Variations in Patterns of Care and Outcomes after Acute Myocardial Infarction for Medicare Beneficiaries in Fee-for-Service and HMO Settings

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Objective. To assess revascularization and mortality after acute myocardial infarction (AMI) for all Medicare patients in fee-for-service (FFS) and health maintenance organization (HMO) settings in California.

Data Sources/Study Setting. Hospital discharge abstract and death certificate data linked with Medicare enrollment files for patients aged 65 and over with Medicare coverage (69,040) discharged from a California-licensed hospital in 1994–1996.

Study Design. Risk-adjusted results were assessed for HMOs and FFS, as well as for FFS beneficiaries from areas served by each plan.

Data Collection/Extraction Methods. Risk models were based on all sampled patients. The HMO patients were aggregated into 17 pseudoplans: 5 individual plans, 4 large plans split geographically (10 observations), and 2 “pseudoplans” of small HMOs. Observed versus expected 30-day mortality rates, lengths-of-stay (LOS) during the index hospitalization and any transfers, revascularization (coronary artery bypass graft [CABG] surgery and/or percutaneous transluminal coronary angioplasty [PTCA]) during the index hospitalization or 30 days after admission, were calculated for each pseudoplan.

Principal Findings. Risk-adjusted death rate was slightly higher in FFS than in HMO settings ($p < .01$ with one risk adjustment model, n.s. with another). Three pseudoplans had significantly ($p < .01$) better than expected mortality rates. One pseudoplan was significantly worse ($p < .05$) with one risk adjustment model but not the other. The LOS and revascularization rates varied widely, but were not associated with outcomes. Plans with among the best results had the lowest LOS and revascularization rates. These pseudoplans were less likely to have their patients initially admitted to a hospital with revascularization capability, but the hospitals they used had higher CABG volumes. Even if CABG facilities were available during the index admission, in these plans with better than expected mortality rates, revascularization was often postponed or carried out elsewhere.

Conclusions. For Medicare patients having an AMI in the mid-1990s in California, risk-adjusted outcomes were no different, or slightly better on average, for those in HMOs than in FFS. Not all plans performed equally well, so understanding what leads to differences in quality is more important than simple comparisons of HMOs versus FFS.

Key Words. Health maintenance organizations (HMOs), acute myocardial infarction (AMI), Medicare, revascularization, quality

There is substantial controversy about the quality of care in health maintenance organizations (HMOs) and other forms of managed care. Although there is a growing literature (Miller and Luft 1994, 1997, 2002), many studies rely on data from a small number of often self-selected plans. Thus, the evidence, which suggests that quality is neither consistently worse nor better in HMOs, may reflect a biased sample. One exception included all 82 HMOs in the nation with 1,000 or more Medicare members, but its data are from 1989 (Clement et al. 1994).

The Medicare program encompasses a broad range of plans. Because claims are not used for payment, HMOs have not always submitted data to Medicare. Apparent differences in utilization or quality may therefore be due to biases in the data reported. Some studies supplement Medicare data with Surveillance, Epidemiology, and End Results (SEER) program information for cancer patients (Merrill et al. 1999; Potosky et al. 1999; Riley et al. 1999). Unfortunately, SEER covers only certain geographic areas with few plans, and diagnosis and treatment differences in cancer care may reflect patient, rather than clinician, decisions.

This study focuses on Medicare beneficiaries in California hospitalized for an acute myocardial infarction (AMI) in 1994–1996. The data are from hospital-submitted discharge abstracts, avoiding the inconsistent reporting of claims by HMOs. To address several limitations of previous work, it includes all HMOs with Medicare beneficiaries, and outcomes are clearly defined: length of stay, mortality, and revascularization within 30 days. Indications for admission after AMI are relatively clear; well-validated risk adjustment

