

# **Development of Severity-Adjustment Models for Hospital Efficiency Data**

**A White Paper Analysis**

**For**

**The Leapfrog Group**

**By**

**The Center for Health Systems Research and Analysis  
University of Wisconsin – Madison**

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## **Forward from the Leapfrog Group**

The Leapfrog Group is asking hospitals to report on their average length of stay for four procedures and conditions – coronary artery bypass graft, percutaneous coronary intervention, acute myocardial infarction, and pneumonia - as part of the resource utilization measures introduced in the 2008 Leapfrog Hospital Survey. Leapfrog will risk-adjust these values to account for patient comorbidities and patient demographics that cause systematic variation in the length of stay for that specific procedure or condition.

The risk-adjustment models presented in this paper to adjust length of stay were developed by the Center for Health Systems Research and Analysis (CHSRA) at the University of Wisconsin – Madison. Leapfrog specifically asked CHSRA to develop models that were based on aggregated patient data, as to minimize the financial burden, time burden, and patient privacy issues for hospitals associated with submitting patient-specific data. Patient-specific data would likely require hospitals to hire a vendor to submit their data, given Leapfrog’s policy of not directly accepting patient-identifiable information. Leapfrog recognizes that more advanced modeling approaches would better address variation, but hospitals would be the ones to bear the cost of a more sophisticated model and it would also likely mean that the models would not be open source in terms of their construction (e.g., use of APR-DRGs).

After an initial review of the models, Leapfrog asked CHSRA to repeat their analysis using the geometric mean length of stay as the adjusted variable, instead of the arithmetic (or simple) mean, as this alternative was recommended by the Principal Investigator. Using the geometric mean for risk-adjustment analysis is the method also suggested by the NQF Technical Advisory Panel to reduce the impact of outliers on a hospital’s results. This adjustment to the models improved the r-squared values, which now range between 12% and 29%.

Leapfrog has been asked why it decided to develop its own risk-adjustment models when other organizations have already developed risk-adjustment models. The models developed by other organizations have been for metrics other than length of stay. Risk-adjustment models are unique to the metric that is being adjusted (e.g., a risk-adjustment model developed for mortality is likely not appropriate for direct application to length of stay). The risk factors that explain variation in length of stay and the magnitude of their explanation are most likely different than the risk factors that explain variation in other metrics.

Leapfrog asked CHSRA to also make recommendations for future enhancements to the models, which are included in the white paper. Leapfrog will continue to review these recommendations and make improvements as feasible.

## **Development of Severity-Adjustment Models for Hospital Efficiency Data**

### **Executive Summary**

At Leapfrog's request, the Center for Health Systems Research and Analysis (CHSRA) of the University of Wisconsin – Madison has analyzed data from the 2003, 2004 and 2005 National Hospital Discharge Surveys (NHDS) and constructed statistical models appropriate for risk adjustment of average lengths of stay reported by member hospitals. Separate models were developed for each of four patient stay categories: Acute Myocardial Infarction (AMI), Coronary Artery Bypass Graft (CABG), Percutaneous Coronary Intervention (PCI) and Pneumonia. These models are understandable, simple to apply and have a significant impact on hospital comparisons.

Candidate risk factors were summarized from prior Leapfrog modeling and a literature review conducted by CHSRA. Only those factors with statistically significant effects were retained. Factors with unanticipated negative effects were also dropped from each model. More elaborate models were fit to the data (employing additional explanatory variables and incorporating DRG classification), but have been left for consideration as future refinements.

Based on this analysis, we recommend the following:

- Initially employ the basic linear models presented in Tables 4 through 7 to risk adjust hospital average log lengths of stay.
- Update the model coefficients each year using the most recent three years of NHDS data.
- Rather than masking results for small hospitals, consider providing a confidence interval for the reported values reflecting the volume of observations.
- Consider adding a “secondary” indicator in the PCI and CABG models to improve the model  $R^2$  values without substantial tabulation effort on the part of member hospitals.
- For future refinements, consider incorporation of a DRG-based component, possibly piggy-backing on CMS's recent efforts to refine the Medicare hospital DRG system.
- Consider presenting both unadjusted and risk-adjusted values to the user.

## Introduction

**Purpose:** The Leapfrog Group is currently revamping its hallmark hospital public reporting initiative, the Leapfrog Hospital Quality and Safety Survey. Among the proposed changes, the 2008 Survey will require hospitals to report on the efficiency of care for CABG, PCI, pneumonia, and AMI patients. The addition of this valuable, cutting-edge information will enable purchasers and consumers to make the critical connection between the cost and quality of their hospital care. Leapfrog has engaged the Center for Health Systems Research and Analysis (CHSRA) of the University of Wisconsin – Madison to develop the severity-adjustment model for this efficiency information.

**Objectives:** Our understanding is that the major project objectives include:

1. Obtain a representative (all-payer, 2003 or later, with diagnosis and procedure codes) dataset of hospital discharges for use in modeling length of stay as a function of selected risk factors (e.g., patient characteristics, diagnosis codes, procedure codes).
2. Propose candidate risk factors based on prior Leapfrog analyses, a literature review and consultation with clinical experts.
3. Using the hospital discharge dataset, fit linear regression models for each of four categories of hospital stay (CABG, PCI, AMI and Pneumonia) suitable on statistical and clinical grounds for application to non-patient-specific discharge data from participating hospitals in risk-adjusting lengths of stay.
4. Prepare a white paper summary of the modeling process and results suitable for hospital review (and possible publication).

**Data Source:** We used data from recent rounds of the National Hospital Discharge Survey (NHDS). The NHDS is an annual three-stage national sample of hospital discharges. The first two stages select a sample of short-stay, general or children's hospitals with six or more staffed beds. The third stage randomly selects discharges within each of the selected hospitals. The most recent published round of the NHDS in 2005 contains information abstracted from 375,000 discharges arising from 444 hospitals.

NHDS discharge records contain information on age, sex, race, marital status, discharge year and month, discharge status (home, transfer, death, etc.), length of stay in days, region (northeast, midwest, south, west), hospital size (beds), hospital ownership type, ICD-9 diagnoses (up to seven codes) and procedures (up to four codes), payment sources, DRG, admission type (emergency, urgent, elective, newborn) and admission source (physician referral, transfer, etc.). These data items are typically available from hospital discharge records and are sufficient to construct risk factors such as those outlined in the Severity Model white paper included with the RFP.

NHDS data is de-identified and can be downloaded directly from the NCHS website at <http://www.cdc.gov/nchs/about/major/hdasd/nhds.htm>. Since the survey is repeated

annually, model coefficients can be updated annually, if necessary. Appendix A provides a file layout for the NHDS data.

**Methodology:** The analysis followed these steps to address the project objectives:

Step 1: CHSRA reviewed prior Leapfrog risk factor development work along with current literature to form a list of candidate risk factors available from the NHDS. This list was reviewed by a clinical expert at CHSRA for face validity/reasonableness.

Step 2: CHSRA constructed SAS code to identify hospital stay categories and candidate risk factors for each NHDS record. We reviewed changes in ICD9 diagnosis and procedure codes that would affect the application of current specifications to data from 2003 through 2005. We found only two cases where coding changes had an impact, one that could be overcome by employing the old codes and one that could not be resolved. The latter case affected only 2003 data in the determination of RF39 – Altered Mental Status, which was not employed in any of the proposed models.

Step 3: CHSRA applied multivariate linear regression to data from the 2003, 2004 and 2005 NHDS rounds to model variation in length of stay (days) as a function of candidate risk factors. Risk factors were screened for statistical significance and the coefficients were reviewed for clinical reasonableness (sign and magnitude). We also compared risk factor coefficients across years for consistency.

Step 4: We summarized the NHDS discharge data into hypothetical hospital groupings, mimicking the tabulations expected of participating hospitals in the future. Risk-adjusted LOS values were obtained from the observed average LOS for each facility by dividing by the expected LOS. Rankings of hospital average lengths of stay before and after risk adjustment were summarized.

Step 5: We provided a draft white paper for review by Leapfrog.

Step 6: After receiving comments from Leapfrog, we made suggested modifications to the analysis and provided this final version of the white paper.

## Results

**Literature Review:** Specifications for the four patient categories (AMI, PCI, CABG and pneumonia) and candidate risk factors were provided by Leapfrog. Appendix B provides a summary of the diagnosis and procedure codes employed to define each category and the risk factors. CHSRA’s review found literature supporting most of the candidate risk factors for each category and indicated that some risk factors defined for one category might also be considered for other categories. Table 1 summarizes the status of each risk factor following this review.

**Table 1 – Literature Review of Risk Factors**

Risk Factor ID	Description	AMI	PCI	CABG	Pneumonia
01	Age >=55	✓	✓	✓	✓
02	Male	✓	✓	✓	✓
03	Site of infarction: anterior or anteriolateral	✓	•		
04	Site of infarction: subendocardial	•	•		
05	Diabetes	✓	✓	✓	
06	Cancer	•	✓		
07	Chronic cerebrovascular disease	•	✓	✓	
08	Chronic renal disease	✓	✓	✓	
09	Chronic liver disease	•	•	+	
10	Obesity	✓	✓		
11	COPD ( <i>definition differs from RF36</i> )	✓	✓	✓	
12	Cardiomyopathy	•	✓	•	
13	Chronic cardiac conditions	✓	✓	✓	
14	History of PTCA		✓		
15	Atherosclerosis and lipid disorders	•	✓	✓	
16	PCI	•		✓	
17	CABG	•	✓		
18	Musculoskeletal conditions		✓	✓	
19	AMI		✓	✓	
20	CAD without prior CABG			✓	
21	CAD with prior CABG	•		✓	
22	Diabetes (RF05) <b>AND</b> Obesity (RF10)	•		+	
30	Cancer except basal or squamous-cell skin cancer				✓
31	Cirrhosis or chronic hepatitis				✓
32	Stroke or transient ischemic attack	+			•
33	Congestive heart failure	+	+	+	✓
34	Kidney disease				✓
35	Suspected or documented HIV				✓
36	COPD ( <i>definition differs from RF11</i> )				✓
37	Inability to take oral medications				✓

Risk Factor ID	Description	AMI	PCI	CABG	Pneumonia
38	Temperature below 95°F or above 104°F				✓
39	Altered mental status				✓
41	Sodium below 130 mEq/L				✓
42	Hematocrit less than 30%				✓
43	Pleural effusion				✓
44	Septicemia				•
45	Respiratory failure				•
<i>Legend</i>					
✓	<i>Original risk factor supported by CHSRA literature review</i>				
•	<i>Original risk factor unsupported by CHSRA literature review</i>				
+	<i>Risk factor suggested by CHSRA literature review</i>				

For initial modeling, we used any risk factor included in the Leapfrog specifications or suggested by the literature review. We refer to these as the “select” risk factors in later discussions.

Appendix C provides a summary of the literature review articles as they relate to each risk factor within each patient category.

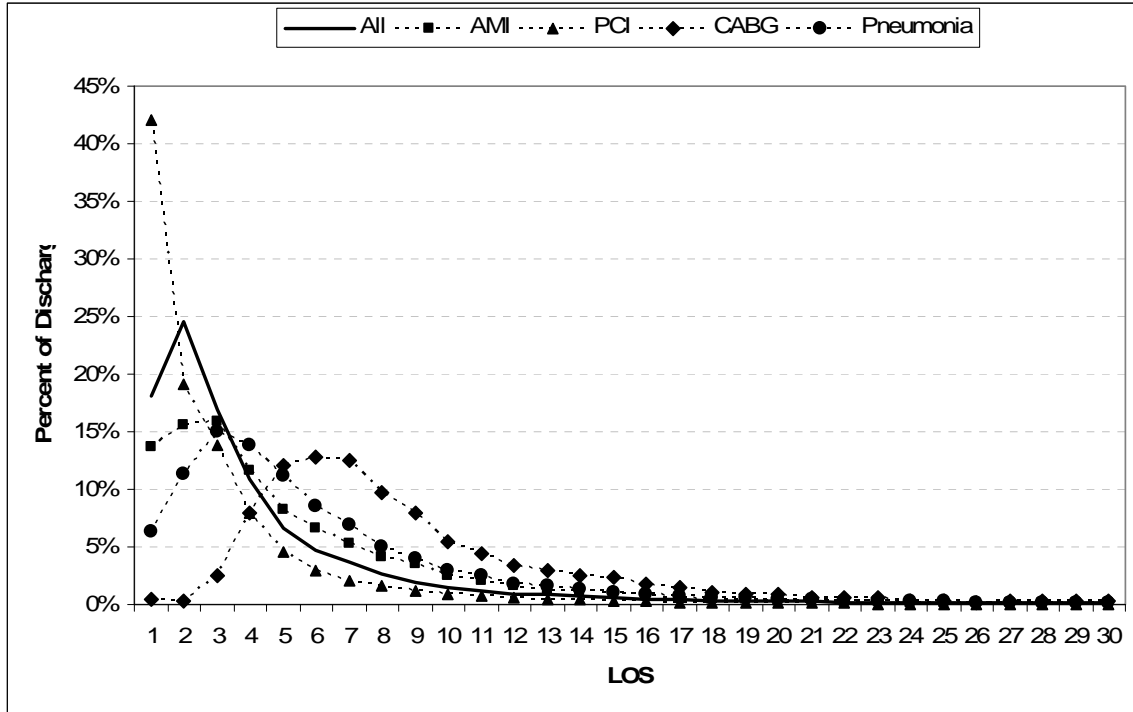
**Data Exploration:** The NHDS data provides several thousand discharges for each of the four patient categories. Table 2 summarizes the discharge counts by year and patient category.

**Table 2 – 2003-2005 NHDS Discharge Counts**

Category	Count
AMI	20,083
PCI	20,382
CABG	7,753
Pneumonia	33,029
All Discharges	1,065,687

Length of stay includes the day of admission and excludes the day of discharge, unless the patient is discharged on the day of admission, in which case the length of stay is defined as one day. Figure 1 shows the distribution of the length of stay by patient category for all three years of the NHDS data.

**Figure 1 – Length of Stay Histogram**



Note that the length of stay distribution is skewed to the right, meaning that large values are not uncommon (i.e., more frequent than would be the case with a comparable normal random variable). This implies that the average length of stay for small hospitals may be distorted by a few outlying observations. The impact of such outliers can be moderated by simple transformations (e.g., log, square root) or by truncating observations beyond a specified threshold.

After discussing this issue with Leapfrog, a log transformation of the length of stay was adopted for final risk modeling. This will require hospitals to report the geometric mean of lengths of stay, rather than (or in addition to) the arithmetic mean. (The arithmetic mean of a group of  $n$  values is the sum of the values divided by  $n$ . The geometric mean is the  $n^{\text{th}}$  root of the product of the values.) The geometric mean is a readily available function in most computational environments, e.g., the GEOMEAN function in Excel. Taking the log of the reported geometric mean yields the arithmetic mean of the log of lengths of stay, which is consistent with the response variable in the proposed linear regression severity adjustment model.

