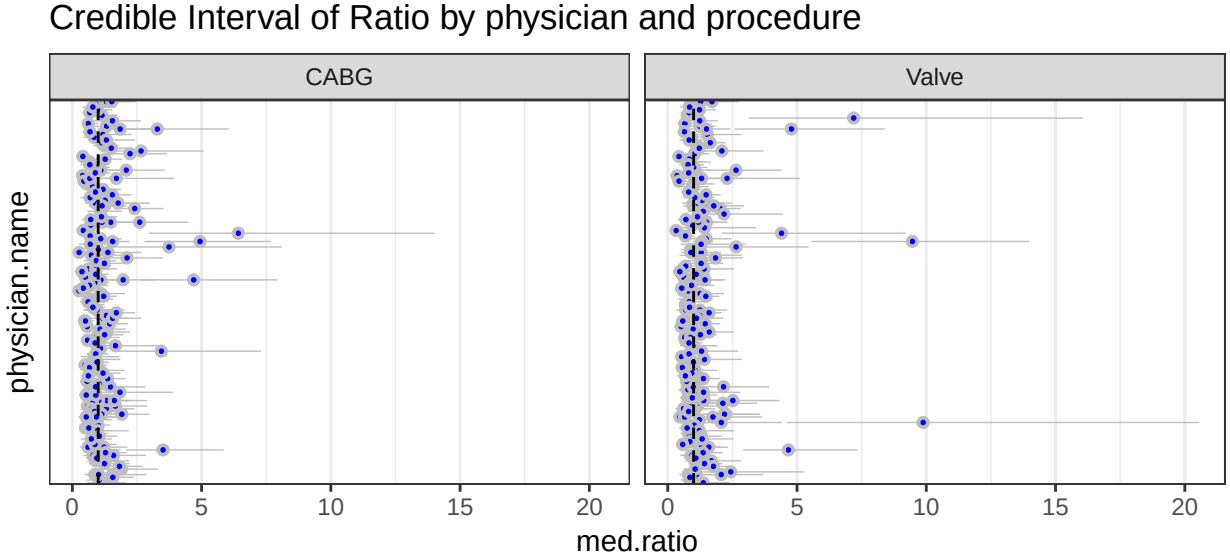
For the sake of ease of interpretation, we use a logit link instead of a probit link. Also, alternatively, we could expand this data into a table of bernoulli trials, but doing so increases computation time fitting our bayesian model, since there are 76, 519 total cases. We use a $N(0,\text{sd}=4)$ priors on all β coefficients. Also, for the random effect for hospital $\text{h}_i \sim N(0,\sigma^2_{\text{hospital}})$ where $\sigma^2_{\text{hospital}}$ follows a folded stuent-t distribution with 3 degrees of freedom and a scale parameter of 10. For the random effect for physician, we use a similar prior structure as for the hospital random effect where $\text{d}_j \sim N(0,\sigma^2_{\text{physician}})$ where $\sigma^2_{\text{physician}}$ follows the same folded t-distribution. However, it is important to note that we leave these random effects inependent from one another. Once we fit this model and generate

posterior draws for these random effects, we estimate that $\sigma_{\text{hospital}} = 0.11\ (0.01, .026)$ and $\sigma_{\text{physician}} = 0.37\ (0.29, 0.46)$. The parenthetical values represent a central 90% credible interval. Although both of these are entirely above zero, it seems clear that $\sigma_{\text{physician}} > \sigma_{\text{hospital}}$, which indicates that there is more heterogeneity on the level of the doctor than that of the hospitals, which is not suprising. These are posterior estimates for the standard error for these random effects. If we are interested in the variance of these standard errors, we need to square these posterior draws and then find the relevant quantiles of interested. Doing this yields the following estimates: $\sigma^2_{\text{hospital}} = .011(0.00013, 0.055)$ and $\sigma^2_{\text{physician}} = 0.137\ (0.0897, 0.201)$ which are obviously smaller since these values were already less than 1.

The above plot shows the posterior medians and a 95% credible interval for the odds-ratios comparing the odds of death in each region to that in Queens for each of the two procedures.

Objective 2

The following forest plot shows the different combinations of observed doctors, hospitals, and procedure type. There are a lot of doctors in these data, and thus, we do not show all of the doctors in the table. However, the plot on the left shows the procedure for ratio of modeled rate of mortality to expected mortality rate, which takes into consideration case mixture. It is important to note that if this ratio is less than one, then the doctor's mortality rate is lower than expected, and thus this doctor is performing better than expected. The opposite holds true for ratios greater than 1. Also, on the plot is a dotted line at the one, which would indicate that the physician is performing as well as we would expect. Analyzing these plots, it seems as though there are more doctors whose ratio is greater than one when performing the valve or valve/CABG operation than when performing CABG. CABG seems higher variance in general, but there are also less doctors doing worse than expected.