Gerald Kominski of UCLA provided the linked hospital discharge record data and Dexter Jung of CMRI supervised the linkage of those data with the Medicare enrollment files. Deborah Rennie of UCSF prepared the analytic files from those linked data. (Preparation and linkage of the discharge abstract and Medicare enrollment data upon which this article is based were performed under contract no. 500-96-P535 titled "Utilization and Quality Control Peer Review Organization for the State of California," sponsored by the Health Care Financing Administration [HCFA], Department of Health and Human Services [DHHS], a result of the Health Care Quality Improvement Program initiated by HCFA, which has encouraged identification of quality improvement projects derived from analysis of patterns of care, and therefore required no special funding on the part of this contractor [California Medical Review, Inc.].) The content of this paper does not necessarily reflect the views or policies of CMRI or DHHS. The author assumes full responsibility for the accuracy and completeness of the ideas presented. Partial support for this project was provided by the Integrated Healthcare Association.

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models are used to account for patient risk factors, and there is little patient discretion in AMI care.

Short-term outcomes and treatment of AMI are only one aspect of quality of care and, some might argue, one over which HMOs have little control. Overall cardiovascular disease rates would better reflect HMO effects on patient behavior and physician prescribing patterns, but would be confounded by benefit differences and patient orientation toward prevention. For AMI patients, HMOs might implement treatment protocols, but patients can certainly have a role in the choice of provider, length of stay, and decisions to transfer or revascularize. Moreover, several studies have examined outcomes and treatment for AMI patients in HMOs and fee-for-service (FFS) settings (Carlisle et al. 1992; Guadagnoli et al. 2000). The primary issue to be addressed in this paper, however, is not whether outcomes after AMI are better or worse for HMO enrollees, but whether there is sufficient homogeneity in outcomes across HMOs and groupings of FFS patients to usefully ask the question in that manner.

METHODS

Routine Preparation of the Data

The California Office of Statewide Health Planning and Development (OSHPD) has published reports on outcomes for patients with AMI since 1996 (Zach, Romano, and Luft 1997). These California Hospital Outcome Project (CHOP) reports use discharge abstracts required of all state-licensed hospitals. Routine edits return questionable data for correction. The CHOP team examines patterns of coding for all variables to identify over- and under-coding, for example, too low a proportion of AMI patients with a diagnosis of hypertension, or too high a proportion with the site of infarct unspecified. A small number of hospitals and all their patients are thereby eliminated.

The confidential file of discharge abstracts includes the patient's social security number, date of birth, and sex, all of which are used to link multiple admissions for the same person. Prior admission data allow the identification of certain conditions, such as heart failure, as having been present before the AMI. During subsequent admissions, revascularization procedures may take place. Linkage to the death certificate file captures out-of-hospital deaths.

To account for differences at admission in the risk of death, the CHOP contractor (UCLA for the data used in this study) estimated two risk models with 30-day mortality as the dependent variable. Model A used only variables

that clearly reflected the situation prior to admission, including age and sex, chronic comorbidities, for example, diabetes and hypertension, and AMI-specific risk factors such as site of infarction. Some diagnoses, such as heart failure, were included only if identified during an earlier admission. Model B included all the risk factors in Model A, plus diagnoses such as shock, that may have occurred subsequently during the stay. Appropriate interaction terms were included in both models. Model A somewhat undercompensates for true case-mix differences because it omits some variables that might be comorbidities; Model B somewhat overcompensates for risk differences because its variables may sometimes be complications of care. The models have been validated with chart data and have been used by other investigators (Zach, Romano, and Luft 1997; Krumholz et al. 1999).

Preparation of a Research File

The risk models and de-identified patient-level data are in the public domain; however, identifiers were needed to select patients of specific HMOs. Medicare enrollment files identify beneficiaries with FFS coverage, and if in an HMO, the specific plan. Social security number, sex, and birth date can serve as linking variables, but are highly confidential. For this project, UCLA sent a file of all AMI patients to California Medical Review, Inc. (CMRI), which has the enrollment files for Medicare beneficiaries in California. California Medical Review, Inc. linked HMO enrollment codes to the discharge data, removed all identifiers, and forwarded the resulting file to the University of California, San Francisco (UCSF). This protocol was approved by the UCSF and the California Department of Health Services human subjects committees.