Other than AMI, discharges qualify for a patient category on the basis of either the primary diagnosis/procedure code or one of the secondary codes assigned. (The AMI category is defined solely by the primary diagnosis.) “Secondary” discharges exhibit significantly longer average lengths of stay than their “primary” counterparts. (See Table 3 below.) Discharges belonging to a category due to a secondary code presumably have a primary diagnosis/procedure that significantly extends the expected hospital stay.

Table 3 shows selected summary statistics for discharges by patient category and by primary vs. secondary coding status. The statistics include the median, mean and standard deviation for the unadjusted length of stay and for the log length of stay.

**Table 3 – Length of Stay Summary Statistics**

Item	AMI	PCI		CABG		Pneumonia	
	Primary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Count	20,083	19,258	1,124	6,338	1,415	27,606	5,423
LOS							
Median	4.00	2.00	6.00	7.00	9.00	4.00	7.00
Mean	5.82	2.80	8.21	9.18	13.51	5.98	10.35
Std Dev	6.90	3.45	10.43	7.17	12.27	5.86	11.51
ln(LOS)							
Median	1.39	0.69	1.79	1.95	2.20	1.39	1.95
Mean	1.38	0.69	1.65	2.05	2.33	1.51	1.95
Std Dev	0.85	0.74	0.96	0.53	0.72	0.73	0.89

Note that, prior to adjustment, the mean length of stay is consistently greater than the median, reflecting the heavy-tailed nature of the distribution. The log transformation results in means closer to the medians, increasing the symmetry of the distribution and reducing the impact of large outliers.

**Risk Adjustment Model:** Within each patient category we fit a sequence of linear regression models to the log lengths of stay. The starting model in each case provided for those select risk factors (see Table 1 above) having statistically significant coefficients with signs consistent with clinical expectations. Based upon input from Leapfrog, these starting models were further simplified by eliminating risk factors with relatively small coefficients and/or affecting a small percentage of discharges, with only minor reductions in model R<sup>2</sup> values.

Refinements, involving additional explanatory variables, were explored in subsequent models in each sequence. While these refinements resulted in improved model performance, we feel that the starting model in each category will be most easily understood and implemented by member hospitals during the rollout of the new efficiency measures. We will allude to some aspects of the more refined models in the discussion section that follows this section.

Tables 4 through 7 summarizes the fitted starting models recommended for initial use in risk adjusting hospital length of stay tabulations.

**Table 4 – AMI Risk Adjustment Model (log LOS)**

Variable	Label	Parameter Estimate	Standard Error	t Value	Pr >  t
<b>Intercept</b>	Intercept	0.90309	0.01407	64.20	<.0001
<b>rf17</b>	CABG	1.06319	0.01865	57.02	<.0001
<b>rf33</b>	Congestive heart failure	0.47231	0.01183	39.93	0.0037
<b>rf32</b>	Stroke or transient ischemic attack	0.58837	0.03061	19.22	0.0201
<b>rf08</b>	Chronic renal disease	0.28977	0.01844	15.72	<.0001
<b>rf01</b>	Age GE 55	0.19802	0.01379	14.36	<.0001
<b>rf06</b>	Cancer	0.23670	0.03378	7.01	<.0001
<b>rf09</b>	chronic liver disease	0.28350	0.08068	3.51	0.0034
<b>rf16</b>	PCI	0.02017	0.01196	1.69	<.0001
	R-Square	0.2416			
	Root MSE	0.74180			

**Table 5 – PCI Risk Adjustment Model (log LOS)**

Variable	Label	Parameter Estimate	Standard Error	t Value	Pr >  t
<b>Intercept</b>	Intercept	0.41126	0.00604	68.05	<.0001
<b>rf19</b>	AMI	0.59360	0.00992	59.81	<.0001
<b>rf33</b>	Congestive heart failure	0.62010	0.01423	43.59	<.0001
<b>rf17</b>	CABG	1.27329	0.04593	27.72	<.0001
<b>rf08</b>	Chronic renal disease	0.46039	0.02325	19.80	<.0001
<b>rf11</b>	COPD	0.24593	0.01655	14.86	<.0001
<b>rf06</b>	Cancer	0.31939	0.03827	8.35	<.0001
<b>rf09</b>	chronic liver disease	0.37100	0.09878	3.76	0.0002
	R-Square	0.2925			
	Root MSE	0.66190			

**Table 6 – CABG Risk Adjustment Model (log LOS)**

Variable	Label	Parameter Estimate	Standard Error	t Value	Pr >  t
<b>Intercept</b>	Intercept	1.89733	0.01886	100.60	<.0001
<b>rf33</b>	Congestive heart failure	0.32368	0.01567	20.65	<.0001
<b>rf19</b>	AMI	0.21230	0.01448	14.66	<.0001
<b>rf08</b>	Chronic renal disease	0.33833	0.02715	12.46	<.0001
<b>rf01</b>	Age GE 55	0.15761	0.01644	9.59	<.0001
<b>rf02</b>	Is Male	-0.10828	0.01342	-8.07	<.0001
<b>rf11</b>	COPD	0.08532	0.01752	4.87	<.0001
<b>rf12</b>	Cardiomyopathy	0.13713	0.03490	3.93	<.0001
<b>rf09</b>	chronic liver disease	0.43287	0.11976	3.61	0.0003
	R-Square	0.1502			
	Root MSE	0.53464			

**Table 7 – Pneumonia Risk Adjustment Model (log LOS)**

Variable	Label	Parameter Estimate	Standard Error	t Value	Pr >  t
<b>Intercept</b>	Intercept	1.25064	0.00943	132.58	<.0001
<b>rf45</b>	Respiratory failure	0.45802	0.01144	40.02	<.0001
<b>rf44</b>	Septicemia	0.32223	0.01284	25.10	<.0001
<b>rf33</b>	Congestive heart failure	0.17931	0.00924	19.41	<.0001
<b>rf43</b>	Pleural effusion	0.37170	0.01890	19.67	<.0001
<b>rf01</b>	Age GE 55	0.14158	0.01044	13.56	<.0001
<b>rf34</b>	Kidney disease	0.11281	0.01123	10.04	<.0001
<b>rf36</b>	COPD	0.06800	0.00878	7.75	<.0001
<b>rf32</b>	Stroke - transient ischemic attack	0.29821	0.04448	6.70	<.0001
<b>rf31</b>	Cirrhosis or chronic hepatitis	0.20157	0.04315	4.67	<.0001
	R-Square	0.1245			
	Root MSE	0.72431			

These simple models yield modest R<sup>2</sup> values ranging from 12% to 29%. The coefficients are statistically significant and are positive with the exception of the RF02 – “Is Male” in the CABG model.

Parameter estimates from each year of the NHDS are shown in Tables 8 through 11.

**Table 8 – AMI Parameters by Year**

Variable	Label	Parameter Estimates			
		All Yrs	2003	2004	2005
<b>Intercept</b>	Intercept	0.90	0.92	0.89	0.90
<b>rf17</b>	CABG	1.06	1.06	1.08	1.05
<b>rf33</b>	Congestive heart failure	0.47	0.47	0.46	0.48
<b>rf32</b>	Stroke or transient ischemic attack	0.59	0.53	0.64	0.60
<b>rf08</b>	Chronic renal disease	0.29	0.34	0.27	0.27
<b>rf01</b>	Age GE 55	0.20	0.19	0.22	0.18
<b>rf06</b>	Cancer	0.24	0.27	0.19	0.24
<b>rf09</b>	chronic liver disease	0.28	0.42	0.15	0.27
<b>rf16</b>	PCI	0.02	0.02	0.03	0.01

**Table 9 – PCI Parameters by Year**

Variable	Label	Parameter Estimates			
		All Yrs	2003	2004	2005
<b>Intercept</b>	Intercept	0.41	0.42	0.41	0.40
<b>rf19</b>	AMI	0.59	0.60	0.60	0.58
<b>rf33</b>	Congestive heart failure	0.62	0.61	0.62	0.64
<b>rf17</b>	CABG	1.27	1.26	1.27	1.29
<b>rf08</b>	Chronic renal disease	0.46	0.57	0.49	0.38
<b>rf11</b>	COPD	0.25	0.23	0.22	0.28
<b>rf06</b>	Cancer	0.32	0.33	0.33	0.30
<b>rf09</b>	chronic liver disease	0.37	0.35	0.13	0.53

**Table 10 – CABG Parameters by Year**

Variable	Label	Parameter Estimates			
		All Yrs	2003	2004	2005
<b>Intercept</b>	Intercept	1.90	1.90	1.88	1.91
<b>rf33</b>	Congestive heart failure	0.32	0.31	0.34	0.32
<b>rf19</b>	AMI	0.21	0.24	0.23	0.17
<b>rf08</b>	Chronic renal disease	0.34	0.38	0.27	0.36
<b>rf01</b>	Age GE 55	0.16	0.11	0.17	0.19
<b>rf02</b>	Is Male	(0.11)	(0.08)	(0.10)	(0.14)
<b>rf11</b>	COPD	0.09	0.09	0.10	0.07
<b>rf12</b>	Cardiomyopathy	0.14	0.17	0.08	0.17
<b>rf09</b>	chronic liver disease	0.43	0.58	0.33	0.50

**Table 11 – Pneumonia Parameters by Year**

Variable	Label	Parameter Estimates			
		All Yrs	2003	2004	2005
<b>Intercept</b>	Intercept	1.25	1.25	1.26	1.24
<b>rf45</b>	Respiratory failure	0.46	0.47	0.46	0.45
<b>rf44</b>	Septicemia	0.32	0.34	0.29	0.34
<b>rf33</b>	Congestive heart failure	0.18	0.19	0.19	0.16
<b>rf43</b>	Pleural effusion	0.37	0.40	0.36	0.36
<b>rf01</b>	Age GE 55	0.14	0.15	0.13	0.14
<b>rf34</b>	Kidney disease	0.11	0.12	0.12	0.11
<b>rf36</b>	COPD	0.07	0.07	0.05	0.08
<b>rf32</b>	Stroke or transient ischemic attack	0.30	0.20	0.27	0.43
<b>rf31</b>	Cirrhosis or chronic hepatitis	0.20	0.14	0.27	0.19

While the model parameter estimates are relatively stable from year to year, we recommend that the estimates from all three years be used for the initial version of the risk adjustment model. If the parameters are re-estimated each year from the NHDS, the oldest year of data should be dropped and the new year added, maintaining a rolling three-year base for the estimates. This should smooth the progression of values over time.

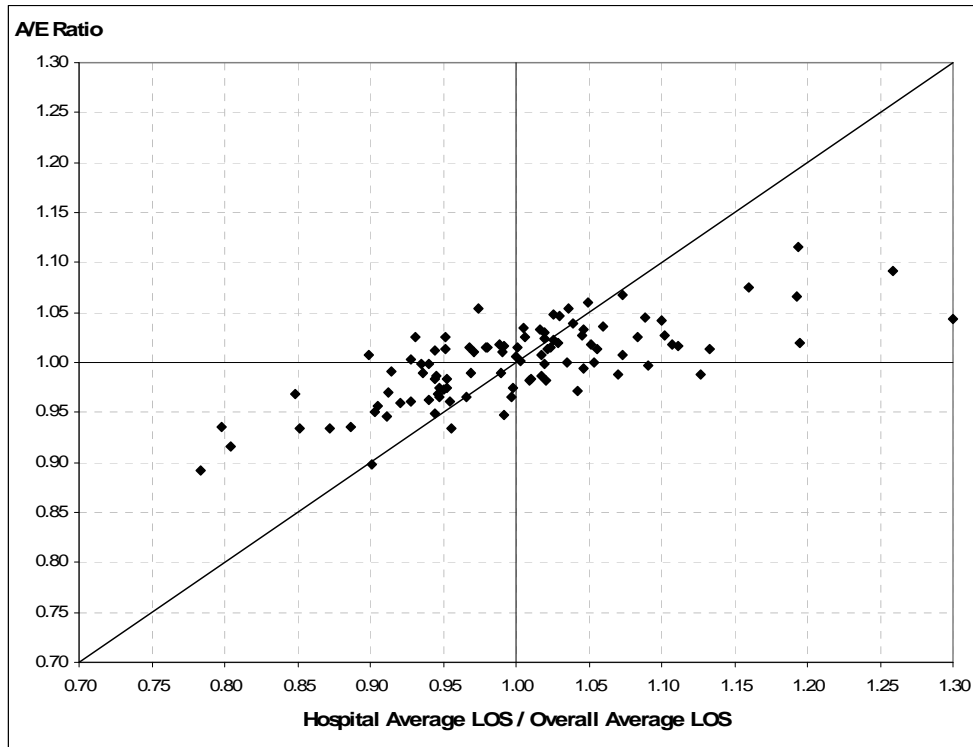
**Application of the Risk Adjustment Model:** To apply the risk adjustment model, each hospital must report the average log length of stay (i.e., the log of the geometric mean) and the percentage of discharges triggering each risk factor for each patient category. The risk factor percentages are multiplied by the corresponding risk factor model coefficients, summed and added to the model intercept to obtain the expected average log length of stay. We recommend that the actual average log length of stay then be divided by the expected average log length of stay, to obtain the actual-to-expected log length of stay ratio for each hospital. These A/E ratios can then be used to determine each hospital’s percentile ranking among other hospitals.

To demonstrate the impact of risk adjustment of hospital lengths of stay, we have randomly assigned NHDS discharges to 100 hypothetical hospitals. We expressed the unadjusted average length of stay for each hospital as a ratio, dividing by the overall average length of stay for all hospitals. We then compared these values to the risk-adjusted A/E ratios. Figure 2 shows the results for AMI discharges.

You can see that the unadjusted lengths of stay ranged from 78% to 130% of the overall average length of stay. After risk adjustment, the actual-to-expected ratios range from 89% to 112%. The reduction in the range of values is due to the dampening impact of the log transformation on lengthy discharges and to the removal of variance attributable to hospital-to-hospital differences in risk factors. Hospitals with unadjusted values above 100% tend to remain above but closer to 100% after risk adjustment. Similarly, hospitals with unadjusted values below 100% tend to remain below but closer to 100% after risk adjustment. Those hospitals within 10% of the average LOS before adjustment tend to be within 5% of the expected LOS after risk adjustment. The risk adjustment impact on

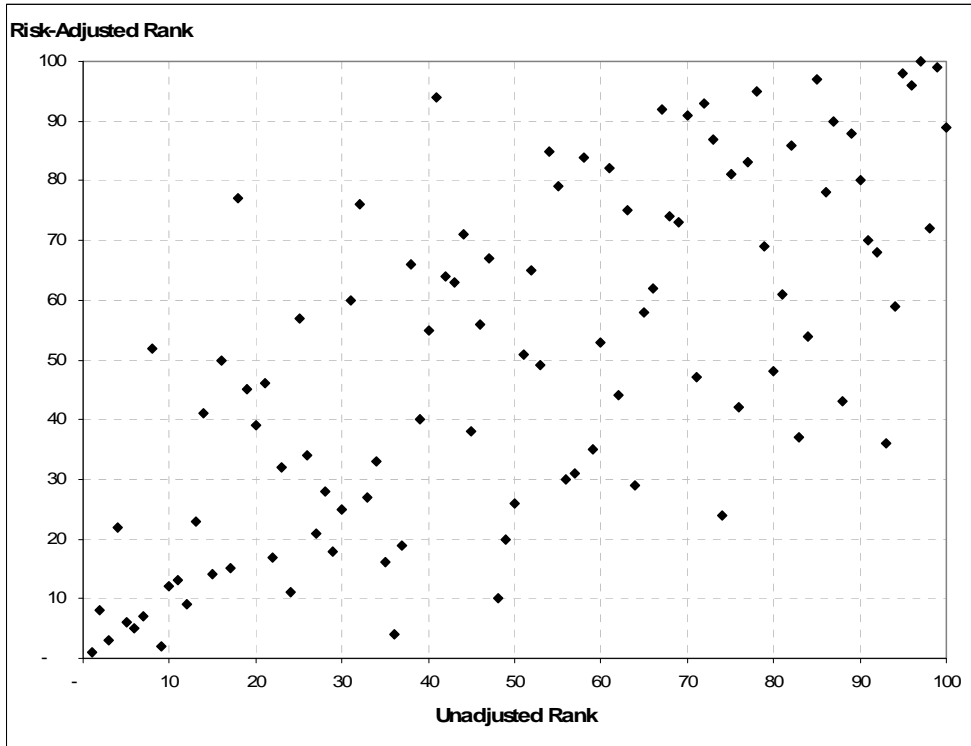
outlying initial values can be significant, as with the hospital that is 130% above the average before risk adjustment and only 5% above expected after risk adjustment.