The following table shows the attributes of physicians with a posterior probability of the ratio being greater than 1 of less than 0.05. In other words, these are physicians with a 0.95 probability of exceding expectations.

physician	hospital	proc	Rate Est.	Lower	Upper	Pr(R>1)
Bennett E	Albany Medical Center	Valve	0.0160	0.0091	0.0262	0.0293
Culliford A	Bellevue Hospital Ctr	CABG	0.0155	0.0084	0.0284	0.0450
Canavan T	Champ.Valley Phys Hosp	CABG	0.0095	0.0050	0.0173	0.0151
Lundy E F	Good Sam - Suffern	CABG	0.0075	0.0034	0.0148	0.0235
Salenger R	Good Sam - Suffern	CABG	0.0067	0.0031	0.0133	0.0492
Lundy E F	Good Sam - Suffern	Valve	0.0141	0.0075	0.0246	0.0418
Patel N C	Lenox Hill Hospital	CABG	0.0107	0.0069	0.0159	0.0487
Palazzo R	LIJ Medical Center	CABG	0.0057	0.0020	0.0136	0.0253
Scheinerman S J	LIJ Medical Center	CABG	0.0068	0.0025	0.0156	0.0132
Graver L	LIJ Medical Center	Valve	0.0213	0.0122	0.0350	0.0061
Palazzo R	LIJ Medical Center	Valve	0.0092	0.0042	0.0183	0.0002
Scheinerman S J	LIJ Medical Center	Valve	0.0109	0.0054	0.0204	0.0001
Jacobowitz I	Maimonides Medical Ctr	CABG	0.0116	0.0062	0.0204	0.0250
Jacobowitz I	Maimonides Medical Ctr	Valve	0.0158	0.0092	0.0256	0.0030
Derose J J	Montefiore - Moses	CABG	0.0111	0.0056	0.0203	0.0209
Goldstein D J	Montefiore - Moses	CABG	0.0092	0.0045	0.0178	0.0172
Michler R E	Montefiore - Weiler	CABG	0.0160	0.0075	0.0322	0.0000
Hall M	North Shore Univ Hosp	CABG	0.0144	0.0088	0.0225	0.0107
Kalimi R	North Shore Univ Hosp	CABG	0.0112	0.0070	0.0174	0.0004
Vatsia S	North Shore Univ Hosp	CABG	0.0095	0.0053	0.0158	0.0325
Hall M	North Shore Univ Hosp	Valve	0.0275	0.0176	0.0413	0.0333
Hartman A	North Shore Univ Hosp	Valve	0.0300	0.0196	0.0443	0.0177
Kalimi R	North Shore Univ Hosp	Valve	0.0216	0.0139	0.0319	0.0238
Vatsia S	North Shore Univ Hosp	Valve	0.0183	0.0107	0.0292	0.0423
Lang S	NY Hospital - Queens	CABG	0.0058	0.0022	0.0130	0.0286
Ciaburri D	NY Methodist Hospital	CABG	0.0119	0.0052	0.0245	0.0466
Ciaburri D	NY Methodist Hospital	Valve	0.0162	0.0075	0.0313	0.0115
Girardi L	NYP- Weill Cornell	CABG	0.0089	0.0056	0.0137	0.0278
Lang S	NYP- Weill Cornell	CABG	0.0108	0.0053	0.0207	0.0000
Girardi L	NYP- Weill Cornell	Valve	0.0173	0.0111	0.0253	0.0012
Krieger K	NYP- Weill Cornell	Valve	0.0223	0.0143	0.0332	0.0288
Kalimi R	Southside Hospital	CABG	0.0108	0.0062	0.0177	0.0034
Kalimi R	Southside Hospital	Valve	0.0209	0.0126	0.0323	0.0069
Fernandez H A	St. Francis Hospital	CABG	0.0123	0.0076	0.0189	0.0054
Taylor J	St. Francis Hospital	CABG	0.0118	0.0078	0.0172	0.0249
Taylor J	St. Francis Hospital	Valve	0.0226	0.0156	0.0318	0.0050
Marvasti M	St. Josephs Hospital	Valve	0.0232	0.0146	0.0348	0.0414
Nazem A	St. Josephs Hospital	Valve	0.0216	0.0139	0.0320	0.0300
Canavan T	St. Peters Hospital	CABG	0.0092	0.0052	0.0154	0.0481
Bennett E	St. Peters Hospital	Valve	0.0161	0.0095	0.0253	0.0081
Sarabu M	Vassar Bros. Med Ctr	CABG	0.0071	0.0033	0.0142	0.0102
Sarabu M	Vassar Bros. Med Ctr	Valve	0.0135	0.0074	0.0231	0.0006
Lansman S	Westchester Med Ctr	CABG	0.0085	0.0039	0.0168	0.0070