The CHOP risk models for all patients were reestimated on Medicare patients aged 65 and over. The probability of death was calculated twice for each patient, once using Model A risk factors and once using Model B risk factors. Patients residing outside California, or without coverage under both Medicare parts A and B were excluded. Patients were then grouped by HMO or FFS, based on their coverage in the month of their AMI.

To prevent the larger plans from being identifiable, each was split into two or three subplans, based on the geographic locations of their patients. (The primary concern here was not that the plans would be identifiable to the casual reader, but to each other. If plan-specific results were presented, some of the plans could probably figure out which point represented their own results, and then by elimination determine which belonged to their chief competitors.)

Patient-level observations were aggregated to these pseudoplan or total FFS versus HMO patients. The probability of a pseudoplan having its observed number of deaths, given the estimated probability of death for each patient, was calculated using the Z-score. The proportion of patients having coronary artery bypass graft surgery (CABG) and/or percutaneous transluminal coronary angioplasty (PTCA) within 30 days after their AMI and the length of stay (LOS) during initial and transfer admissions were also calculated. Logistic models for revascularization and ordinary least-squares models for LOS were estimated using the risk variables from the mortality model.

Medical practice may vary geographically within a state as large as California, and an HMO may reflect practice styles in the areas from which it draws its enrollees. Observed and expected death and revascularization rates and LOS were computed for FFS beneficiaries in each three-digit zip code area and were weighted by the proportion of each pseudoplan's patients to give the outcomes for "local" FFS patients.

RESULTS

Linkage of the discharge abstracts with the enrollment file yielded 69,040 discharges in 1994–1996 for Medicare patients aged 65 and over. The coefficients of the reestimated risk models based on just those patients aged 65 and over were very similar to the original CHOP models (see online version at <http://www.blackwellpublishing.com/products/journals/suppmat/HESR/HESR02067/HESR02067sm.htm>). The c-statistics of .713–.816 were similar to other studies using administrative data (Krumholz et al. 1999; Alter et al. 2001). More important for the purposes of this study, the models are well calibrated and are quite accurate for groups of patients. For example, using Model A, the lowest 5 percent of cases by risk had a 2.7 percent predicted death rate versus 2.4 percent observed, and the highest 5 percent had 49 percent predicted and 48 percent observed death rates.

For revascularization, the lowest 5 percent of cases by predicted risk had predicted and observed rates of 4.8 percent and 3.7 percent, while the top 5 percent of cases had predicted and observed rates of 58.8 percent and 54.9 percent, respectively. For LOS, the distributions are narrower, but the fit is also quite precise (see online version).

A total of 349 patients with zip codes outside California and 4,008 patients with only part A or only part B of Medicare were dropped, leaving 38,319 patients in FFS and 25,835 in HMOs. Of the latter, 2,128 were in

HMOs with fewer than 300 patients and were initially grouped together. Nine large HMOs collectively accounted for 23,707 patients. Four of these were split geographically. The analysis was therefore based on 17 pseudoplans (5 moderate-sized ones representing themselves, 4 created from 2 of the large ones, 6 created from the 2 largest plans, and 2 from a geographic split of the small plan aggregation). The splits are based on contiguous three-digit zip code areas representing regions such as the Los Angeles, San Diego, or San Francisco Bay areas. An eighteenth observation represents FFS beneficiaries.

Observed and Expected Mortality

The 30-day observed death rate for FFS beneficiaries was 18.62 percent, versus expected rates of 18.29 percent with Model A ($p = .059$) and 18.48 percent with Model B ($p = .335$). For all HMO enrollees, the observed death rate was 15.85 percent, not significantly different from the expected rates of 16.26 percent and 15.97 percent for Models A and B, respectively. Comparing FFS and HMO enrollees in a logistic regression with a dummy variable for FFS coverage, mortality rates were significantly higher ($p < .01$) among FFS beneficiaries under Model A (standardized mortality ratio or SMR = 1.047), but not under Model B (SMR = 1.018). Thus, the initial “bottom line” is that Medicare beneficiaries in California HMOs in the mid-1990s fared no worse, and perhaps a little better, in terms of short-term mortality after a heart attack than their FFS colleagues.