**Figure 2 – AMI Length of Stay Before and After Risk Adjustment**



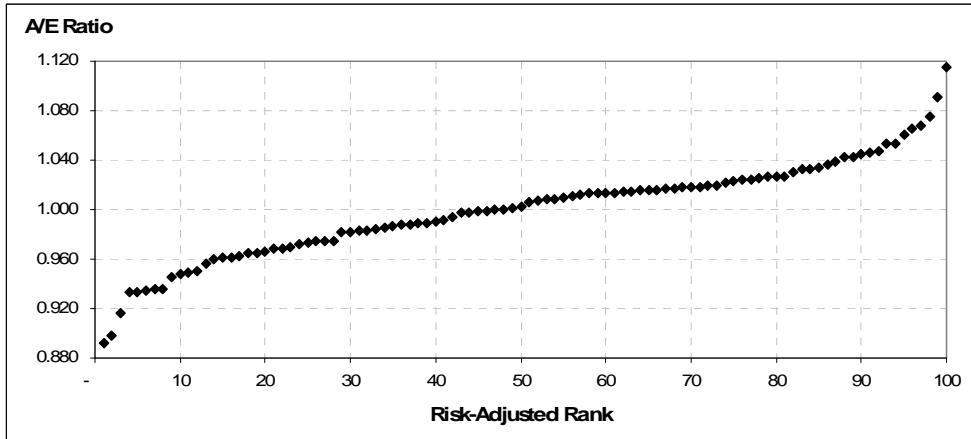
To better visualize the impact of risk adjustment on hospital ranking, we ranked the unadjusted average lengths of stay, ranked the risk-adjusted A/E ratios, and compared the results. (Rank=1 is the shortest average length of stay or the smallest A/E ratio as appropriate) Figure 3 shows the relationship between the unadjusted and risk-adjusted hospital rankings of AMI lengths of stay.

**Figure 3 – AMI Length of Stay Rankings – Unadjusted vs. Risk-Adjusted**



We see that there are examples of significant change in hospital ranking due to risk adjustment. For example, hospitals with unadjusted ranks near 40 have risk-adjusted ranks ranging from 5 to 95. It should be noted, however, that relatively small risk adjustments to a hospital's value in the middle of the LOS distribution (where there are many close neighbors) can result in significant changes in the relative ranking of the hospital. For example, risk adjustment for one hospital moves it from 101% of the average to 98% of the expected value, a change of less than 0.2 days. This results in a change in ranking from 56 to 30 out of 100 hospitals. Figure 4 shows that the middle 40 hospitals (ranked 31 through 70) span an A/E ratio range of only 4%. So, modest variations in a mainstream hospital's A/E ratios over time may result in seemingly dramatic variations in rankings.

**Figure 4 – AMI Risk-Adjusted A/E Ratio vs. Risk-Adjusted Ranking**



The rank correlation coefficient provides a convenient measure of the consistency in ranking between the unadjusted and risk-adjusted values. For the AMI category, the correlation is 70%. For PCI, CABG and pneumonia, the correlations are 64%, 79% and 73%, respectively. On average, the CABG category rankings are least affected by the proposed risk adjustment. Nevertheless, Figure 5 indicates that some hospital rankings are significantly affected by risk adjustment in this category.

**Figure 5 – CABG Length of Stay Rankings – Unadjusted vs. Risk-Adjusted**

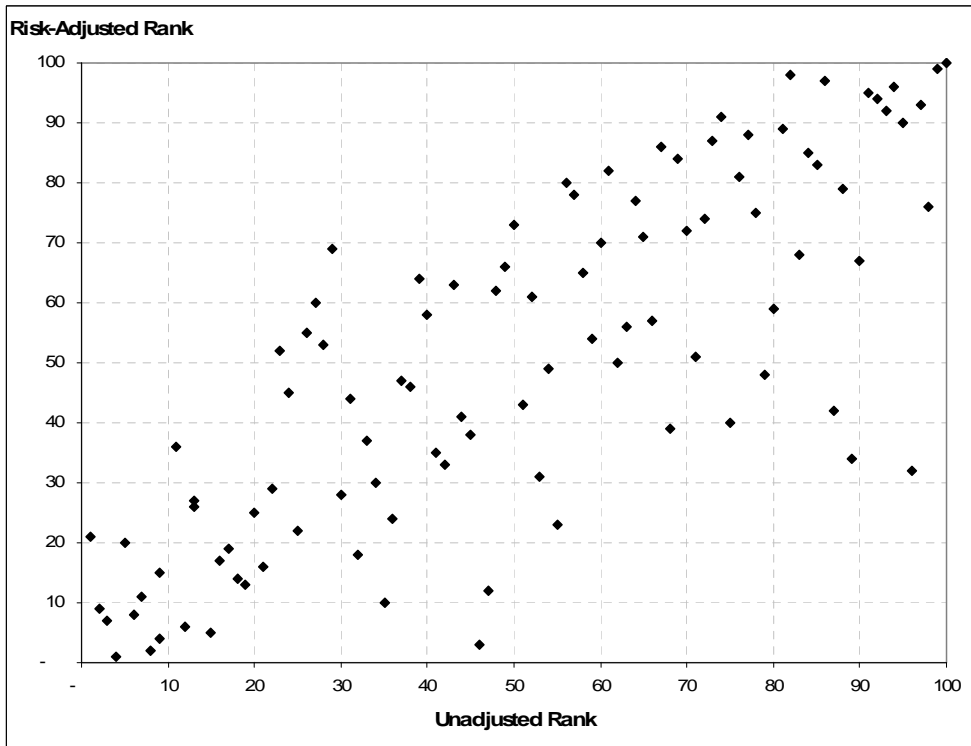


Table 12a provides another perspective on the impact of risk adjustment. Since modest changes values in the middle of the data can result in significant changes in ranking, we focus our attention on those hospitals in the outer quartiles. Table 12a shows the number

hospitals by unadjusted LOS quartile and by risk-adjusted A/E quartiles. The quartile row and column labels are augmented by the average length of stay for the 25 hospitals in that quartile. For the unadjusted quartiles, the values are the average LOS expressed as a percentage of the overall average LOS for all hospitals. For the risk-adjusted quartiles, the label values are the average A/E ratios.

**Table 12a – AMI Quartile Ranking Before and After Risk Adjustment**

Unadjusted Quartile	Risk-Adjusted Quartile				Total
	1 - 0.949	2 - 0.989	3 - 1.015	4 - 1.047	
1 - 0.899	16	6	2	1	25
2 - 0.969	8	7	8	2	25
3 - 1.021	1	7	8	9	25
4 - 1.113	0	5	7	13	25
Total	25	25	25	25	100

Once again we see that the range of LOS values shrinks after risk adjustment, from (89%, 111%) to (95%, 105%). We also see that the middle quartile LOS values are much closer to each other than is the case for the first and second or the third and fourth quartiles.

Examining the downward diagonals, we see that 44 of 100 hospital quartiles are unchanged by risk adjustment. Of the remaining 56 hospitals, 28 have increased quartiles and an equal number have decreased quartiles. Five hospitals increase by more than one quartile and six decrease by more than one quartile. Twelve hospitals enter the fourth quartile and twelve leave. Nine hospitals enter the first quartile and nine depart.

Tables 12b through 12d provide similar tabulations for the PCI, CABG and pneumonia discharges.

**Table 12b – PCI Quartile Ranking Before and After Risk Adjustment**

Unadjusted Quartile	Risk-Adjusted Quartile				Total
	1 - 0.878	2 - 0.940	3 - 0.982	4 - 1.040	
1 - 0.904	17	6	2	0	25
2 - 0.965	2	10	9	4	25
3 - 1.018	6	5	6	8	25
4 - 1.117	0	4	8	13	25
Total	25	25	25	25	100

**Table 12c – CABG Quartile Ranking Before and After Risk Adjustment**

Unadjusted Quartile	Risk-Adjusted Quartile				Total
	1 - 0.946	2 - 0.970	3 - 0.991	4 - 1.019	
1 - 0.888	19	5	1	0	25
2 - 0.961	5	10	10	0	25
3 - 1.013	1	6	10	8	25
4 - 1.134	0	4	4	17	25
Total	25	25	25	25	100

**Table 12d – Pneumonia Quartile Ranking Before and After Risk Adjustment**

Unadjusted Quartile	Risk-Adjusted Quartile				Total
	1 - 0.970	2 - 0.996	3 - 1.010	4 - 1.037	
1 - 0.934	16	6	3	0	25
2 - 0.976	5	10	8	2	25
3 - 1.014	4	6	7	8	25
4 - 1.076	0	3	7	15	25
Total	25	25	25	25	100

The results of this section are illustrative only, based on 100 hypothetical hospitals formed from random groupings of the NHDS discharges. If we group the same discharges into 48 hospitals, each approximately twice the size of those above, we would observe less variation in unadjusted hospital averages and a less risk adjustment effect. Table 13a below shows the quartile tabulations for AMI discharges with these larger hospital groupings.

**Table 13a – AMI Quartile Ranking Before and After Risk Adjustment (48 large hospital groupings)**

Unadjusted Quartile	Risk-Adjusted Quartile				Total
	1 - 0.966	2 - 0.990	3 - 1.008	4 - 1.035	
1 - 0.917	7	5	0	0	12
2 - 0.978	3	3	5	1	12
3 - 1.016	2	3	6	1	12
4 - 1.092	0	1	1	10	12
Total	12	12	12	12	48

Comparing Tables 12a and 13a, we see that the range of unadjusted LOS values is smaller for the larger hospital groupings. Similarly, the range of risk-adjusted A/E ratios has shrunk. The percentage of hospitals with no quartile change after risk adjustment has increased from 44% to 54% (26 of 48). If we calculate the rank correlation, we find it has increased from 70% to 75%, indicating that larger hospital rankings are less affected by risk adjustment.

So, the actual impact of risk adjustment on rankings and quartile assignment will depend, among other things, on the mix of hospital sizes. These results provide only a sense of the nature and magnitude of the impact.

## Discussion

These initial risk adjustment models remove some portion of the variation in hospital average lengths of stay, specifically that associated with the identified risk factors. Since the risk models only explain 12% to 29% of variation in patient log lengths of stay, a large portion of the variation remains. This residual variance can result in unreliable hospital averages, especially if the number of discharges is relatively small. That is, small hospital's average length of stay can be significantly affected by, 1) an unusual composition of “lurking” risk factors not considered by the risk adjustment model, or, 2) a single very long stay (i.e., an “outlier”). Large hospitals' patient profiles will trend toward a typical mix of risk factors (unless, for example, the hospital caters to a niche clientele) and the impact of an outlier or two will be diluted across a large number of discharges. Adoption of the log transformation (via the geometric mean) dampens the outlier impact on small hospital results. We can further address the credibility issue for small hospitals in two ways: increase our model  $R^2$  in order to reduce residual variance and/or exempt small hospitals from the reporting process.

The residual variance can be reduced by including additional risk factors, if they can be uncovered. We explored more elaborate models, incorporating adjustments for each DRG (Medicare) to which a discharge might belong, and were able to increase the model  $R^2$  values to 23% to 38%. These models, however, require a great number of parameters to be estimated and then applied to the discharge data. Nevertheless, such models should be considered for future use since they appear to significantly improve model performance. For now, Leapfrog has opted for a simple model structure, avoiding the need for member hospitals to obtain and implement any diagnostic grouping software (proprietary or otherwise) in order to determine risk factors for each discharge.

We also fit models including a primary/secondary indicator for the non-AMI categories. This increased the  $R^2$  significantly for the PCI model (from 18% to 33%), modestly for the CABG model (from 10% to 16%) and not at all for the pneumonia model (13%). [Aside: For pneumonia, risk factors RF44 – Septicemia and RF45 – Respiratory Failure appear to serve the role that the secondary indicator would otherwise play in the model. SO, with RF44 and RF45 in the model already, the secondary indicator has little marginal value.] This refinement of the PCI and CABG models would require member hospitals to determine if a discharge is included in the category is due to a secondary procedure code alone. We suspect this “secondary” effect is a proxy for the existence of a more significant primary procedure. As expected, when DRG information is brought into the model, the significance of the “secondary” effect diminishes.

Hospitals with small discharge counts can be excluded from the reporting system (providing no information to the user) or identified to the user (i.e., caution the user that the ranking is suspect). It might be possible to expand the reporting timeframe for smaller hospitals to increase the volume of discharges used to construct the averages, but doing so increases the average lag in reporting values. An approach to identifying the volatility of the results for small hospitals is to display the standard deviation of the unadjusted average stays and risk-adjusted A/E values, possibly in the form of confidence

intervals. The confidence interval limits could be translated to ranking/percentile values. Small hospitals would have wider rank/percentile confidence intervals.

More involved credibility adjustment schemes might also be applied, where the reported value for a hospital is a weighted average of the expected average length of stay derived from the risk-adjustment model and the unadjusted average stay. The weight on the unadjusted average stay increases as the number of discharges in the average increases. In essence, the credibility adjustment “shrinks” the risk-adjusted A/E ratio toward 1.000 for smaller hospitals. The proper shrinkage depends upon estimates of variances of length of stay within vs. between hospitals. The within-hospital variance is readily estimated; the between-hospital variance estimation requires data in which discharges from the same hospital can be linked. This linkage cannot be done with the NHDS data. These credibility adjustment schemes generally motivated by hierarchical models or mixed effect models for the underlying process (length of stay). One characterization of these methods is that they assume a hospital is average until proven otherwise. This may not be a reasonable starting assumption for all small hospitals. Nevertheless, such techniques deserve attention as the ranking system is refined.