physician	hospital	proc	Rate Est.	Lower	Upper	Pr(R>1)
Malekan R	Westchester Med Ctr	CABG	0.0094	0.0043	0.0190	0.0028
Spielvogel D	Westchester Med Ctr	CABG	0.0075	0.0037	0.0136	0.0015
Lansman S	Westchester Med Ctr	Valve	0.0159	0.0087	0.0274	0.0140
Malekan R	Westchester Med Ctr	Valve	0.0175	0.0091	0.0319	0.0062
Spielvogel D	Westchester Med Ctr	Valve	0.0140	0.0081	0.0226	0.0004

This table shows the physicians whose ratio has a posterior probability of exceding 1 of greater than 0.95. In other words, these are physicians with a high probability of doing worse than expected, since a ratio of greater than 1 indicates that the modeled rate is greater than the expected mortality rate.

physician	hospital	proc	Rate Est.	Lower	Upper	Pr(R>1)
Schwartz C F	Bellevue Hospital Ctr	CABG	0.0146	0.0082	0.0251	0.9936
Schwartz C F	Bellevue Hospital Ctr	Valve	0.0280	0.0162	0.0466	0.9995
Hoffman D	Beth Israel Med Ctr	Valve	0.0255	0.0149	0.0409	0.9606
Aldridge J	Buffalo General Hosp	Valve	0.0232	0.0129	0.0413	0.9919
Ashraf M	Buffalo General Hosp	Valve	0.0186	0.0116	0.0313	0.9867
El Amir N	Champ.Valley Phys Hosp	Valve	0.0168	0.0088	0.0306	0.9893
Bell-Thomson J	Erie County Med Ctr	CABG	0.0175	0.0104	0.0293	1.0000
Picone A	Erie County Med Ctr	CABG	0.0211	0.0116	0.0364	0.9988
Bell-Thomson J	Erie County Med Ctr	Valve	0.0233	0.0146	0.0367	1.0000
Loulmet D F	Lenox Hill Hospital	CABG	0.0169	0.0096	0.0286	1.0000
Ciuffo G B	Lenox Hill Hospital	Valve	0.0496	0.0291	0.0791	0.9969
Stephens G A	Maimonides Medical Ctr	CABG	0.0250	0.0122	0.0478	0.9963
Saunders P	Maimonides Medical Ctr	Valve	0.0243	0.0108	0.0541	0.9772
Stephens G A	Maimonides Medical Ctr	Valve	0.0337	0.0181	0.0596	0.9889
Weinstein S	Montefiore - Moses	Valve	0.0309	0.0135	0.0690	1.0000
Bello R A	Montefiore - Weiler	Valve	0.0422	0.0271	0.0623	0.9795
D Alessandro D A	Montefiore - Weiler	Valve	0.0328	0.0197	0.0532	0.9982
Adams D H	Mount Sinai Hospital	CABG	0.0122	0.0078	0.0187	0.9738
Anyanwu A C	Mount Sinai Hospital	CABG	0.0282	0.0158	0.0492	0.9848
Ciuffo G B	Mount Sinai Hospital	CABG	0.0297	0.0179	0.0465	0.9945
Griepp R	Mount Sinai Hospital	CABG	0.0165	0.0075	0.0351	0.9983
Nguyen K	Mount Sinai Hospital	CABG	0.0167	0.0077	0.0364	1.0000
Reddy R C	Mount Sinai Hospital	CABG	0.0258	0.0173	0.0377	0.9999
Stelzer P	Mount Sinai Hospital	CABG	0.0210	0.0123	0.0343	0.9985
Ciuffo G B	Mount Sinai Hospital	Valve	0.0564	0.0361	0.0847	0.9991
Nguyen K	Mount Sinai Hospital	Valve	0.0321	0.0153	0.0672	1.0000
Reddy R C	Mount Sinai Hospital	Valve	0.0490	0.0344	0.0681	1.0000
Zias E	Mount Sinai Hospital	Valve	0.0326	0.0201	0.0522	0.9837
Tortolani A	NY Methodist Hospital	CABG	0.0235	0.0124	0.0414	0.9708
Argenziano M	NYP- Columbia Presby.	CABG	0.0227	0.0146	0.0341	0.9961