Figure 1 brings the analysis down to the level of the pseudoplan and presents the observed and expected 30-day mortality rates using Model A for each pseudoplan and FFS. (In the online version, the figures are presented in color. The color scale is linked to the Z-score from Model A. The red range indicates higher than expected mortality, but none of the values reaches a Z-score of 1.96, equivalent to $p = .05$. The blue range indicates better than expected mortality.) In the figures in print, the observations for pseudoplans that have better than expected outcomes are indicated by open circles; those with worse than expected mortality by solid circles. The points are almost evenly split between more and fewer deaths than expected, but three pseudoplans have significantly fewer ($p < .01$) deaths than expected (indicated by a ■ symbol). All the pseudoplans had lower *expected* death rates than FFS. Results were similar for Model B risk adjustment (not shown), except for one pseudoplan with a higher than expected death rate ($p < .05$), identified with a solid vertical rectangle symbol. The symbols from this

Figure 1: Observed versus Predicted 30-Day Death Rate for Medicare HMO Patients in California, 1994–1996

blue horizontal rectangle = significantly better than expected, Models A & B
 red square = FFS
 orange vertical rectangle = significantly worse than expected, Model B

Note that these symbols are the same and represent the same pseudoplans in all six figures.

relationship are reflected across figures. For example, in a figure focusing on length of stay (LOS), the pseudoplans with better than expected mortality will be identified by the open circle and fat horizontal rectangle symbols.

To test the hypothesis that health plans merely reflect practices in their geographic areas, Figure 2 presents the ratio of observed to expected deaths, or SMR, in each pseudoplan versus the SMR for FFS patients in its local area. (Because HMOs often draw their enrollees from overlapping geographic areas, the groupings of FFS outcomes cannot be mutually exclusive.) Pseudoplan ratios range from 0.77 to 1.09; those for FFS patients in the same areas range from 0.96 to 1.11, with no apparent relationship ($r = .004$).

Controlling for patient risk factors, LOS for FFS patients was 0.79 days ($p < .0001$) longer for index plus transfer stays. (A transfer stay is defined as a second hospitalization that begins on the same day or the day after the end of

Figure 2: Observed/Expected 30-Day Mortality Ratios for HMOs versus FFS Patients in Their Local Areas

Figure 3: Revascularization Rates within 30 Days for HMO Patients and FFS Patients in Their Local Areas

the index hospitalization.) There was no overall relationship between pseudoplan and local FFS stays for either index admission or total LOS (not shown). Of FFS patients, 15 percent were transferred to another hospital

Figure 4: Revascularization Rates within 30 Days versus During Index Admission

versus 22 percent of HMO patients (12–33 percent range across pseudoplaus). The pseudoplaus with among the best outcomes tend to have short index stays followed by transfers (not shown).

There was substantially more variation in the 30-day revascularization rate among the pseudoplaus (14.7 percent to 39.2 percent) than in FFS in their local areas (27.5 percent to 34.4 percent) (Figure 3). The three low-mortality outliers had substantially lower revascularization rates than was observed among FFS beneficiaries in their areas. Risk adjustment did not alter these findings. Although revascularization is unlikely to improve 30-day mortality, there is procedure-related risk. Thus, one may argue that the lower mortality rate among HMO enrollees might be due to their lower likelihood of receiving revascularization. It is useful, therefore, to examine the settings in which it is done.

Revascularization may depend on the capabilities of the hospital to which the patient was initially admitted (McClellan, McNeil, and Newhouse 1994). Figure 4 contrasts the overall revascularization rate within 30 days versus revascularization during the index admission. An additional 7–12 percent of the HMO patients underwent revascularization in another admission within 30 days of their AMI, with the percentage being greater in pseudoplaus with low rates during the index admission. The three

Figure 5: Proportion of All AMI Index Admissions That Are to a Hospital Capable of Providing CABG versus CABG volume in Those Hospitals

low-mortality outliers had very low index admission revascularization rates (2.8–5.2 percent), and even though three to four times as many procedures were done subsequently, their overall 30-day rates were still very low. The cluster of pseudoplans with lower than expected mortality points in the lower left-hand corner had very low rates of revascularization on the initial admission.