Finally, in an effort to make the risk adjustment mechanism as transparent as possible, we recommend that Leapfrog consider presenting both unadjusted and risk-adjusted values to the user. This allows the user to observe the magnitude of the adjustments and weigh each according to each user’s own criteria.

## **Recommendations**

1. Initially employ the basic linear models presented in Tables 4 through 7 above to risk adjust hospital average log lengths of stay. These models are simple to apply, have statistically significant and understandable risk factor effects, and have a significant impact on rankings.
2. Update the model coefficients each year using the most recent three years of NHDS data.
3. Rather than masking results for small hospitals, consider providing a confidence interval for the reported values reflecting the volume of observations. (We can demonstrate these calculations, if there is interest in this approach.) Be aware that credibility adjustment schemes often employ the “average until proven otherwise” assumption.
4. Consider adding a “secondary” indicator in the PCI and CABG models to improve the model  $R^2$  values without substantial tabulation effort on the part of member hospitals. (We can provide the revised model parameters in this case.)
5. For future refinements, consider incorporation of a DRG-based component, possibly piggy-backing on CMS’s recent efforts to refine the Medicare hospital DRG system. Such a refinement may double the model  $R^2$ , but will require that member hospitals classify each discharge, look up a DRG-specific average length of stay, and aggregate the results.
6. Consider presenting both unadjusted and risk-adjusted values to the user.

**Appendix A**  
**National Hospital Discharge Survey File Layout Example (2005)**

Item Number	Location	Number of Positions	Item description	Code description
1	1-2	2	Survey Year	05
2	3	1	Newborn status	1=Newborn 2=Not newborn
3	4	1	Units for age	1=Years 2=Months 3=Days
4	5-6	2	Age in years, months, or days	If units=years: 00-99* If units=months: 01-11 If units=days: 00-28 *Ages 100 and over were recoded to 99
5	7	1	Sex	1=Male 2=Female
6	8	1	Race	1=White 2=Black/African American 3=American Indian/Alaskan Native 4=Asian 5=Native Hawaiian or other Pacific Isldr 6=Other 8=Multiple race indicated 9=Not stated
7	9	1	Marital status	1=Married 2=Single 3=Widowed 4=Divorced 5=Separated 9=Not stated
8	10-11	2	Discharge month	01-12=January to December
9	12	1	Discharge Status	1=Routine/discharged home 2=Left against medical advice 3=Discharged/transferred to short-term facility 4=Discharged/transferred to long-term care institution 5=Alive, disposition not stated 6=Dead 9=Not stated or not reported
10	13-16	4	Days of care	Use to calculate number of days of care. Values of zero generated by the computer from admission and discharge dates were changed to one. (Discharges for which dates of admission and discharge are the same are identified in Item Number 11)

Item Number	Location	Number of Positions	Item description	Code description
11	17	1	Length of stay flag	0=Less than 1 day 1=One day or more
12	18	1	Geographic region	1=Northeast 2=Midwest 3=South 4=West
13	19	1	Number of beds, recode	1=6-99 2=100-199 3=200-299 4=300-499 5=500 and over
14	20	1	Hospital ownership	1=Proprietary 2=Government 3=Nonprofit, including church
15	21-25	5	Analysis weight	Use to obtain weighted estimates
16	26-27	2	First two digits of survey year	20
17	28-32	5	Diagnosis code #1	*
18	33-37	5	Diagnosis code #2	*
19	38-42	5	Diagnosis code #3	*
20	43-47	5	Diagnosis code #4	*
21	48-52	5	Diagnosis code #5	*
22	53-57	5	Diagnosis code #6	*
23	58-62	5	Diagnosis code #7	*
24	63-66	4	Procedure code#1	*
25	67-70	4	Procedure code#2	*
26	71-74	4	Procedure code#3	*
27	75-78	4	Procedure code#4	*

Item Number	Location	Number of Positions	Item description	Code description
28	79-80	2	Principal expected source of payment	01=Worker's compensation 02=Medicare 03=Medicaid 04=Other government 05=Blue Cross/Blue Shield 06=HMO/PPO 07=Other private insurance 08=Self-pay 09=No charge 10=Other 99=Not stated
29	81-82	2	Secondary expected source of payment	Same coding as item 28 above, except Not Stated left blank (not coded to 99)
30	83-85	3	Diagnosis-Related Groups (DRG)	Grouper version 22
31	86	1	Type of Admission	1 = Emergency 2 = Urgent 3 = Elective 4 = Newborn 9 = Not available
32	87-88	2	Source of Admission	01 = Physician referral 02 = Clinical referral 03 = HMO referral 04 = Transfer from a hospital 05 = Transfer from skilled nursing facility 06 = Transfer from other health facility 07 = Emergency room 08 = Court/law enforcement 09 = Other 99 = Not available

## **Appendix B**

### **Patient Category and Risk Factor Specifications**

*Source: Efficiency Measures – Specifications, v5.0b, January 17, 2008*

#### **AMI – Case Count**

##### **Inclusion criteria:**

- Discharge date within [Reporting Time Period](#)
- Inpatient discharges include deaths during the hospital stay
- A principal diagnosis code in the following table:

##### **ICD-9-CM Diagnosis Codes**

410.00 Anterolateral wall, acute myocardial infarction-episode of care unspecified  
410.01 Anterolateral wall, acute myocardial infarction-initial episode  
410.10 Other anterior wall, acute myocardial infarction-episode of care unspecified  
410.11 Other anterior wall, acute myocardial infarction-initial episode  
410.20 Inferolateral wall, acute myocardial infarction-episode of care unspecified  
410.21 Inferolateral wall, acute myocardial infarction-initial episode  
410.30 Inferoposterior wall, acute myocardial infarction-episode of care unspecified  
410.31 Inferoposterior wall, acute myocardial infarction-initial episode  
410.40 Other inferior wall, acute myocardial infarction-episode of care unspecified  
410.41 Other inferior wall, acute myocardial infarction-initial episode  
410.50 Other lateral wall, acute myocardial infarction-episode of care unspecified  
410.51 Other lateral wall, acute myocardial infarction-initial episode  
410.60 True posterior wall, acute myocardial infarction-episode of care unspecified  
410.61 True posterior wall, acute myocardial infarction-initial episode  
410.70 Subendocardial, acute myocardial infarction – episode of care unspecified  
410.71 Subendocardial, acute myocardial infarction – initial episode  
410.80 Other specified sites, acute myocardial infarction-episode of care unspecified  
410.81 Other specified sites, acute myocardial infarction-initial episode  
410.90 Unspecified site, acute myocardial infarction-episode of care unspecified  
410.91 Unspecified site, acute myocardial infarction-initial episode

##### **Exclusions:**

- Patient age < 18
- Deaths in ER without inpatient admission

#### **PCI – Case Count**

##### **Inclusion criteria:**

- Discharge date within [Reporting Time Period](#)
- Inpatient discharges include deaths during the hospital stay
- Any one or more primary or secondary procedure code in the following table:

##### **ICD-9-CM PCI procedure codes**

00.66 Percutaneous transluminal coronary angioplasty (PTCA) or coronary atherectomy

(code effective 10/1/2005; CHSRA used 36.01, 36.02 and 36.05 for earlier periods)  
36.06 Insertion of non-drug eluting coronary stent(s) (added by Leapfrog)  
36.07 Insertion of drug-eluting coronary stent(s) (added by Leapfrog)

**Exclusions:**

- Patient age < 18
- Patients not admitted to this hospital for an inpatient stay, e.g., ambulatory procedures

**CABG – Case Count**

**Inclusion criteria:**

- Discharge date within [Reporting Time Period](#)
- Inpatient discharges include deaths during the hospital stay
- Any one or more primary or secondary procedure codes in the following table:

**ICD-9-CM CABG procedure codes**

- 36.10 Aortocoronary bypass for heart revascularization, not otherwise specified
- 36.11 Aortocoronary bypass for one coronary artery
- 36.12 Aortocoronary bypass for two coronary artery
- 36.13 Aortocoronary bypass for three coronary artery
- 36.14 Aortocoronary bypass for four or more coronary arteries
- 36.15 Single internal mammary –coronary artery bypass
- 36.16 Double internal mammary –coronary artery bypass
- 36.17 Abdominal-coronary artery bypass
- 36.19 Other bypass anastomosis for heart revascularization

**Exclusions:**

- Patient age < 18

**Pneumonia – Case Count**

**Inclusion criteria:**

- Discharge date within [Reporting Time Period](#)
- Inpatient discharges include deaths during the hospital stay
- A principal diagnosis code in Table A
- OR**
- A principal diagnosis code in Table B **AND** any secondary diagnosis code in Table A.

**Table A – Pneumonia**

**ICD-9-CM Diagnosis Codes**

- 481 Pneumococcal pneumonia (Streptococcus pneumoniae pneumonia)
- 482.0 Pneumonia due to Klebsiella pneumoniae
- 482.1 Pneumonia due to Pseudomonas
- 482.2 Pneumonia due to Hemophilus influenzae (H. influenzae)
- 482.30 Pneumonia due to Streptococcus, unspecified
- 482.31 Pneumonia due to Group A

482.32 Pneumonia due to Group B  
482.39 Pneumonia due to other Streptococcus  
482.40 Pneumonia due to Staphylococcus, unspecified  
482.41 Pneumonia due to Staphylococcus aureus  
482.49 Pneumonia due to other Staphylococcus pneumonia  
482.81 Pneumonia due to Anaerobes  
482.82 Pneumonia due to Escherichia coli (E. coli)  
482.83 Pneumonia due to other gram-negative bacteria  
482.84 Pneumonia due to Legionnaires' disease  
482.89 Pneumonia due to other specified bacteria  
482.9 Bacterial pneumonia unspecified  
483.0 Pneumonia due to Mycoplasma pneumoniae  
483.1 Pneumonia due to Chlamydia  
483.8 Pneumonia due to other specified organism  
485 Bronchopneumonia, organism unspecified  
486 Pneumonia, organism unspecified

**Table B**

**ICD-9-CM Diagnosis Codes – Septicemia**

038.0 Streptococcal septicemia  
038.10 Staphylococcal septicemia, unspecified  
038.11 Staphylococcus aureus septicemia  
038.19 Other staphylococcal septicemia  
038.2 Pneumococcal septicemia (Streptococcus pneumoniae septicemia)  
038.3 Septicemia due to anaerobes  
038.40 Septicemia due to gram-negative organism, unspecified  
038.41 Septicemia due to Hemophilus influenzae (H. influenzae)  
038.42 Septicemia due to Escherichia coli (E. coli)  
038.43 Septicemia due to Pseudomonas  
038.44 Septicemia due to Serratia  
038.49 Septicemia due to other  
038.8 Other specified septicemias  
038.9 Unspecified septicemia

**ICD-9-CM Diagnosis Codes – Respiratory Failure**

518.81 Acute respiratory failure  
518.84 Acute and chronic respiratory failure

**Exclusions:**

- Patient age < 18

## Risk Factor Definitions

### ***RF03 -- Site of infarction: anterior or anterolateral***

*Applies to AMI, PCI*

#### **Principal diagnosis ICD-9-CM Diagnosis Codes**

410.01	Anterolateral wall, acute myocardial infarction-initial episode
410.11	Other anterior wall, acute myocardial infarction-initial episode

### ***RF04 -- Site of infarction: subendocardial***

*Applies to AMI, PCI*

#### **Principal diagnosis ICD-9-CM Diagnosis Codes**

410.71	Subendocardial, acute myocardial infarction
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### ***RF05 -- Diabetes***

*Applies to AMI, CABG, PCI*

#### **Any diagnosis ICD-9-CM Diagnosis Codes**

250.01	Diabetes mellitus without mention of complication, Type I (juvenile type), not stated as uncontrolled	
250.03	Diabetes mellitus without mention of complication, Type I (juvenile type), uncontrolled	
250.1x	Diabetes w/ ketoacidosis	v1.2
250.2x	Diabetes w/ hyperosmolar coma	v1.2
250.3x	Diabetes w/ coma	v1.2
250.4x	Diabetes w/ renal manifestestations	v1.2
250.5x	Diabetes w/ ophthalmic manifestations	v1.2
250.6x	Diabetes w/ neurologic manifestations	v1.2
250.7x	Diabetes w/ circulatory disease	v1.2
250.8x	Diabetes with other specified manifestations	v1.2
250.9x	Diabetes with unspecified complication	v1.2
648.00 to 648.04	Diabetes mellitus in pregnancy	
648.81	Abnormal glucose tolerance of mother, with delivery	

### ***RF06 -- Cancer***

*Applies to AMI, PCI*

#### **Any diagnosis ICD-9-CM Diagnosis Codes**

140.0 to 208.9	Malignant neoplasms
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**RF07 -- Chronic cerebrovascular disease**

*Applies to AMI, CABG, PCI*

**Any diagnosis ICD-9-CM Diagnosis Codes**

437.x	Other cerebrovascular disease
438.x	Late effects of cerebrovascular disease

**RF08 -- Chronic renal disease**

*Applies to AMI, CABG, PCI*

**Any diagnosis ICD-9-CM Diagnosis Codes**

403.00	Hypertensive chronic kidney disease, malignant, without mention of renal failure
403.01	Hypertensive chronic kidney disease, malignant, with renal failure
403.10	Hypertensive chronic kidney disease, benign, without mention of renal failure
403.11	Hypertensive chronic kidney disease, benign, with renal failure
403.90	Hypertensive chronic kidney disease, unspecified, without mention of renal failure
403.91	Hypertensive chronic kidney disease, unspecified, with renal failure
404.00 to 404.03	Hypertensive heart and chronic kidney disease, malignant
404.10 to 404.13	Hypertensive heart and chronic kidney disease, benign
404.90 to 404.93	Hypertensive heart and chronic kidney disease, unspecified
582.	Chronic nephritis
583.	Nephritis NOS
585. to 587.	Chronic kidney disease Renal failure, unspecified Renal sclerosis, unspecified

**RF09 -- Chronic liver disease**

*Applies to AMI, PCI*

**Any diagnosis ICD-9-CM Diagnosis Codes**

571.x	Chronic liver disease/cirrhosis
572.1	Portal pyemia
572.2	Hepatic coma
572.3	Portal hypertension
572.4	Hepatorenal syndrome
572.8	Other sequelae of chronic liver disease

**RF10 -- Obesity**

*Applies to AMI, PCI*

**Any diagnosis ICD-9-CM Diagnosis Codes**

278.00	Obesity, unspecified
278.01	Morbid obesity

**RF11 -- COPD**

*Applies to AMI, CABG, PCI*

**WARNING: Definition differs from RF36**

**-- COPD**

**Any diagnosis ICD-9-CM Diagnosis Codes**

491.21	Obstructive chronic bronchitis, with (acute) exacerbation
493.20	Chronic obstructive asthma without mention of status asthmaticus or acute exacerbation or unspecified
493.21	Chronic obstructive asthma, with status asthmaticus
496.	Chronic airway obstruction, not elsewhere classified

**RF12 -- Cardiomyopathy**

*Applies to AMI, CABG, PCI*

**Any diagnosis ICD-9-CM Diagnosis Codes**

425.x	Cardiomyopathy
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**RF13 -- Chronic cardiac conditions**