physician	hospital	proc	Rate Est.	Lower	Upper	Pr(R>1)
Naka Y	NYP- Columbia Presby.	CABG	0.0234	0.0161	0.0330	0.9902
Stewart A S	NYP- Columbia Presby.	CABG	0.0227	0.0154	0.0328	0.9801
Argenziano M	NYP- Columbia Presby.	Valve	0.0434	0.0294	0.0617	0.9985
Chen J M	NYP- Columbia Presby.	Valve	0.0306	0.0143	0.0637	1.0000
Naka Y	NYP- Columbia Presby.	Valve	0.0446	0.0323	0.0595	0.9557
Quaegebeur J	NYP- Columbia Presby.	Valve	0.0311	0.0142	0.0638	0.9737
Naka Y	NYP- Weill Cornell	CABG	0.0203	0.0114	0.0314	1.0000
Tortolani A	NYP- Weill Cornell	CABG	0.0187	0.0098	0.0345	0.9997
Chen J M	NYP- Weill Cornell	Valve	0.0261	0.0120	0.0556	0.9685
Naka Y	NYP- Weill Cornell	Valve	0.0388	0.0228	0.0574	1.0000
Tortolani A	NYP- Weill Cornell	Valve	0.0359	0.0194	0.0629	1.0000
Culliford A	NYU Hospitals Center	CABG	0.0150	0.0082	0.0261	0.9510
Loulmet D F	NYU Hospitals Center	CABG	0.0167	0.0097	0.0274	0.9925
Mosca R S	NYU Hospitals Center	CABG	0.0142	0.0064	0.0308	0.9987
Ribakove G	NYU Hospitals Center	CABG	0.0195	0.0111	0.0330	0.9757
Deanda A	NYU Hospitals Center	Valve	0.0287	0.0161	0.0492	0.9985
Mosca R S	NYU Hospitals Center	Valve	0.0272	0.0127	0.0562	0.9932
Joyce F	St. Elizabeth Med Ctr	CABG	0.0228	0.0147	0.0339	0.9516
Joyce F	St. Elizabeth Med Ctr	Valve	0.0364	0.0251	0.0509	0.9745
Lamendola C	St. Francis Hospital	Valve	0.0436	0.0312	0.0590	0.9871
Robinson N	St. Francis Hospital	Valve	0.0394	0.0292	0.0520	0.9717
Rosenberg J	St. Josephs Hospital	CABG	0.0356	0.0236	0.0526	0.9801
Rosenberg J	St. Josephs Hospital	Valve	0.0563	0.0394	0.0780	0.9847
Swistel D	St. Lukes at St. Lukes	Valve	0.0467	0.0331	0.0638	0.9974
Reich H	St. Peters Hospital	Valve	0.0226	0.0130	0.0375	0.9780
Knight P	Strong Memorial Hosp	CABG	0.0204	0.0139	0.0292	0.9967
Alfieris G	Strong Memorial Hosp	Valve	0.0300	0.0133	0.0648	0.9830
Knight P	Strong Memorial Hosp	Valve	0.0339	0.0252	0.0444	0.9986
McLarty A	Univ.Hosp-Stony Brook	CABG	0.0280	0.0164	0.0461	0.9968
McLarty A	Univ.Hosp-Stony Brook	Valve	0.0530	0.0321	0.0836	0.9919

Objective 3

Dr. Tortolani has performed these procedures at both the NY Methodist Hospital and NYP-Weill Cornell. To assess whether Dr. Tortolani has a higher mortality rate than expected, we will use information from both these hospitals. The following table shows which the Observed Mortality Ratio(OMR), Expected Mortality Ratio (EMR), median and credible interval for the ratio between modeled mortality ratio and EMR, and the probability of whether that ratio is greater than 1.

hospital	proc	n	OMR	EMR	m.Ratio	Lower	Upper	Pr(R>1)
NY Methodist Hospital	CABG	138	2.17	1.27	1.8496	0.9781	3.2572	0.9708

hospital	proc	n	OMR	EMR	m.Ratio	Lower	Upper	Pr(R>1)
NY Methodist Hospital	Valve	221	3.62	2.12	1.4952	0.8706	2.4267	0.9293
NYP- Weill Cornell	CABG	4	25.00	0.57	3.2866	1.7165	6.0461	0.9997
NYP- Weill Cornell	Valve	5	20.00	0.75	4.7802	2.5859	8.3890	1.0000