The HMOs contract with, or direct their patients to selected hospitals (Chernew, Scanlon, and Hayward 1998; Escarce et al. 1999; Erickson et al. 2000). Figure 5 shows that 57 percent of FFS patients are initially admitted to a hospital with CABG capability, and the mean volume of such hospitals is 268 CABG procedures per year. Ten of the pseudoplans exhibit a similar pattern, but six with better than expected outcomes have only 14–27 percent of their initial admissions occurring at CABG-capable hospitals. Figure 6 focuses on just those patients who ultimately received CABG surgery within 30 days. There is a cluster of pseudoplans in the upper left-hand corner with relatively low volumes and a high proportion of patients operated on in the index hospital. This is a pattern that is similar to that of FFS, and none of these plans has better than expected mortality rates. In contrast, the pseudoplans with better outcomes operate during the initial hospitalization only half the time, with the exception of two plans that have very high CABG volumes in the hospitals used for their index admissions.

Figure 6: For Patients Having CABG within 30 Days of AMI Admission and Initially Admitted to a Hospital with CABG Capability, Percent Undergoing CABG at the Index Hospital versus the Annual CABG Volume at That Hospital

COMMENT

Medicare beneficiaries in California's HMOs admitted for acute myocardial infarction during 1994–1996 were younger and had fewer comorbidities than those in FFS. Thus, their lower observed 30-day mortality rate of 15.85 percent relative to 18.62 percent for FFS patients is not surprising. Accounting for patient differences in risk, the FFS rate was slightly worse, but given the large sample, statistically significantly so, than the rate for HMO enrollees in general.

One does not join “HMOs in general” however, and the results for individual pseudoplans suggest that it matters *which* plan one joins. Among the 17 pseudoplans examined, three had significantly better than expected mortality rates. One had worse than expected rates under one, but not both, risk models. Given a $p = .05$ significance level, one outlier observation would be expected out of 17 points. While this might account for one outlier, it is not likely to explain all three of the good outliers, two of which are significant, ($p < .01$) in both models, and the other had values of $p < .01$ and $p < .03$.

There is substantial controversy about the identification of outliers, which is sometimes due to chance. Chance may account for any of the selected

mortality results, but there is strong circumstantial evidence presented in these figures that some of these HMOs have different practice or hospital use patterns that appear related to the differences in risk-adjusted mortality.

Two principal concerns with this type of analysis were addressed directly. Hospital payment by HMOs is often not dependent on diagnostic related group (DRG) category, as is the case for FFS patients. Thus, some hospitals might “undercode” diagnoses for HMO patients. If so, HMOs would receive a *lower* predicted mortality rate than they truly “deserved.” If the variation in expected rates across pseudoplans reflected variable undercoding, there would be a negative relationship between the expected rate and the observed/expected mortality rate. This was not observed; in Figure 1 the low outliers have among the lowest expected mortality rates, and the high outlier has an unremarkable expected rate.

The second major area of concern was that differences across HMOs might merely reflect the geographic areas they serve. There are, indeed, substantial differences in risk-adjusted mortality rates among patients in FFS. Some areas exhibited 10 percent more deaths than expected—an excess greater than in any of the pseudoplans. Given that these “FFS areas” merely reflect the experience in overlapping locales from which HMO enrollees are drawn, and are not mutually exclusive, the true geographic variation is likely to be larger. Local FFS outcomes, however, were unrelated to outcomes across pseudoplans. It is possible, however, that HMOs select the best hospitals and clinicians within a geographic area, or may otherwise alter usual practices.