*Applies to AMI, CABG, PCI*

**Any diagnosis ICD-9-CM Diagnosis Codes**

398.90	Rheumatic heart disease, unspecified	
398.91	Rheumatic heart failure (congestive)	
398.99	Other rheumatic heart diseases	
402.xx	Hypertensive heart disease	v1.2
414.8	Other specified forms of chronic ischemic heart disease	
414.9	Chronic ischemic heart disease, unspecified	
416.x	Chronic pulmonary heart disease	v1.2
429.1	Myocardial degeneration	
429.2	Cardiovascular disease, unspecified	
429.3	Cardiomegaly	
443.81	Peripheral angiopathy in diseases classified elsewhere	
443.89	Other unspecified peripheral vascular disease	
443.9	Peripheral vascular disease, unspecified	
V12.50	Unspecified circulatory disease (history)	
V15.1	Surgery to heart and great vessels (history)	

**RF14 -- History of PTCA**

*Applies to PCI*

**Any diagnosis ICD-9-CM Diagnosis Codes**

V45.82	Percutaneous transluminal coronary angioplasty status
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**RF15 -- Atherosclerosis and lipid disorders**

*Applies to AMI, CABG, PCI*

**Any diagnosis ICD-9-CM Diagnosis Codes**

272.x	Diseases of lipoid metabolism
414.00	Coronary atherosclerosis
414.01	Coronary atherosclerosis of native coronary vessel
414.02	Coronary atherosclerosis of autologous vein bypass graft
414.03	Coronary atherosclerosis of nonautologous biological bypass graft
414.04	Coronary atherosclerosis of artery bypass graft
414.05	Coronary atherosclerosis of unspecified type of bypass graft
440.x	Atherosclerosis

**RF16 -- PCI**

*Applies to AMI, CABG*

**Any procedure . . .**

ICD-9-CM Procedure Codes

00.66	Percutaneous transluminal coronary angioplasty (PTCA) or coronary artherectomy (CHSRA used 36.01, 36.02 and 3.05 for periods prior to 10/1/2005)
<i>Other codes indicate single/multiple vessels (00.40-00.43) or stenting (00.45-00.48, 36.06, 36.07) but are SECONDARY to this code and should not be used to identify a PCI.</i>	

**or . . .**

CPT-4 Procedure Codes

92982	Percutaneous transluminal coronary balloon angioplasty, single vessel
92984	Percutaneous transluminal coronary balloon angioplasty, additional vessels
92995	Percutaneous transluminal coronary arthrectomy w/wo balloon, single vessel
92996	Percutaneous transluminal coronary arthrectomy w/wo balloon, additional vessels
92980	Trancatheter placement of intracoronary stent(s), percutaneous, single vessel
92981	Trancatheter placement of intracoronary stent(s), percutaneous, additional vessels

**RF17 -- CABG**

*Applies to AMI, PCI*

**Any procedure . . .**

ICD-9-CM Procedure Codes

36.10 to 36.19	Bypass anasthmosis for heart revascularization
36.2	Heart revascularization by arterial implant

**or . . .**

**CPT-4 Procedure Codes**

33510 to 33523	Coronary artery bypass graft
33533 to 33536	Coronary artery bypass graft

***RF18 -- Musculoskeletal conditions***

*Applies to CABG, PCI*

**Any diagnosis ICD-9-CM Diagnosis Codes**

715.x	Osteoarthritis and allied disorders
720.0	Ankylosing spondylitis
721.90	Spondylosis of unspecified site without mention of myelopathy
714.0x to 714.33	Rheumatoid arthritis

***RF19 – AMI***

*Applies to CABG, PC*

*(Changed by CHSRA to correspond to change in AMI patient category logic version 5.0b on 1/17/2008)*

**Principal diagnosis ICD-9-CM Diagnosis Codes**

410.00	Anterolateral wall, acute myocardial infarction-episode of care unspecified
410.01	Anterolateral wall, acute myocardial infarction-initial episode
410.10	Other anterior wall, acute myocardial infarction-episode of care unspecified
410.11	Other anterior wall, acute myocardial infarction-initial episode
410.20	Inferolateral wall, acute myocardial infarction-episode of care unspecified
410.21	Inferolateral wall, acute myocardial infarction-initial episode
410.30	Inferoposterior wall, acute myocardial infarction-episode of care unspecified
410.31	Inferoposterior wall, acute myocardial infarction-initial episode
410.40	Other inferior wall, acute myocardial infarction-episode of care unspecified
410.41	Other inferior wall, acute myocardial infarction-initial episode
410.50	Other lateral wall, acute myocardial infarction-episode of care unspecified
410.51	Other lateral wall, acute myocardial infarction-initial episode
410.60	True posterior wall, acute myocardial infarction-episode of care unspecified
410.61	True posterior wall, acute myocardial infarction-initial episode
410.70	Subendocardial, acute myocardial infarction – episode of care unspecified
410.71	Subendocardial, acute myocardial infarction – initial episode
410.80	Other specified sites, acute myocardial infarction-episode of care unspecified
410.81	Other specified sites, acute myocardial infarction-initial episode
410.90	Unspecified site, acute myocardial infarction-episode of care unspecified

410.91	Unspecified site, acute myocardial infarction-initial episode
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**RF20 – Coronary Artery Disease without prior CABG**

*Applies to CABG*

**Any diagnosis ICD-9-CM Diagnosis Codes**

410.xx to 414.07	AMI / Ischemic heart disease
414.10 to 414.19	Aneurysm and dissection of heart
414.8 to 414.9	Chronic ischemic heart disease

but **EXCLUDE** if

**Any diagnosis ICD-9-CM Diagnosis Codes**

V45.81	Aortocoronary bypass status
996.03	Mechanical complication of cardiac device, implant, and graft due to coronary bypass graft

**RF21 -- Coronary Artery Disease with prior CABG**

*Applies to AMI, CABG*

**Any diagnosis ICD-9-CM Diagnosis Codes (Group A)**

410.xx to 414.07	AMI / Ischemic heart disease
414.10 to 414.19	Aneurysm and dissection of heart

**AND\***

**Any diagnosis ICD-9-CM Diagnosis Codes (Group B)**

V45.81	Aortocoronary bypass status
996.03	Mechanical complication of cardiac device, implant, and graft due to coronary bypass graft

*\* Must have at least one diagnosis from Group A and at least one diagnosis from Group B.*

**RF22 – Diabetes AND Obesity**

*Applies to AMI*

**IMPORTANT:**

**Determine first whether case has RF05 – Diabetes present**

**Determine first whether case has RF10 – Obesity present**

RF05 – Diabetes is present (see table RF05)

**AND\***

RF10 – Obesity is present (see table RF10)

\* If both RF05 and RF10 factors are present for the case, then RF22 is present for the case.

***RF30 -- Any cancer except basal or squamous-cell skin cancer***

*Applies to Pneumonia*

**Any diagnosis** ICD-9-CM Diagnosis Codes

140.0 to 171.9
174.0 to 199.1
200.0 to 208.91
233.0 to 234.9

***RF31 -- Cirrhosis or chronic hepatitis***

*Applies to Pneumonia*

**Any diagnosis** ICD-9-CM Diagnosis Codes

571.2	Alcoholic cirrhosis of liver
571.4	Chronic hepatitis
571.5	Cirrhosis of liver without mention of alcohol
571.6	Biliary cirrhosis

***RF32 -- Stroke or transient ischemic attack***

*Applies to Pneumonia*

**Any diagnosis** ICD-9-CM Diagnosis Codes

430.x	Subarachnoid hemorrhage
431.x	Intracerebral hemorrhage
432.x	Intracranial hem nec/nos
433.x1	Cerebral infarction
434.x1	Cerebral infarction
435.x	Transient cerebral ischemia
436.x	Acute, but ill-defined, cerebrovascular disease

***RF33 -- Congestive heart failure***

*Applies to Pneumonia*

**Any diagnosis** ICD-9-CM Diagnosis Codes

428.x	Heart failure
402.01	Hypertensive heart disease, malignant, with heart failure failure
402.11	Hypertensive heart disease, benign, with heart failure failure
402.91	Hypertensive heart disease, unspecified, with heart failure
404.01	Hypertensive heart and renal disease, malignant, with congestive heart failure
404.03	Hypertensive heart and renal disease, malignant, with congestive heart failure

	and renal failure
404.11	Hypertensive heart and renal disease, benign, with congestive heart failure
404.13	Hypertensive heart and renal disease, benign, with congestive heart failure and renal failure
404.91	Hypertensive heart and renal disease, unspecified, with congestive heart failure
404.93	Hypertensive heart and renal disease, unspecified, with congestive heart failure and renal failure

**RF34 -- Kidney disease**

*Applies to Pneumonia*

**Any diagnosis** ICD-9-CM Diagnosis Codes

580.x	Acute nephritis
581.x	Nephrotic syndrome
582.x	Chronic nephritis
583.x	Nephritis NOS
584.x	Acute renal failure
585.x	Chronic renal failure
586.x	Renal failure, unspecified
587.x	Renal sclerosis, unspecified
588.x	Impaired renal function
589.x	Small kidney
590.x	Kidney infection
591.x	Hydronephrosis
592.x	Renal/ureteral calculus
593.x	Other renal & ureteral disease
403.xx	Hypertensive renal disease
404.xx	Hypertensive heart/renal disease

**RF35 -- Suspected or documented HIV**

*Applies to Pneumonia*

**Any diagnosis** ICD-9-CM Diagnosis Codes

042.x	Human immunodeficiency virus (HIV) disease
V08.x	Asymptomatic human immunodeficiency virus (HIV) infection status
795.71	Non-specific serologic evidence of human immunodeficiency virus

**RF36 – COPD**

*Applies to Pneumonia*

**WARNING: Definition differs from RF11**

**-- COPD**

**Any diagnosis** ICD-9-CM Diagnosis Codes

496.x	Chronic airway obstruction, not elsewhere classified
491.2	Obstructive chronic bronchitis
491.8	Other chronic bronchitis

491.9	Unspecified chronic bronchitis
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**RF37 -- Inability to take oral medications**

*Applies to Pneumonia*

**Any diagnosis ICD-9-CM Diagnosis Codes**

787.2	Dysphagia
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**RF38 -- Temperature below 35°C (95°F) or above 40°C (104°F)**

*Applies to Pneumonia*

**Any diagnosis ICD-9-CM Diagnosis Codes**

780.6	Fever
780.7	Malaise and fatigue
780.8	Hyperhidrosis
780.9	Other general symptoms

**RF39 -- Altered mental status**

*Applies to Pneumonia*

**Any diagnosis ICD-9-CM Diagnosis Codes**

780.0	Alteration of consciousness
780.93	Memory loss

**RF41 -- Sodium below 130 mEq/L**

*Applies to Pneumonia*

**Any diagnosis ICD-9-CM Diagnosis Codes**

276.1	Hyposmolality and/or hyponatremia
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**RF42 -- Hematocrit less than 30%**

*Applies to Pneumonia*

**Any diagnosis ICD-9-CM Diagnosis Codes**

285.9	Anemia, unspecified
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**RF43 -- Pleural effusion**

*Applies to Pneumonia*

**Any diagnosis ICD-9-CM Diagnosis Codes**

511.9	Unspecified pleural effusion
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**RF44 -- Septicemia**

*Applies to Pneumonia*

**Any diagnosis ICD-9-CM Diagnosis Codes**

038.0	Septicemia	
038.10	Staphylococcal septicemia, unspecified	
038.11	Staphylococcus aureus septicemia	
038.19	Other staphylococcal septicemia	
038.2	Pneumococcal septicemia	
038.3	Septicemia due to anaerobes	
038.40	Septicemia due to gram-negative organism, unspecified	v1.2
038.41	Septicemia due to hemophilus influenzae (h. influenzae)	
038.42	Septicemia due to escherichia coli (e. coli)	
038.43	Septicemia due to pseudomonas	
038.44	Septicemia due to serratia	
038.49	Other septicemia due to gram-negative organisms	
038.8	Other specified septicemias	
038.9	Unspecified septicemia	

***RF45 -- Respiratory failure***

*Applies to Pneumonia*

**Any diagnosis ICD-9-CM Diagnosis Codes**

518.81	Acute respiratory failure	
518.84	Acute and chronic respiratory failure	

# AMI

## Appendix C Literature Review Summary

### Acute Myocardial Infarction

	Risk Factors	Citation	Comments
RF01	Age>=55	Spencer, F. A.; Lessard, D.; Gore, J. M.; Yarzebski, J., and Goldberg, R. J. Declining length of hospital stay for acute myocardial infarction and postdischarge outcomes: a community-wide perspective. Arch Intern Med. 2004 Apr 12; 164(7):733-40.	Table 2 Factors Associated with a hospital LOS > median LOS Age 55-64, 65-74, > or = 75
RF02	Male	Spencer, F. A.; Lessard, D.; Gore, J. M.; Yarzebski, J., and Goldberg, R. J. Declining length of hospital stay for acute myocardial infarction and postdischarge outcomes: a community-wide perspective. Arch Intern Med. 2004 Apr 12; 164(7):733-40.	Table 2 Factors Associated with a hospital LOS > median LOS <b>Women</b>
RF03	Site of infarction: anterior or anteriolateral	Spencer, F. A.; Lessard, D.; Gore, J. M.; Yarzebski, J., and Goldberg, R. J. Declining length of hospital stay for acute myocardial infarction and postdischarge outcomes: a community-wide perspective. Arch Intern Med. 2004 Apr 12; 164(7):733-40.	Table 2 Factors Associated with a hospital LOS > median LOS Anterior (AMI factors)
RF04	Site of infarction: subendocardial		
RF05	Diabetes	Spencer, F. A.; Lessard, D.; Gore, J. M.; Yarzebski, J., and Goldberg, R. J. Declining	Table 2 Factors Associated with a hospital LOS > median LOS Diabetes

AMI

	Risk Factors	Citation	Comments
		length of hospital stay for acute myocardial infarction and postdischarge outcomes: a community-wide perspective. Arch Intern Med. 2004 Apr 12; 164(7):733-40.	
		Lichtman, J.H.; Spertus, J.A.; Reid, K.J.; Radford, M.J.; Rumsfeld, J.S.; Allen, N.B; Masoudi, F.A.; Weintraub, W.S.; Harlan M. Krumholz, H.M. Acute Noncardiac Conditions and In-Hospital Mortality in Patients With Acute Myocardial Infarction. Circulation. 2007, 116:1925-1930.	“The length of stay was greater for patients with acute noncardiac conditions,....” Page 1929 Table 1 Acute noncardiac conditions (Diabetes ketoacidosis)
RF06	Cancer		
RF07	Chronic cerebrovascular disease		
RF08	Chronic renal disease	Afshinnia, F.; Ayazi, P., and Chadow, H. L. Glomerular filtration rate on admission independently predicts short-term in-hospital mortality after acute myocardial infarction. Am J Nephrol. 2006; 26(4):408-14.	“Abstract: BACKGROUND: Risk of cardiovascular events is higher in patients with chronic kidney disease.” Page 408
		Spencer, F. A.; Lessard, D.; Gore, J. M.; Yarzebski, J., and Goldberg, R. J. Declining length of hospital stay for acute myocardial infarction and postdischarge outcomes: a community-wide perspective. Arch Intern Med. 2004 Apr 12; 164(7):733-40.	Table 2 Factors Associated with a hospital LOS > median LOS hypertension (medical history)