Within the Methodist hospital, there is 0.97 or 0.93 probability that Dr. Tortolani is doing worse than expected in CABG and valve or valve/CABG procedures. These both seem quite high. Understanding that Dr. Tortolani also has performed these procedures at Cornell is important. However, it is also important to understand that he has only performed 4 CABG and 5 valve procedures there. The probability that the ratios are greater than 1 is 0.843 and 1.00 for the CABG and valuve procedures, resepectively. These probabilities reflect a smaller sample size and higher observed mortality rate. There seems to be evidence that Dr. Tortolani is doing worse than expected in these procedures.

Objective 4

The following table shows similar information as the previous table. However, this is for each doctor at NYP-Columbia Presbyterian Hospital, including the doctors who also work elsewhere and their respective hospitals. However, for this, we also include the total number of cases for each of the doctors because it helps to quantify our uncertainty better in this context.

physician	hospital	proc	n	OMR	EMR	m.Ratio	Lower	Upper	Pr(R>1)
Argenziano M	C. Presby	CABG	150	4.00	1.25	1.8186	1.1705	2.7303	0.9961
Naka Y	C. Presby	CABG	298	3.02	1.50	1.5596	1.0758	2.2021	0.9902
Smith C	C. Presby	CABG	114	2.63	1.03	1.2685	0.7880	1.9322	0.8415
Stewart A S	C. Presby	CABG	178	3.37	1.51	1.5051	1.0211	2.1717	0.9801
Takayama H	C. Presby	CABG	75	1.33	1.75	0.8392	0.4377	1.5041	0.2854
Williams M R	C. Presby	CABG	150	0.67	1.45	1.1455	0.7193	1.7458	0.7200
Argenziano M	C. Presby	Valve	388	4.38	2.46	1.7646	1.1931	2.5066	0.9985
Chen J M	C. Presby	Valve	1	0.00	0.31	9.8787	4.6131	20.5491	1.0000
Naka Y	C. Presby	Valve	580	4.66	3.38	1.3210	0.9546	1.7603	0.9557
Quaegebeur J	C. Presby	Valve	2	0.00	1.43	2.1779	0.9900	4.4617	0.9737
Smith C	C. Presby	Valve	674	2.08	3.03	0.8303	0.5504	1.2051	0.1723
Stewart A S	C. Presby	Valve	558	4.48	3.57	1.2169	0.8679	1.6571	0.8772
Takayama H	C. Presby	Valve	126	2.38	3.08	0.9175	0.4952	1.5922	0.3836
Williams M R	C. Presby	Valve	445	3.60	4.19	0.7594	0.5036	1.1075	0.0804
Naka Y	W. Cornell	CABG	2	0.00	0.41	4.9401	2.7884	7.6663	1.0000
Chen J M	W. Cornell	Valve	6	0.00	1.26	2.0690	0.9535	4.4111	0.9685
Naka Y	W. Cornell	Valve	2	0.00	0.41	9.4630	5.5646	13.9903	1.0000

Using this information, we could set a probability threshold of the ratio between modeled

mortality rates and EMR to decide whether there should be concern for any of the clinicians' performance. To illustrate, we decide that the threshold is that if there is 0.80 probability that a doctor is underperforming, then we should be concerned. Under these conditions, we should be concerned about the valve operations for doctors Argenziano, Chen, Naka, Quaegebeur, and Stewart (no CABG procedures meet this criteria). If we investigate this further, we see that both Checn and Quaeagebeur have an extremely small procedure loads, and so this probability is only reflective of prior and population information. Check and Naka both perform very little operations at NYP-Weill Cornell, and their ratio is also quite high, but the similar story holds. However, there should be concern for Argenziano, Naka, and Stewart because they all have high case-loads and high probability that they are underperforming.

