CHAPTER NINE:
PRESENTATION AND INTERPRETATION OF FINAL MODELS

In this chapter, the final risk-adjustment models developed through the process described in Chapter Eight are presented. These models represent a best effort to elucidate the relationship between AMI mortality and various demographic and clinical risk factors.

ACUTE MYOCARDIAL INFARCTION: DEATH

The risk-adjustment models for AMI mortality were classified according to whether one or more hospitalizations occurred during the 8 weeks before the index admission. If there were prior hospitalizations, then more information about possible comorbidities was available. For example, cerebrovascular disease could be used as a risk factor in Model A if it was diagnosed during a prior hospitalization. If no records from prior hospitalizations were available, cerebrovascular disease could not be used as a risk factor in Model A because it could have represented an in-hospital complication of the AMI. Overall, 8.1% of the 68,012 study cases had one or more prior hospitalizations.

Table 9.1 shows the AMI Model A parameters for cases with no prior admissions; Table 9.2 shows the Model A parameters for cases with one or more prior admissions. Table 9.3 shows the Model B parameters for cases with no prior admissions; Table 9.4 shows the Model B parameters for cases with one or more prior admissions. Each risk variable in these tables is defined in Chapter Seven.

The columns in these tables provide the following information:

1. **The parameter estimate** is a measure of the risk associated with a covariate. A negative parameter estimate indicates that the covariate has a protective effect (reduces risk); a positive parameter estimate indicates that the covariate has a harmful effect (increases risk). The further this parameter estimate is from zero, the greater the impact of this covariate on the risk of AMI death. These numbers are maximum likelihood estimates, meaning that they are more consistent with the observed data than any other possible set of parameter estimates.

   The relationship between these parameter estimates and the probability of death can be expressed in this way:

   $$\ln(p/[1-p]) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_n x_n$$

   where p represents the probability of in-hospital death within 30 days after an AMI, β_0 represents the intercept term, $x_1 \ldots x_n$ represent risk variables, and $\beta_1 \ldots \beta_n$ represent

the associated parameter estimates. Solving for the probability of death, this formula can be rewritten as:

$$p = 1/(1 + e^{[\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta}$$

2. The p-value is a measure of the statistical significance of a parameter estimate. It is based on the Wald statistic, which approximately follows a chi square distribution. A small p-value (less than 0.05) indicates that the observed data are *not* consistent with the null hypothesis that the true value of the parameter is zero.

3. **The estimated odds ratio** associated with a covariate is another measure of risk, which may be easier to interpret than the parameter estimate. It equals the odds of death (p/[1-p], where p is the probability of death) among patients with a risk factor, divided by the odds of death among patients without that characteristic, adjusted for all of the other factors in the model. When the outcome is relatively infrequent, this odds ratio approximates the relative risk. An odds ratio less than one indicates that the covariate has a protective effect; an odds ratio greater than one indicates that the covariate has a harmful effect.

   The estimated odds ratios were derived by exponentiating the corresponding parameter estimates. For example, the odds ratio of 1.46 for CHRRENAB in Table 9.2 is equal to $e^{0.3797}$. This odds ratio represents the odds of death among AMI patients with chronic renal failure, divided by the odds of death among similar patients without chronic renal failure.

   Note that the odds ratio for age, which is a continuously distributed variable, must be interpreted differently from other odds ratios. In this case, the estimated odds ratio represents the odds of death among patients of a certain age, divided by the odds of death among patients who are one year younger. The odds ratio associated with a ten-year age difference can be computed by raising the one-year odds ratio to the tenth power.

   If a risk factor is involved in a two-way interaction with any other risk factor, these odds ratios may be misleading. With a statistically significant ($p<0.05$) interaction, the effect of a particular risk factor on outcomes varies according to the level of a second risk factor. For example, the odds ratio associated with risk factor A may equal 4 if risk factor B is absent, but may equal 2 if that risk factor is present. To calculate the odds ratio for one variable conditioned on a specific value of a second (interacting) variable, use this formula:

$$\begin{aligned} OR(x_1 \mid x_2 = \delta) &= \text{odds}(x_1 = a \mid x_2 = \delta) / \text{odds}(x_1 = b \mid x_2 = \delta) \\ &= e^{([\beta_1 * a] + [\beta_3 * a * \delta])} / e^{([\beta_1 * b] + [\beta_3 * b * \delta])} \end{aligned}$$

   where x_1 and x_2 represent the two interacting risk factors, β_1 and β_2 represent the corresponding parameter estimates (β_2 drops out of the above formula because x_2 is

fixed equal to δ), β_3 represents the parameter estimate for the two-way interaction, and a and b represent two possible values of the first risk factor (x_1).