# AMI

	Risk Factors	Citation	Comments
		Lichtman, J.H.; Spertus, J.A.; Reid, K.J.; Radford, M.J.; Rumsfeld, J.S.; Allen, N.B.; Masoudi, F.A.; Weintraub, W.S.; Harlan M. Krumholz, H.M. Acute Noncardiac Conditions and In-Hospital Mortality in Patients With Acute Myocardial Infarction. Circulation. 2007, 116:1925-1930.	“The length of stay was greater for patients with acute noncardiac conditions,....” Page 1929 Table 1 Acute noncardiac conditions (end-stage renal disease, hypertension)
RF09	Chronic liver disease		
RF10	Obesity	Wells, B.; Gentry, M.; Ruiz-Arango, A.; Dias, J.; and Landolfo, C.K. Relation Between Body Mass Index and Clinical Outcome in Acute Myocardial Infarction. The American Journal of Cardiology. 2006 Aug 15; 98(4): 474-477.	“In conclusion, despite the association between obesity and development of coronary artery disease, <b>obesity does not adversely impact in-hospital outcomes in AMI</b> . However, obesity is associated with AMI at a younger age.” Page 1925.
RF11	COPD (definition differs from RF36)	Lichtman, J.H.; Spertus, J.A.; Reid, K.J.; Radford, M.J.; Rumsfeld, J.S.; Allen, N.B.; Masoudi, F.A.; Weintraub, W.S.; Harlan M. Krumholz, H.M. Acute Noncardiac Conditions and In-Hospital Mortality in Patients With Acute Myocardial Infarction. Circulation. 2007, 116:1925-1930.	“The length of stay was greater for patients with acute noncardiac conditions,....” Page 1929 Table 1 Acute noncardiac conditions (COPD)
RF12	Cardiomyopathy		
RF13	Chronic cardiac conditions	Spencer, F. A.; Lessard, D.; Gore, J. M.; Yarzebski, J., and	Table 2 Factors Associated with a hospital LOS > median LOS

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	<b>Risk Factors</b>	<b>Citation</b>	<b>Comments</b>
		Goldberg, R. J. Declining length of hospital stay for acute myocardial infarction and postdischarge outcomes: a community-wide perspective. Arch Intern Med. 2004 Apr 12; 164(7):733-40.	Stroke, angina (medical history)
		Spencer, F. A.; Lessard, D.; Gore, J. M.; Yarzebski, J., and Goldberg, R. J. Declining length of hospital stay for acute myocardial infarction and postdischarge outcomes: a community-wide perspective. Arch Intern Med. 2004 Apr 12; 164(7):733-40.	Table 2 Factors Associated with a hospital LOS > median LOS Stroke, angina (medical history)
RF15	Atherosclerosis and lipid disorders		
RF16	PCI		
RF17	CABG		
RF21	CAD with prior CABG		
RF22	Diabetes (RF05) and Obesity (RF10)		
RF32 (Add)	Stroke or transient ischemic attack	Spencer, F. A.; Lessard, D.; Gore, J. M.; Yarzebski, J., and Goldberg, R. J. Declining length of hospital stay for acute myocardial infarction and postdischarge outcomes: a community-wide perspective. Arch Intern Med. 2004 Apr 12; 164(7):733-40.	Table 2 Factors Associated with a hospital LOS > median LOS Stroke (medical history)
		Lichtman, J.H.; Spertus, J.A.; Reid, K.J.; Radford, M.J.; Rumsfeld, J.S.; Allen, N.B; Masoudi, F.A.; Weintraub, W.S.; Harlan M. Krumholz, H.M. Acute Noncardiac	“The length of stay was greater for patients with acute noncardiac conditions,....” Page 1929 Table 1 Acute noncardiac conditions (stroke)

**AMI**

<b>Risk Factors</b>		<b>Citation</b>	<b>Comments</b>
		Conditions and In-Hospital Mortality in Patients With Acute Myocardial Infarction. <i>Circulation</i> . 2007, 116:1925-1930.	
RF33 (Add)	Congestive Heart Failure	Spencer, F. A.; Lessard, D.; Gore, J. M.; Yarzebski, J., and Goldberg, R. J. Declining length of hospital stay for acute myocardial infarction and postdischarge outcomes: a community-wide perspective. <i>Arch Intern Med</i> . 2004 Apr 12; 164(7):733-40.	Table 2 Factors Associated with a hospital LOS > median LOS Heart Failure (medical history)

**CABG**

**CABG**

	Risk Factors	Citation	Comments
RF01	Age>=55	Johnston, G.; Goss, J. R.; Malmgren, J. A., and Spertus, J. A. Health status and social risk correlates of extended length of stay following coronary artery bypass surgery. <i>Ann Thorac Surg.</i> 2004 Feb; 77(2):557-62.	“Seventeen preoperative clinical variables tested were significantly associated with extended SLOS. The elements with the greatest statistical significance were congestive heart failure” (CHF); preop IABP (intraaortic balloon pump); ejection fraction less than 40%; comorbidity score more than or equal to 2 (sum of diabetes, hypertension, COPD, pulmonary disease, PVD, CVA and creatinine $\geq$ 2.0); cardiogenic shock, and preoperative stay of more than 2 days .Selfreported variables that were significantly associated with extended SLOS included: not being married , unemployment , one or more social risk factors (living alone, not having someone to trust and confide in, feeling lonely often, and not having enough social contact);, and multiple SF-36 and SAQ domains. Pages 559 & 560.
		Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. <i>HSR.</i> 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: Age
		van de Pol, M.A.; van Houdenhoven, M.; Hans, E.W.; Boersma, E.; Bax, J.J.; Feringa, H.H.H.; Schouten, O.; van	Univariate analysis showed that <b>advanced age</b> , previous myocardial infarction, congestive heart failure,

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	Risk Factors	Citation	Comments
		Sambeek, M.R.H.M; and Poldermans, D. Influence of Cardiac Risk Factors and Medication on Length of Hospitalization in Patients Undergoing Major Vascular Surgery. The American Journal of Cardiology. 2006 May 15; 97(10): 1423-1426.	previous cerebrovascular accident, hypertension, renal dysfunction, and COPD were associated with a prolonged LOS. Page 1424.
RF02	Male	Cowper, P. A.; DeLong, E. R.; Hannan, E. L.; Muhlbaier, L. H.; Lytle, B. L.; Jones, R. H.; Holman, W. L.; Pokorny, J. J.; Stafford, J. A.; Mark, D. B., and Peterson, E. D. Trends in postoperative length of stay after bypass surgery. Am Heart J. 2006 Dec; 152(6):1194-200.	Determinants of postoperative LOS “Baseline patient factors associated with longer stays included older age, <b>female sex</b> , minority race, urgency of procedure, severity of coronary disease, and comorbid illnesses such as COPD, diabetes, and renal insufficiency. Similar factors were identified as predictors of LOS in a recent national study of postoperative LOS after bypass surgery.” Page 1199.
		Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: <b>Female</b>
RF05	Diabetes	Baker, R. A.; Hallsworth, L. J., and Knight, J. L. Stroke after coronary artery bypass grafting. Ann Thorac Surg. 2005 Nov; 80(5):1746-50.	“ <b>Diabetes</b> , history of stroke, and older age (were identified as risk factors for stroke after coronary bypass.” Page 1746. Preoperatively, stroke patients were older weighed less, were more likely to be diabetic, hypertensive,

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	Risk Factors	Citation	Comments
			<p>have creatinine levels greater than 0.12 mmol/L and have a history of stroke than those who did not suffer a postoperative stroke. Page 1748</p> <p>LOS for stroke patients (n=51) = 20.2 ± 12.8</p> <p>LOS for non stroke patients (n=4329)= 8.7 ± 5.3. Page 1748</p>
		<p>Cowper, P. A.; DeLong, E. R.; Hannan, E. L.; Muhlbaier, L. H.; Lytle, B. L.; Jones, R. H.; Holman, W. L.; Pokorny, J. J.; Stafford, J. A.; Mark, D. B., and Peterson, E. D. Trends in postoperative length of stay after bypass surgery. Am Heart J. 2006 Dec; 152(6):1194-200.</p>	<p>Determinants of postoperative LOS</p> <p>“Baseline patient factors associated with longer stays included older age, female sex, minority race, urgency of procedure, severity of coronary disease, and comorbid illnesses such as COPD, <b>diabetes</b>, and renal insufficiency. Similar factors were identified as predictors of LOS in a recent national study of postoperative LOS after bypass surgery.” Page 1199.</p>
		<p>Johnston, G.; Goss, J. R.; Malmgren, J. A., and Spertus, J. A. Health status and social risk correlates of extended length of stay following coronary artery bypass surgery. Ann Thorac Surg. 2004 Feb; 77(2):557-62.</p>	<p>“Seventeen preoperative clinical variables tested were significantly associated with extended SLOS. The elements with the greatest statistical significance were congestive heart failure” (CHF); preop IABP (intraaortic balloon pump); ejection fraction less than 40%; comorbidity score more than or equal to 2 (sum of <b>diabetes</b>, hypertension, COPD, pulmonary disease, PVD, CVA and creatinine ≥ 2.0); cardiogenic shock, and preoperative stay of more than 2</p>

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	Risk Factors	Citation	Comments
			days .Selfreported variables that were significantly associated with extended SLOS included: not being married , unemployment , one or more social risk factors (living alone, not having someone to trust and confide in, feeling lonely often, and not having enough social contact); and multiple SF-36 and SAQ domains. Pages 559 & 560.
		Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: Diabetes
RF07	Chronic cerebrovascular disease	van de Pol, M.A.; van Houdenhoven, M.; Hans, E.W.; Boersma, E.; Bax, J.J.; Feringa, H.H.H.; Schouten, O.; van Sambeek, M.R.H.M; and Poldermans, D. Influence of Cardiac Risk Factors and Medication on Length of Hospitalization in Patients Undergoing Major Vascular Surgery. The American Journal of Cardiology. 2006 May 15; 97(10): 1423-1426.	Univariate analysis showed that advanced age, previous myocardial infarction, congestive heart failure, <b>previous cerebrovascular accident</b> , hypertension, renal dysfunction, and COPD were associated with a prolonged LOS. Page 1424.
RF08	Chronic renal disease	Afshinnia, F.; Ayazi, P., and Chadow, H. L. Glomerular filtration rate on admission independently predicts short-term in-hospital mortality after acute myocardial infarction. Am J Nephrol. 2006; 26(4):408-14.	“Abstract: BACKGROUND: Risk of cardiovascular events is higher in patients with chronic kidney disease.” Page 408
		Baker, R. A.; Hallsworth, L. J., and	“Diabetes, history of stroke, and older

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Risk Factors	Citation	Comments
	<p>Knight, J. L. Stroke after coronary artery bypass grafting. <i>Ann Thorac Surg.</i> 2005 Nov; 80(5):1746-50.</p>	<p>age were identified as risk factors for stroke after coronary bypass.” Page 1746.</p> <p>Preoperatively, stroke patients were older weighed less, were more likely to be diabetic, <b>hypertensive</b>, have <b>creatinine levels greater than 0.12 mmol/L</b> and have a history of stroke than those who did not suffer a postoperative stroke. Page 1748</p> <p>LOS for stroke patients (n=51) = 20.2 ±12.8</p> <p>LOS for non stroke patients (n=4329)= 8.7 ± 5.3. Page 1748</p>
	<p>Cowper, P. A.; DeLong, E. R.; Hannan, E. L.; Muhlbaier, L. H.; Lytle, B. L.; Jones, R. H.; Holman, W. L.; Pokorny, J. J.; Stafford, J. A.; Mark, D. B., and Peterson, E. D. Trends in postoperative length of stay after bypass surgery. <i>Am Heart J.</i> 2006 Dec; 152(6):1194-200.</p>	<p>Determinants of postoperative LOS</p> <p>“Baseline patient factors associated with longer stays included older age, female sex, minority race, urgency of procedure, severity of coronary disease, and comorbid illnesses such as COPD, diabetes, and <b>renal insufficiency</b>.</p> <p>Similar factors were identified as predictors of LOS in a recent national study of postoperative LOS after bypass surgery.” Page 1199.</p>
	<p>Johnston, G.; Goss, J. R.; Malmgren, J. A., and Spertus, J. A. Health status and social risk correlates of extended length of stay following coronary artery bypass surgery. <i>Ann Thorac Surg.</i> 2004 Feb; 77(2):557-62.</p>	<p>“Seventeen preoperative clinical variables tested were significantly associated with extended SLOS. The elements with the greatest statistical significance were congestive heart failure” (CHF); preop IABP (intraaortic balloon pump); ejection</p>

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	Risk Factors	Citation	Comments
			fraction less than 40%; comorbidity score more than or equal to 2 (sum of diabetes, <b>hypertension</b> , COPD, pulmonary disease, PVD, CVA and creatinine $\geq$ 2.0); cardiogenic shock, and preoperative stay of more than 2 days .Selfreported variables that were significantly associated with extended SLOS included: not being married , unemployment , one or more social risk factors (living alone, not having someone to trust and confide in, feeling lonely often, and not having enough social contact);, and multiple SF-36 and SAQ domains. Pages 559 & 560.
		Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: Renal Failure, not on dialysis Renal Failure, on dialysis
RF11	COPD (definition differs from RF36)	Cowper, P. A.; DeLong, E. R.; Hannan, E. L.; Muhlbaier, L. H.; Lytle, B. L.; Jones, R. H.; Holman, W. L.; Pokorny, J. J.; Stafford, J. A.; Mark, D. B., and Peterson, E. D. Trends in postoperative length of stay after bypass surgery. Am Heart J. 2006 Dec; 152(6):1194-200.	Determinants of postoperative LOS “Baseline patient factors associated with longer stays included older age, female sex, minority race, urgency of procedure, severity of coronary disease, and comorbid illnesses such as <b>COPD</b> , diabetes, and renal insufficiency. Similar factors were identified as predictors of LOS in a recent national study of

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	Risk Factors	Citation	Comments
			postoperative LOS after bypass surgery.” Page 1199.
		Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: COPD
		Johnston, G.; Goss, J. R.; Malmgren, J. A., and Spertus, J. A. Health status and social risk correlates of extended length of stay following coronary artery bypass surgery. Ann Thorac Surg. 2004 Feb; 77(2):557-62.	“Seventeen preoperative clinical variables tested were significantly associated with extended SLOS. The elements with the greatest statistical significance were congestive heart failure” (CHF); preop IABP (intraaortic balloon pump); ejection fraction less than 40%; comorbidity score more than or equal to 2 (sum of diabetes, hypertension, <b>COPD</b> , pulmonary disease, PVD, CVA and creatinine $\geq 2.0$ ); cardiogenic shock, and preoperative stay of more than 2 days .Selfreported variables that were significantly associated with extended SLOS included: not being married , unemployment , one or more social risk factors (living alone, not having someone to trust and confide in, feeling lonely often, and not having enough social contact);, and multiple SF-36 and SAQ domains. Pages 559 & 560.
		van de Pol, M.A.; van Houdenhoven, M.; Hans, E.W.; Boersma, E.; Bax, J.J.; Feringa, H.H.H.; Schouten, O.; van	Univariate analysis showed that advanced age, previous myocardial infarction, congestive heart failure,