Objective 5

According to the table below, Dr. Ciaburri does not have an observed mortality in the data set. However, analyzing this number alone is not sufficient because it may be due to a relatively small procedue load. Analzying credible interval for the ratios of modeled mortality rate to expected mortaility rate shows that Dr. Ciaburri does in fact exceed expectation, especially for the valve surgery in the Methodist hospital. Also, observing the probability that their ratio is greater than 1 supports the idea that Dr. Ciaburri is exceeding expectation. However, both of these measures are not complete for ranking physicians. If I were to rank physicians, I would rank them according to their upper bound of the credible interval for the ratio of interest. This way we can take into consideration the variance of these estimates, which is important. These are still conditional on both hospital and procedure. We do a weighted average across the modeled probabilities and expected mortaility rate, weighting the number of cases from each physician. Although this is ad-hoc, it makes sense to use it as a rating system for physicians or hospitals. Doing it this way, we see that Dr. Ciaburri is ranked quite highly, but he is not the highest ranked physician, who is actualy Dr. Spielvogel.

hospital	proc	n	OMR	EMR	m.Ratio	Lower	Upper	Pr(R>1)
NY Methodist Hospital	CABG	65	0	2.22	0.5364	0.2357	1.1021	0.0466
NY Methodist Hospital	Valve	117	0	3.43	0.4724	0.2194	0.9116	0.0115
NYP- Weill Cornell	CABG	1	0	1.00	0.9493	0.4495	1.8858	0.4424
NYP- Weill Cornell	Valve	2	0	2.79	0.6562	0.3187	1.2503	0.1100
Vassar Bros. Med Ctr	CABG	1	0	0.60	0.9303	0.3844	2.1107	0.4318
Vassar Bros. Med Ctr	Valve	1	0	0.60	1.7478	0.8004	3.6519	0.9240

name	total.n	med.ratio	lower.ratio	upper.ratio	prob.above.1
Palazzo R	413	0.3493848	0.1699925	0.6670523	0.0002
Scheinerman S J	515	0.3719183	0.1917654	0.6707655	0.0001
Spielvogel D	911	0.4291044	0.2570080	0.6776561	0.0003
Sarabu M	576	0.4396269	0.2445989	0.7458709	0.0004
Malekan R	282	0.4392069	0.2335621	0.7866211	0.0029
Girardi L	1165	0.5706406	0.3699288	0.8358629	0.0019

name	total.n	med.ratio	lower.ratio	upper.ratio	prob.above.1
Jacobowitz I	729	0.5363971	0.3187381	0.8475615	0.0025
Lansman S	508	0.5091901	0.2821688	0.8673839	0.0066
Kalimi R	893	0.6071168	0.3914022	0.8928109	0.0041
Taylor J	1215	0.6505925	0.4491830	0.9117341	0.0048
Graver L	607	0.5800945	0.3482375	0.9272234	0.0110
Ciaburri D	187	0.4979645	0.2362139	0.9348948	0.0150
Bennett E	694	0.6233800	0.3725041	0.9674016	0.0166
Lang S	699	0.5551089	0.2869688	0.9784334	0.0211
Hall M	613	0.6610654	0.4200686	0.9900744	0.0226

Objective 6

To recognize high and low achieving hospitals, we use a similar process as we do for the physicians. We use the posterior samples for the modeled rates for each of the combinations of the physicians and the procedures. We then average these modeled rates weighted by the number of cases, and then also average the EMR in a similar fashion. We then take these draws to calculate these ratios and and find the posterior credible intervals. We sort these hospitals according to the upper bound of the credible interval for this ratio and rank them in this way.

rank	name	hosp.n	lower.ratio	med.ratio	upper.ratio	Pr(R>1)
1	LIJ Medical Center	1716	0.3282934	0.4896890	0.7032847	0.0000
2	Westchester Med Ctr	2235	0.3737278	0.5186043	0.7047616	0.0000
3	NYP- Weill Cornell	2507	0.5264098	0.6913059	0.8857455	0.0007
4	Vassar Bros. Med Ctr	1771	0.4781258	0.6765876	0.9394283	0.0082
5	North Shore Univ Hosp	3859	0.6664775	0.8061658	0.9619156	0.0081
36	Strong Memorial Hosp	2549	1.1866698	1.4913070	1.8407000	0.9996
37	St. Lukes at St. Lukes	962	1.0356058	1.3960893	1.8408676	0.9854
38	M I Bassett Hospital	453	0.7827039	1.2392815	1.8882139	0.8345
39	Champ.Valley Phys Hosp	398	0.7053901	1.1895523	1.9037703	0.7559
40	Arnot Ogden Med Ctr	725	0.8702100	1.3324804	1.9444474	0.9161

Objective 7

Using a model based recommendations allow us to take into consideration not only other variables, but it also allows us to quantify our uncertainty more efficiently in our estimates. This uncertainty quantification is crucial in making meaningful recommendations because it allows us to meaningfull account for different circumstances like small case load with very high or low observed mortality rates.