4. **The upper and lower confidence limits for the odds ratio** are an expression of confidence in the estimated odds ratio. There is a 95% probability that the true value of the odds ratio is between the lower confidence limit and the upper confidence limit. If the interval between these confidence limits includes one, then the null hypothesis that the covariate has no effect on the outcome cannot be rejected.

   The confidence limits for the odds ratio were computed by exponentiating the upper and lower confidence limits for the corresponding parameter estimate. These confidence limits were computed by adding 1.96 times the estimated standard error of the parameter estimate to its original value (upper limit), and subtracting 1.96 times the estimated standard error of the parameter estimate from its original value (lower limit). These standard errors are not shown, but are available upon request from OSHPD.

   If a risk factor is involved in a two-way interaction with another risk factor, these confidence limits may be misleading. To calculate the confidence limits for one variable conditioned on a specific value of a second (interacting) variable, one must refer to the covariance matrix of parameter estimates (available upon request from OSHPD).

Table 9.1 shows that the following factors are associated with a significantly increased risk of death among AMI cases **without** prior hospitalizations: congestive heart failure (CHF), high-risk or metastatic malignancy, complicated diabetes, late effects of cerebrovascular disease, chronic liver disease, chronic kidney disease, female sex, age, anterior wall site, inferior wall site, and other or unspecified site. Hypertension and hypothyroidism are associated with a significantly decreased risk of death among AMI cases **without** prior hospitalizations. The interaction terms indicate that the incremental risk of death due to CHF declines with age, is greatest among cases with subendocardial infarctions, and is least among those with an unspecified or other site. The incremental risk associated with several other risk factors, including female sex, other or unspecified site, and chronic kidney disease, declines with age (although the incremental risk with inferior site increases with age). Prior coronary bypass surgery is associated with a decreased risk of death only among AMI cases with other or unspecified site. Finally, the incremental risk associated with diabetes is relatively small among cases with other or unspecified site.

Table 9.2 shows that the following factors are associated with a significantly increased risk of death among AMI cases **with** prior hospitalizations: CHF, high-risk or metastatic malignancy, chronic kidney disease, mitral valve disorders (if diagnosed on a prior hospitalization), skin ulcer (if diagnosed on a prior hospitalization), female sex, age, anterior wall site, inferior wall site, and other or unspecified site. Hypertension is associated with a significantly decreased risk of death among AMI cases **with** prior hospitalizations. Prior coronary artery bypass surgery is associated with a marginally decreased risk of death. The interaction between CHF and age indicates that the incremental risk of death due to CHF declines with age (reaching zero at 92 years of

age). This model includes fewer predictors than the preceding model because of its smaller sample size.

The following Model B factors are associated with a significantly increased risk of death among AMI cases **without** prior hospitalizations (Table 9.3): pulmonary edema, shock, cerebrovascular disease, paroxysmal ventricular tachycardia, acidosis, hypernatremia and related electrolyte disorders, hypotension, complete atrioventricular block, epilepsy, and acute kidney disease. All but the last two were derived exclusively from the index record. Race is not associated with the risk of death; however, uninsured and emergency patients do face a higher risk of death. Among AMI cases with shock, pulmonary edema, cerebrovascular disease, hypotension, and acute kidney disease confer no additional risk, and CHF confers little additional risk.

The following Model B factors are associated with a significantly increased risk of death among AMI cases **with** prior hospitalizations (Table 9.4): pulmonary edema, shock, cerebrovascular disease, paroxysmal ventricular tachycardia, acidosis, hypernatremia and related electrolyte disorders, and acute kidney disease. All but the last one were derived exclusively from the index record. Payer source and race are not associated with the risk of death. Among AMI cases with shock, pulmonary edema confers no additional risk.