**CABG**

	Risk Factors	Citation	Comments
		Sambeek, M.R.H.M; and Poldermans, D. Influence of Cardiac Risk Factors and Medication on Length of Hospitalization in Patients Undergoing Major Vascular Surgery. The American Journal of Cardiology. 2006 May 15; 97(10): 1423-1426.	previous cerebrovascular accident, hypertension, renal dysfunction, and <b>COPD</b> were associated with a prolonged LOS. Page 1424.
RF12	Cardiomyopathy		
RF13	Chronic cardiac conditions	Johnston, G.; Goss, J. R.; Malmgren, J. A., and Spertus, J. A. Health status and social risk correlates of extended length of stay following coronary artery bypass surgery. Ann Thorac Surg. 2004 Feb; 77(2):557-62.	“Seventeen preoperative clinical variables tested were significantly associated with extended SLOS. The elements with the greatest statistical significance were congestive heart failure” (CHF); preop IABP (intraaortic balloon pump); ejection fraction less than 40%; comorbidity score more than or equal to 2 (sum of diabetes, hypertension, COPD, pulmonary disease, <b>PVD</b> , CVA and creatinine $\geq 2.0$ ); cardiogenic shock, and preoperative stay of more than 2 days .Selfreported variables that were significantly associated with extended SLOS included: not being married , unemployment , one or more social risk factors (living alone, not having someone to trust and confide in, feeling lonely often, and not having enough social contact);, and multiple SF-36 and SAQ domains. Pages 559 & 560.
RF15	Atherosclerosis and lipid disorders	Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality	Table 1: Risk Adjustment Model for CABG Surgery:

## CABG

Risk Factors		Citation	Comments
		Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Severity of atherosclerotic disease (previous stroke, carotid disease, aortoiliac disease, femoral-popliteal disease, calcified aorta.)
RF16	PCI	Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: Emergency Transfer to OR post -PCI
RF18	Musculoskeletal conditions	Warrington, K.J.; Kent, P.D.; Frye, R.L.; Lymp, J.F.; Kopecky; S.L.; Goronzy, J.J.; Weyand, C.M. Rheumatoid Arthritis is an Independent Risk Factor for Multi-vessel Coronary Artery Disease: A Case Control Study. Arthritis Res Ther. 2005;7(5):R984-R991.	
RF19	AMI - initial episode of care	Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: Previous MI < 6 hours, 6-23 hours, 1-7 days, > 7 days (
RF20	CAD without prior CABG	Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: Extent of CAD (left main, 70-89% or left main, > 89%).
RF21	CAD with prior CABG	Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate	Table 1: Risk Adjustment Model for CABG Surgery: Previous open heart surgery (one, two

**CABG**

	Risk Factors	Citation	Comments
		on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	or more)
RF22	Diabetes (RF05) and Obesity (RF10)	Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: Diabetes and BSA
Add?	Mental health status (used of the 5 item mental health subscale of the medical Outcomes Trust SF-20 Questionnaire.	Halpin, L. S. and Barnett, S. D. Preoperative state of mind among patients undergoing CABG: effect on length of stay and postoperative complications. J Nurs Care Qual. 2005 Jan-2005 Mar 31; 20(1):73-80.	“We found that a preoperative pessimistic state of mind increased LOS by almost 2 days as compared to patients -with an optimistic state of mind, despite adjustment for gender, age, and disease severity” Page 76
Add?	Social factors, preoperative stay > 2 days,	Johnston, G.; Goss, J. R.; Malmgren, J. A., and Spertus, J. A. Health status and social risk correlates of extended length of stay following coronary artery bypass surgery. Ann Thorac Surg. 2004 Feb; 77(2):557-62.	“Seventeen preoperative clinical variables tested were significantly associated with extended SLOS. The elements with the greatest statistical significance were congestive heart failure” (CHF); preop IABP (intraaortic balloon pump); ejection fraction less than 40%; comorbidity score more than or equal to 2 (sum of diabetes, hypertension, COPD, pulmonary disease, PVD, CVA and creatinine $\geq$ 2.0); cardiogenic shock, and <b>preoperative stay of more than 2 days</b> .Selfreported variables that were significantly associated with extended SLOS included: <b>not being married , unemployment , one or more social risk factors (living</b>

**CABG**

	Risk Factors	Citation	Comments
			<p><b>alone, not having someone to trust and confide in, feeling lonely often, and not having enough social contact);, and multiple SF-36 and SAQ domains. Pages 559 &amp; 560.</b></p>
R33 (Add?)	Congestive Heart Failure	<p>Johnston, G.; Goss, J. R.; Malmgren, J. A., and Spertus, J. A. Health status and social risk correlates of extended length of stay following coronary artery bypass surgery. <i>Ann Thorac Surg.</i> 2004 Feb; 77(2):557-62.</p>	<p>“Seventeen preoperative clinical variables tested were significantly associated with extended SLOS. The elements with the greatest statistical significance were congestive heart failure” (<b>CHF</b>); preop IABP (intraaortic balloon pump); ejection fraction less than 40%; comorbidity score more than or equal to 2 (sum of diabetes, hypertension, <b>COPD</b>, pulmonary disease, PVD, CVA and creatinine <math>\geq 2.0</math>); cardiogenic shock, and preoperative stay of more than 2 days .Selfreported variables that were significantly associated with extended SLOS included: not being married , unemployment , one or more social risk factors (living alone, not having someone to trust and confide in, feeling lonely often, and not having enough social contact);, and multiple SF-36 and SAQ domains. Pages 559 &amp; 560.</p>
		<p>Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. <i>HSR.</i> 2008 Feb;</p>	<p>Table 1: Risk Adjustment Model for CABG Surgery: CHF, this admission CHF, previous admission</p>

## CABG

	Risk Factors	Citation	Comments
		43(1part 1): 300-312. Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: Malignant ventricular arrhythmias
RF09 Chronic liver disease (Add?)		Glance, L.G.; Dick, A.; Mukamel, D.B.; Li, Y.; Osler, T.M. Are High-Quality Cardiac Surgeons Less Likely to Operate on High-Risk Patients Compared to Low-Quality Surgeons? Evidence from New York State. HSR. 2008 Feb; 43(1part 1): 300-312.	Table 1: Risk Adjustment Model for CABG Surgery: Hepatic Failure

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CABG

Risk Factors		Citation	Comments
RF01	Age>=55	Jacobson, K. M.; Hall Long, K.; McMurtry, E. K.; Naessens, J. M., and Rihal, C. S. The economic burden of complications during percutaneous coronary intervention. Qual Saf Health Care. 2007 Apr; 16(2):154-9	Patients experiencing complications were older, more likely to present w/emergent PCI, recent or prior MI, multi-vessel disease, and comorbid conditions than patients who did not experience these events. Page 154 “Length of stay was also markedly longer among complicated PCI episodes with an observed mean difference of 4.5 days between complicated an uncomplicated PCIs.” Page 157 Complicated patients were older (71 vs 66 years of age). Page 156
		Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322. “Patients who had ≥1 complication were significantly more likely to be <b>&gt;75 years of age</b> , women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction

## PCI

	Risk Factors	Citation	Comments
			disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”
RF02	Male	Jacobson, K. M.; Hall Long, K.; McMurtry, E. K.; Naessens, J. M., and Rihal, C. S. The economic burden of complications during percutaneous coronary intervention. Qual Saf Health Care. 2007 Apr; 16(2):154-9	Patients experiencing complications were older, more likely to present w/emergent PCI, recent or prior MI, multi-vessel disease, and comorbid conditions than patients who did not experience these events. Page 154 “Length of stay was also markedly longer among complicated PCI episodes with an observed mean difference of 4.5 days between complicated an uncomplicated PCIs.” Page 157 Complicated patients were more likely <b>female</b> . Page 156
		Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322. “Patients who had ≥1 complication

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	Risk Factors	Citation	Comments
			<p>were significantly more likely to be &gt;75 years of age, <b>women</b>, and nonwhite. Table 1 also indicates that patients with <math>\geq 1</math> complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”</p>
RF03	Site of infarction: anterior or anteriolateral		
RF04	Site of infarction: subendocardial		
RF05	Diabetes	<p>Baker, R. A.; Hallsworth, L. J., and Knight, J. L. Stroke after coronary artery bypass grafting. Ann Thorac Surg. 2005 Nov; 80(5):1746-50.</p>	<p>“<b>Diabetes</b>, history of stroke, and older age were identified as risk factors for stroke after coronary bypass.” Page 1746.                      Preoperatively, stroke patients were older weighed less, were more likely to be diabetic, hypertensive, have creatinine levels greater than 0.12 mmol/L and have a history of stroke than those who did not suffer a postoperative stroke.</p>

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	Risk Factors	Citation	Comments
			Page 1748 LOS for stroke patients (n=51) = 20.2 ± 12.8 LOS for non stroke patients (n=4329)= 8.7 ± 5.3. Page 1748
		Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322. “Patients who had ≥1 complication were significantly more likely to be >75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction disorder, chronic renal failure, <b>or insulin-dependent diabetes</b> . In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, <b>noninsulin-dependent diabetes</b> , or obesity, or be

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	Risk Factors	Citation	Comments
			a current smoker.”
RF06	Cancer	Jacobson, K. M.; Hall Long, K.; McMurtry, E. K.; Naessens, J. M., and Rihal, C. S. The economic burden of complications during percutaneous coronary intervention. Qual Saf Health Care. 2007 Apr; 16(2):154-9	Patients experiencing complications were older, more likely to present w/emergent PCI, recent or prior MI, multi-vessel disease, and comorbid conditions than patients who did not experience these events. Page 154 “Length of stay was also markedly longer among complicated PCI episodes with an observed mean difference of 4.5 days between complicated an uncomplicated PCIs.” Page 157 Page 156 (Complicated patients were cancer patients). Page 156
RF07	Chronic cerebrovascular disease	Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322. “Patients who had ≥1 complication were significantly more likely to be >75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, <b>cerebral vascular disease</b> , chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock,

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	<b>Risk Factors</b>	<b>Citation</b>	<b>Comments</b>
			cardiomyopathy, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”
RF08	Chronic renal disease	Afshinnia, F.; Ayazi, P., and Chadow, H. L. Glomerular filtration rate on admission independently predicts short-term in-hospital mortality after acute myocardial infarction. <i>Am J Nephrol.</i> 2006; 26(4):408-14.	“Abstract: BACKGROUND: Risk of cardiovascular events is higher in patients with chronic kidney disease.” Page 408
		Jacobson, K. M.; Hall Long, K.; McMurtry, E. K.; Naessens, J. M., and Rihal, C. S. The economic burden of complications during percutaneous coronary intervention. <i>Qual Saf Health Care.</i> 2007 Apr; 16(2):154-9	Patients experiencing complications were older, more likely to present w/emergent PCI, recent or prior MI, multi-vessel disease, and comorbid conditions than patients who did not experience these events. Page 154 “Length of stay was also markedly longer among complicated PCI episodes with an observed mean difference of 4.5 days between complicated an uncomplicated PCIs.” Page 157 With the exception of diabetes all comorbid conditions of interest were more prevalent among patients who experienced complications compared with pts who were free of these

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	Risk Factors	Citation	Comments
			adverse events. . Page 156 (Table 1: moderate or severe renal disease).
		Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	<p>“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322.</p> <p>“Patients who had ≥1 complication were significantly more likely to be &gt;75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction disorder, <b>chronic renal failure</b>, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”</p>

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	Risk Factors	Citation	Comments
RF09	Chronic liver disease		
RF10	Obesity	Steinberg, B.A.; Cannon, C.P.; Hernandez, A.F.; Pan, W.; Peterson, E.D.; Fonarow, G.C. Medical therapies and invasive treatments for coronary artery disease by body mass: the "obesity paradox" in the Get With The Guidelines database. Am J Cardiol. 2007 Nov 1;100(9):1331-5.	<p>“Although the effect was smaller, BMI also significantly predicted length of stay in multivariable analysis. Underweight patients had nearly an identical length of stay compared with their healthy-weight counterparts (adjusted mean ratio 1.02, 95% CI 0.99 to 1.06, p = 0.23), (5.60 and <b>overweight and obese patients had a significantly shorter length of hospitalization</b> days for healthy-weight patients vs 5.06 and 5.08 days for overweight and obese patients, respectively, adjusted mean ratio 0.97, 95% CI 0.95 to 0.98, p =0.0001 for the 2 comparisons). Page 1333</p>
		Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	<p>“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322.</p> <p>“Patients who had ≥1 complication were significantly more likely to be &gt;75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, cerebral vascular disease, chronic obstructive</p>

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	Risk Factors	Citation	Comments
			<p>pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or <b>obesity</b>, or be a current smoker.”</p>
RF11	COPD (definition differs from RF36)	<p>Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.</p>	<p>“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322.</p> <p>“Patients who had ≥1 complication were significantly more likely to be &gt;75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, cerebral vascular disease, <b>chronic obstructive pulmonary disease</b>, peripheral vascular disease, cardiogenic shock, cardiomyopathy,</p>

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	Risk Factors	Citation	Comments
			<p>conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”</p>
RF12	Cardiomyopathy	<p>Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.</p>	<p>“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322.</p> <p>“Patients who had ≥1 complication were significantly more likely to be &gt;75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, <b>cardiomyopathy</b>, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without</p>

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	Risk Factors	Citation	Comments
			<p>complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”</p>
RF13	Chronic cardiac conditions	<p>Jacobson, K. M.; Hall Long, K.; McMurtry, E. K.; Naessens, J. M., and Rihal, C. S. The economic burden of complications during percutaneous coronary intervention. Qual Saf Health Care. 2007 Apr; 16(2):154-9</p>	<p>Patients experiencing complications were older, more likely to present w/emergent PCI, recent or prior MI, multi-vessel disease, and comorbid conditions than patients who did not experience these events. Page 154  “Length of stay was also markedly longer among complicated PCI episodes with an observed mean difference of 4.5 days between complicated an uncomplicated PCIs.” Page 157  Page 156 (Table 1: hypertension, PVD.).</p>
		<p>Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.</p>	<p>“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322.  “Patients who had ≥1 complication were significantly more likely to be &gt;75 years of age, women, and nonwhite. Table 1 also indicates that</p>

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	Risk Factors	Citation	Comments
			<p>patients with <math>\geq 1</math> complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, <b>peripheral vascular disease</b>, cardiogenic shock, cardiomyopathy, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”</p>
RF14	History of PTCA (Percutaneous transluminal coronary angioplasty status) V4582	Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	<p>“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 <math>\pm</math> \$9,635, with an average length of stay of 3.0 <math>\pm</math> 3.2 days, compared with \$26,807 <math>\pm</math> \$27,596 and 8.0 <math>\pm</math> 8.9 days for patients who did develop complications.” Page 322.</p> <p>“Patients who had <math>\geq 1</math> complication were significantly more likely to be &gt;75 years of age, women, and nonwhite. Table 1 also indicates that patients with <math>\geq 1</math> complication were significantly more likely to have an acute myocardial infarction,</p>