Table 9.1: Acute myocardial infarction mortality Model A, cases with no prior admissions (N = 62,570)

Variable	*Parameter Estimate*	*p value*	*Lower CI for Odds Ratio*	*Odds Ratio*	*Upper CI for Odds Ratio*
INTERCPT	-7.9073	0.0001	0.00	0.00	0.00
FEMALE	0.8848	0.0001	1.71	2.42	3.43
AGE	0.0652	0.0001	1.06	1.07	1.07
CHFB	2.6180	0.0001	9.40	13.71	20.00
CHRLIVEB	0.9713	0.0001	2.02	2.64	3.46
CHRRENAB	1.6767	0.0001	2.35	5.35	12.15
DBTCMPB	0.4890	0.0001	1.49	1.63	1.79
HRSECMAB	0.4500	0.0001	1.26	1.57	1.96
HTB	-0.5920	0.0001	0.52	0.55	0.59
LATECVAB	0.3428	0.0001	1.21	1.41	1.63
PRCABG	0.0649	0.2567	0.95	1.07	1.19
SITE_ANT	1.5947	0.0001	4.42	4.93	5.49
SITE_INF	0.2129	0.3250	0.81	1.24	1.89
SITE_OI	3.9967	0.0001	33.93	54.42	87.28
THYROIDB	-0.7267	0.0001	0.40	0.48	0.58
I_CHFANT	-0.5274	0.0001	0.51	0.59	0.69
I_CHFBAG	-0.0239	0.0001	0.97	0.98	0.98
I_CHFINF	-0.3788	0.0001	0.58	0.68	0.81
I_CHFOTH	-0.9683	0.0001	0.32	0.38	0.46
I_CHRAGE	-0.0175	0.0019	0.97	0.98	0.99
I_FEMAGE	-0.0093	0.0001	0.99	0.99	1.00
I_INFAGE	0.0134	0.0001	1.01	1.01	1.02
I_OTHAGE	-0.0213	0.0001	0.97	0.98	0.99
I_OTHDBC	-0.3439	0.0051	0.56	0.71	0.90
I_OTHPRC	-0.4591	0.0007	0.48	0.63	0.82

Table 9.2: Acute myocardial infarction mortality Model A, cases with one or more prior admissions (N = 5,442)

Variable	*Parameter Estimate*	*p value*	*Lower CI for Odds Ratio*	*Odds Ratio*	*Upper CI for Odds Ratio*
INTERCPT	-6.6575	0.0001	0.00	0.00	0.00
FEMALE	0.0165	0.8291	0.88	1.02	1.18
AGE	0.0554	0.0001	1.05	1.06	1.07
CHFB	2.2927	0.0001	3.60	9.90	27.27
CHRRENAB	0.3797	0.0005	1.18	1.46	1.81
HRSECMAB	0.5821	0.0005	1.29	1.79	2.48
HTB	-0.3918	0.0001	0.58	0.68	0.79
MITVALVP	0.5222	0.0061	1.16	1.69	2.45
PRCABG	-0.1927	0.0981	0.66	0.82	1.04
SITE_ANT	1.2781	0.0001	2.94	3.59	4.38
SITE_INF	1.0931	0.0001	2.38	2.98	3.74
SITE_OI	1.9546	0.0001	5.67	7.06	8.80
SKNULCRP	0.7440	0.0007	1.37	2.10	3.24
I_CHFBAG	-0.0250	0.0003	0.96	0.98	0.99

Table 9.3: Acute myocardial infarction mortality Model B, cases with no prior admissions (N = 62,220)