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	<b>Risk Factors</b>	<b>Citation</b>	<b>Comments</b>
			congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, <b>previous PCI</b> , or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”
RF15	Atherosclerosis and lipid disorders	Jacobson, K. M.; Hall Long, K.; McMurtry, E. K.; Naessens, J. M., and Rihal, C. S. The economic burden of complications during percutaneous coronary intervention. Qual Saf Health Care. 2007 Apr; 16(2):154-9	Patients experiencing complications were older, more likely to present w/emergent PCI, recent or prior MI, multi-vessel disease, and comorbid conditions than patients who did not experience these events. Page 154 “Length of stay was also markedly longer among complicated PCI episodes with an observed mean difference of 4.5 days between complicated an uncomplicated PCIs.” Page 157 Page 156 (Table 1: Calcified artery, number of diseased vessels etc.).
		Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions.	“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days,

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<b>Risk Factors</b>		<b>Citation</b>	<b>Comments</b>
		The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	<p>compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322.</p> <p>“Patients who had ≥1 complication were significantly more likely to be &gt;75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an acute myocardial infarction, congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”</p>
RF17	CABG	Jacobson, K. M.; Hall Long, K.; McMurtry, E. K.; Naessens, J. M., and Rihal, C. S. The economic burden of complications during percutaneous coronary intervention. Qual Saf Health Care. 2007 Apr; 16(2):154-9	<p>Patients experiencing complications were older, more likely to present w/emergent PCI, recent or prior MI, multi-vessel disease, and comorbid conditions than patients who did not experience these events. Page 154</p> <p>“Length of stay was also markedly longer among complicated PCI</p>

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	Risk Factors	Citation	Comments
			<p>episodes with an observed mean difference of 4.5 days between complicated an uncomplicated PCIs.” Page 157 Page 156 (Table 1:Prior CABG).</p>
		<p>Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.</p>	<p>“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322.</p> <p>“Patients who had ≥1 complication were significantly more likely to be &gt;75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an <b>acute myocardial infarction</b>, congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a <b>previous CABG</b>, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be</p>

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	Risk Factors	Citation	Comments
			a current smoker.”
RF18	Musculoskeletal conditions	Warrington, K.J.; Kent, P.D.; Frye, R.L.; Lymp, J.F.; Kopecky; S.L.; Goronzy, J.J; Weyand, C.M. Rheumatoid Arthritis is an Independent Risk Factor for Multi-vessel Coronary Artery Disease: A Case Control Study. Arthritis Res Ther. 2005;7(5):R984-R991.	
RF19	AMI	Jacobson, K. M.; Hall Long, K.; McMurtry, E. K.; Naessens, J. M., and Rihal, C. S. The economic burden of complications during percutaneous coronary intervention. Qual Saf Health Care. 2007 Apr; 16(2):154-9	Patients experiencing complications were older, more likely to present w/emergent PCI, <b>recent or prior MI</b> , multi-vessel disease, and comorbid conditions than patients who did not experience these events. Page 154 “Length of stay was also markedly longer among complicated PCI episodes with an observed mean difference of 4.5 days between complicated an uncomplicated PCIs.” Page 157
		Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322. “Patients who had ≥1 complication were significantly more likely to be >75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were

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	Risk Factors	Citation	Comments
			<p>significantly more likely to have an <b>acute myocardial infarction</b>, congestive heart failure, cerebral vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”</p>
RF33 (Add)	Congestive Heart Failure	Kugelmass, A.D.; Cohen, D.J.; Brown , P.P.; Simon, A.W.; Becker, E.R.; Culler, S.D. Hospital Resources Consumed in Treating Complications Associated With Percutaneous Coronary Interventions. The American Journal of Cardiology. 2006 Feb; 97(1):322-327.	<p>“The observed average cost of a PCI hospitalization for patients who did not develop complications was \$13,861 ± \$9,635, with an average length of stay of 3.0 ± 3.2 days, compared with \$26,807 ± \$27,596 and 8.0 ± 8.9 days for patients who did develop complications.” Page 322.</p> <p>“Patients who had ≥1 complication were significantly more likely to be &gt;75 years of age, women, and nonwhite. Table 1 also indicates that patients with ≥1 complication were significantly more likely to have an acute myocardial infarction, <b>congestive heart failure</b>, cerebral</p>

# PCI

	<b>Risk Factors</b>	<b>Citation</b>	<b>Comments</b>
			vascular disease, chronic obstructive pulmonary disease, peripheral vascular disease, cardiogenic shock, cardiomyopathy, conduction disorder, chronic renal failure, or insulin-dependent diabetes. In contrast, patients without complications were significantly more likely to have had a previous CABG, previous PCI, or previous myocardial infarction, have unstable angina, hypertension, hypercholesterolemia, noninsulin-dependent diabetes, or obesity, or be a current smoker.”



## Pneumonia

	Risk Factors	Citation	Comments
RF01	Age >=55	PSI	A risk factor included in the scoring for the PSI.
RF02	Male	PSI	A risk factor included in the scoring for the PSI. Male (Points assigned = age. Female (Points assigned = age minus 10)
RF30	Any cancer except basal or squamous-cell skin cancer	PSI	A risk factor (neoplastic disease) included in the scoring for the PSI.
RF31	Cirrhosis or chronic hepatitis	PSI	A risk factor (liver disease) included in the scoring for the PSI.
RF32	Stroke or transient ischemic attack		
RF33	Congestive Heart Failure	PSI	A risk factor included in the scoring for the PSI.
RF34	Kidney disease	PSI	A risk factor (renal disease) included in the scoring for the PSI.
RF35	Suspected or documented HIV	Christensen, D.; Feldman, C.; Rossi, P.; Marrie, T.; Blasi, F.; Luna, C.; Fernandez, P.; Porras, J.; Martinez, J.; Weiss, K.; Levy, G.; Lode, H.; Gross, P.; File, T.; Ramirez, J. HIV infection does not influence clinical outcomes in hospitalized patients with bacterial community-acquired pneumonia: results from the CAPO international cohort study. Clin Infect Dis; 2005 Aug 15;41(4):554-6.	“In a case-control study, outcomes for 58 human immunodeficiency virus (HIV)-positive patients with community-acquired pneumonia (CAP) were compared with outcomes for 174 HIV-negative patients with CAP. No differences were found in the time to clinical stability, the length of hospitalization, and mortality. Clinical outcomes for hospitalized patients with CAP may not be influenced by HIV infection” Page 554 <b>Note: Small study</b>
RF36	COPD (definition differs from RF11)	Restrepo, M.I.; Mortensen, E.M.; Pugh, J.A.; Anzueto, A. COPD is associated with increased mortality in patients with community acquired Pneumonia. Eur Respir J 2006; 28: 346-351.	“For this study cohort, the median length of stay was longer by 2 days in COPD versus non-COPD patients (7 ± 8 versus 9 ± 25 days; p = 0.05).” Page 348.

Risk Factors		Citation	Comments
RF37	Inability to take oral medications	Halm, E.A and Teirstein, A.S. Management of Community-Acquired Pneumonia. N Engl J Med; 347(25): 2039-2045.	Table 2 One of Criteria for Determining The Appropriateness of Discharge (Patient is able to take oral antibiotics).
RF38	Temperature below 35°C (95°F) or above 40°C (104°F)	PSI	A risk factor included in the scoring for the PSI.
RF39	Altered mental status	PSI	A risk factor included in the scoring for the PSI.
RF40	(no longer used, effective v1.1)		
RF41	Sodium below 130 mEq/L	PSI	A risk factor included in the scoring for the PSI.
		Nair, V.; Niederman, M. S.; Masani, N., and Fishbane, S. Hyponatremia in community-acquired pneumonia. Am J Nephrol. 2007; 27(2):184-90.	“Hyponatremia is a common complication present at the time of admission for CAP. It is associated with more severe illness, increased mortality risk and extended hospital stays.”
RF42	Hematocrit less than 30%	PSI	A risk factor included in the scoring for the PSI.
RF43	Pleural effusion	PSI	A risk factor included in the scoring for the PSI.
RF44	Septicemia		
RF45	Respiratory Failure		

## Appendix D

### Literature Review Bibliography

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## **ADDENDUM on August 7, 2009**

The risk-adjustment models were re-run in March 2009 with National Inpatient Sample data from 2004-2006, using the same risk factors that were used in the initial model development. The definition of each risk factor was unchanged from the initial model and the risk factor definitions can be found in **Appendix B**.

The patient cohort for CABG was modified, to exclude CABG patients with concomitant valve replacement. The list of inclusion and exclusion codes used to define the revised CABG cohort can be found in **Appendix E**.

The intercepts and parameter estimates listed in **Tables 4-7 have been updated** for all four procedures and conditions and can be found in **Appendix F**.

## **Appendix E**

### **Updated Patient Category Specifications**

#### **CABG – Case Count**

##### **Inclusion criteria:**

- Discharge date within [Reporting Time Period](#)
- Inpatient discharges include deaths during the hospital stay
- Any one or more primary or secondary procedure codes in the following table:

##### **ICD-9-CM CABG procedure codes**

- 36.10 Aortocoronary bypass for heart revascularization, not otherwise specified
- 36.11 Aortocoronary bypass for one coronary artery
- 36.12 Aortocoronary bypass for two coronary artery
- 36.13 Aortocoronary bypass for three coronary artery
- 36.14 Aortocoronary bypass for four or more coronary arteries
- 36.15 Single internal mammary –coronary artery bypass
- 36.16 Double internal mammary –coronary artery bypass
- 36.17 Abdominal-coronary artery bypass
- 36.19 Other bypass anastomosis for heart revascularization

##### **Exclusions:**

- Patient age < 18
- Patients with a concomitant valve replacement (patients having one or more of the procedure codes listed in the table below)

##### **ICD-9-CM codes for valve replacement or repair:**

- 35.10 Open heart valvuloplasty without replacement, unspecified valve
- 35.11 Open heart valvuloplasty of aortic valve without replacement
- 35.12 Open heart valvuloplasty of mitral valve without replacement
- 35.13 Open heart valvuloplasty of pulmonary valve without replacement
- 35.14 Open heart valvuloplasty of tricuspid valve without replacement
- 35.20 Replacement of unspecified heart valve
- 35.21 Replacement of aortic valve with tissue graft
- 35.22 Other replacement of mitral valve with tissue graft
- 35.23 Replacement of mitral valve with tissue graft
- 35.24 Other replacement of mitral valve
- 35.25 Replacement of pulmonary valve with tissue graft
- 35.26 Other replacement of pulmonary valve
- 35.27 Replacement of tricuspid valve with tissue graft
- 35.28 Other replacement of tricuspid valve

**Appendix F**  
**Updated Risk Factor Specifications (based on NIS 2004-2006 data; redefined CABG cohort)**

**Table 4 – AMI Risk Adjustment Model (log LOS)**

Variable	Label	Parameter Estimate	Standard Error	t Value	Pr >  t
<b>Intercept</b>	Intercept	0.89001	0.01400	63.59	<.0001
<b>rf17</b>	CABG	1.07372	0.01843	58.26	<.0001
<b>rf33</b>	Congestive heart failure	0.47127	0.01168	40.34	<.0001
<b>rf32</b>	Stroke or transient ischemic attack	0.60306	0.03003	20.08	<.0001
<b>rf08</b>	Chronic renal disease	0.27317	0.01649	16.56	<.0001
<b>rf01</b>	Age GE 55	0.19501	0.01364	14.29	<.0001
<b>rf06</b>	Cancer	0.20621	0.03366	6.13	<.0001
<b>rf09</b>	chronic liver disease	0.17659	0.07813	2.26	0.0238
<b>rf16</b>	PCI	0.02430	0.01168	2.08	0.0376
	R-Square	0.2464			
	Root MSE	0.73926			

**Table 5 – PCI Risk Adjustment Model (log LOS)**

Variable	Label	Parameter Estimate	Standard Error	t Value	Pr >  t
<b>Intercept</b>	Intercept	0.39415	0.00587	67.18	<.0001
<b>rf19</b>	AMI	0.59815	0.00956	62.59	<.0001
<b>rf33</b>	Congestive heart failure	0.63364	0.01359	46.64	<.0001
<b>rf17</b>	CABG	1.24960	0.04616	27.07	<.0001
<b>rf08</b>	Chronic renal disease	0.43370	0.01938	22.38	<.0001
<b>rf11</b>	COPD	0.23267	0.01571	14.81	<.0001
<b>rf06</b>	Cancer	0.31173	0.03575	8.72	<.0001
<b>rf09</b>	chronic liver disease	0.36931	0.08733	4.23	<.0001
	R-Square	0.2946			
	Root MSE	0.66411			

**Table 6 – CABG Risk Adjustment Model (log LOS)**

Variable	Label	Parameter Estimate	Standard Error	t Value	Pr >  t
<b>Intercept</b>	Intercept	1.87700	0.01866	100.60	<.0001
<b>rf33</b>	Congestive heart failure	0.33908	0.01642	20.65	<.0001
<b>rf19</b>	AMI	0.22003	0.01428	15.41	<.0001
<b>rf08</b>	Chronic renal disease	0.28071	0.02418	11.61	<.0001
<b>rf01</b>	Age GE 55	0.15964	0.01608	9.93	<.0001
<b>rf02</b>	Is Male	(0.11506)	0.01367	(8.42)	<.0001
<b>rf11</b>	COPD	0.07247	0.01737	4.17	<.0001
<b>rf12</b>	Cardiomyopathy	0.10640	0.03490	3.05	0.0023
<b>rf09</b>	chronic liver disease	0.33451	0.10139	3.30	0.0010
	R-Square	0.1702			
	Root MSE	0.50571			

**Table 7 – Pneumonia Risk Adjustment Model (log LOS)**

Variable	Label	Parameter Estimate	Standard Error	t Value	Pr >  t
<b>Intercept</b>	Intercept	1.23987	0.00926	133.85	<.0001
<b>rf45</b>	Respiratory failure	0.45011	0.01088	41.38	<.0001
<b>rf44</b>	Septicemia	0.33271	0.01200	27.74	<.0001
<b>rf33</b>	Congestive heart failure	0.17929	0.00907	19.76	<.0001
<b>rf43</b>	Pleural effusion	0.34784	0.01820	19.12	<.0001
<b>rf01</b>	Age GE 55	0.13457	0.01018	13.22	<.0001
<b>rf34</b>	Kidney disease	0.10544	0.01052	10.03	<.0001
<b>rf36</b>	COPD	0.06683	0.00857	7.80	<.0001
<b>rf32</b>	Stroke - transient ischemic attack	0.28648	0.04394	6.52	<.0001
<b>rf31</b>	Cirrhosis or chronic hepatitis	0.20736	0.04186	4.95	<.0001
	R-Square	0.1275			
	Root MSE	0.72346			