Variable	*Parameter Estimate*	*p value*	*Lower CI for Odds Ratio*	*Odds Ratio*	*Upper CI for Odds Ratio*
INTERCP	-8.5115	0.0001	0.00	0.00	0.00
FEMALE	0.4956	0.0130	1.11	1.64	2.43
AGE	0.0638	0.0001	1.06	1.07	1.07
RACBLA	-0.0888	0.2011	0.80	0.92	1.05
RACHISP	0.0301	0.5653	0.93	1.03	1.14
INSMCAL	0.1145	0.0881	0.98	1.12	1.28
INSNON	0.3486	0.0001	1.23	1.42	1.63
ACIDOSI	0.9477	0.0001	2.23	2.58	2.99
ACRENA	1.2331	0.0001	3.02	3.43	3.90
ATYP_E	0.4080	0.0001	1.42	1.50	1.60
CHFB	1.5734	0.0001	3.14	4.82	7.41
CHRLIVE	0.7832	0.0001	1.63	2.19	2.95
CHRREN	1.5440	0.0012	1.84	4.68	11.94
COATRB	0.5436	0.0001	1.52	1.72	1.95
DBTCMP	0.3199	0.0001	1.24	1.38	1.53
EPILEPB	1.1079	0.0001	2.54	3.03	3.61
HRSECM	0.4872	0.0001	1.27	1.63	2.08
HTB	-0.4721	0.0001	0.58	0.62	0.67
HYPERM	0.2701	0.0001	1.17	1.31	1.47
HYPOTE	0.5618	0.0001	1.58	1.75	1.95
LATECV	0.3697	0.0001	1.23	1.45	1.70
OTHCVAI	1.1647	0.0001	2.78	3.20	3.70
PRCABG	0.1416	0.0257	1.02	1.15	1.30
PULEDE	1.0239	0.0001	2.52	2.78	3.08
PVENTA	0.3420	0.0001	1.29	1.41	1.54
SHOCKI	3.3812	0.0001	25.72	29.41	33.62
SITE_AN	1.3807	0.0001	3.53	3.98	4.48
SITE_INF	-0.2739	0.2606	0.47	0.76	1.23
SITE_OI	4.1045	0.0001	35.82	60.61	102.56
THYROID	-0.6902	0.0001	0.41	0.50	0.61
I_CHFAN	-0.4963	0.0001	0.52	0.61	0.72
I_CHFBA	-0.0128	0.0001	0.98	0.99	0.99
I_CHFINF	-0.3959	0.0001	0.56	0.67	0.81
I_CHFOT	-0.9033	0.0001	0.33	0.41	0.50
I_CHRAG	-0.0187	0.0036	0.97	0.98	0.99
I_FEMAG	-0.0043	0.1097	0.99	1.00	1.00
I_INFAG	0.0161	0.0001	1.01	1.02	1.02
I_OTHAG	-0.0247	0.0001	0.97	0.98	0.98

Table 9.4: Acute myocardial infarction mortality Model B, cases with one or more prior admissions (N = 5,415)

Variable	*Parameter Estimate*	*p value*	*Lower CI for Odds Ratio*	*Odds Ratio*	*Upper CI for Odds Ratio*
INTERCPT	-6.9556	0.0001	0.00	0.00	0.00
FEMALE	0.0612	0.4625	0.90	1.06	1.25
AGE	0.0543	0.0001	1.04	1.06	1.07
RACBLACK	-0.1678	0.3095	0.61	0.85	1.17
RACHISP	0.0280	0.8461	0.77	1.03	1.36
INSMCAL	0.2185	0.2070	0.89	1.24	1.75
INSNONE	0.2650	0.3571	0.74	1.30	2.29
ACIDOSI	0.7871	0.0001	1.47	2.20	3.29
ACRENALB	0.8309	0.0001	1.77	2.30	2.98
CHFB	1.5434	0.0061	1.55	4.68	14.10
CHRRENAB	0.2486	0.0417	1.01	1.28	1.63
HRSECMAB	0.6197	0.0006	1.31	1.86	2.64
HTB	-0.3882	0.0001	0.57	0.68	0.80
HYPERMOI	0.5921	0.0001	1.41	1.81	2.32
MITVALVP	0.3125	0.1510	0.89	1.37	2.09
OTHCVAI	1.1685	0.0001	2.20	3.22	4.71
PRCABG	-0.1277	0.3119	0.69	0.88	1.13
PULEDEMI	0.9546	0.0001	1.98	2.60	3.41
PVENTACI	0.5744	0.0001	1.36	1.78	2.32
SHOCKI	2.1912	0.0001	6.78	8.95	11.80
SITE_ANT	1.1246	0.0001	2.48	3.08	3.82
SITE_INF	0.9915	0.0001	2.11	2.70	3.44
SITE_OI	1.9199	0.0001	5.38	6.82	8.65
SKNULCRP	0.6957	0.0033	1.26	2.01	3.19
I_CHFBAG	-0.0188	0.0121	0.97	0.98	1.00
I_SHKPUL	-1.1124	0.0003	0.18	0.33	0.60