The data on LOS and revascularization support this conclusion. Although risk-adjusted total stays (index admission plus any transfers) were 0.79 days shorter for HMO patients, there was no relationship between LOS in the pseudoplans and their local area. The pseudoplans with the better mortality outcomes exhibit a consistent pattern that differs from both FFS and the pseudoplans with results that are similar to or worse than expected. The former tend to have a lower proportion of their AMI patients initially admitted to hospitals with CABG capabilities and tend to rely on referrals to other hospitals for revascularization. The CABG-capable hospitals these pseudoplan patients initially use have much higher average CABG volumes and the volume difference is even greater among the hospitals used for subsequent admissions (not shown). While many AMI patients are brought by ambulance to the nearest hospital, some are not, and this may account for the differential admission patterns. Even when admitted to a CABG-capable hospital, only half the patients who ultimately get CABG in the better pseudoplans have their procedure during the index admission, in contrast to the pattern among

the other pseudoplans and FFS of heavy reliance on the index hospital, even if it is low volume. The substantial literature on the volume–outcome relationship for revascularization suggests these patterns are purposeful (Dudley et al. 2000).

Overall, these findings of marked plan differences are somewhat surprising. Kaiser is clearly different in its structure, financial incentives, and physician panel; the non-Kaiser HMOs in California contract in varying ways with physicians and hospitals or use intermediary medical groups (Robinson 1999). Although the identities of the HMOs were concealed in the linked file sent for analysis, different HMOs are represented among the “good” outliers. Those pseudoplans with worse than expected mortality rates (the solid points) had mortality and revascularization patterns similar to FFS in their local areas (see Figures 2 and 3). On the other hand, the open circle points (those with better than expected mortality), showed no relationship to local FFS patterns.

In many areas of the state, physician and hospital networks were very similar among non-Kaiser HMOs, so there was little reason to expect selective contracting to yield markedly different sets of providers. The HMOs do exercise some quality review, however, and some may exclude a small number of providers with quality problems and this would not be apparent in overall network breadth. The HMOs also develop practice guidelines, for example, with respect to use of beta-blockers after AMI, and may directly influence LOS, transfers, and revascularization. Some HMOs use hospitals similar to those used by FFS patients, and their outcomes appear similar. Other HMOs, through means as yet undetermined, apparently steer their patients to selected hospitals that are less likely to offer CABG surgery, but if they do, they have higher volumes. Furthermore, these same plans are much less likely than FFS and the other plans to have CABG surgery done in the index admission even if the hospital is capable. The fact that these different patterns of care are associated with different risk-adjusted mortality rates is worthy of further investigation.

One might expect a few points among 17 to be outliers just by chance. One might also expect an organization like Kaiser to have different practice patterns for its enrollees in terms of the hospitals they use, LOS, and revascularization. The HMO enrollees probably have better outpatient drug coverage than does the average FFS beneficiary. The surprising result from this analysis is that those observations with better outcomes also have different practice patterns with respect to gross measures, such as the frequency and location of revascularization. Moreover, these different patterns appear for several HMOs, so it cannot be just a “Kaiser effect.”

In marked contrast to these California results, Cutler, McClellan, and Newhouse (2000) found little difference in the patterns of care for AMI patients in Massachusetts, and argue that nearly all the difference in HMO costs is due to lower charges. As indicated above, Kaiser does not account for all the observed differences in practice patterns. California, however, does have a much higher prevalence of group practices, and if some HMOs concentrate their patients in such groups, this may explain the differences in clinical patterns. It may also be the case that the presence of Kaiser has created a public acceptance of more coordination of care, and this may allow some of the more conventional independent practice associations to exercise more controls over where their patients will be treated.

These findings highlight the need to move beyond simple comparisons of FFS versus HMOs to deeper analyses of the reasons for performance differences. Remembering the substantial variation in practice patterns across the FFS "comparison plans," all of which have FFS payments to physicians and DRG payments to hospitals, the variation across HMOs is probably not just due to financial arrangements. Instead, specific practice guidelines, quality review, and other features should be examined. The differential practice patterns and better outcomes in some plans may also be due to different physicians and hospitals. If so, one should learn how those providers were chosen.

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APPENDIX

The goal of the risk adjustment models in this paper was to adjust for differences in patient risk that were present on admission, while not adjusting for differences that might reflect either complications or treatment decisions. Some diagnoses, such as diabetes or hypertension, even if first noticed during the hospital stay, were almost certainly present at the time of admission. Other diagnoses, such as heart failure or shock, may have been present at admission or may have developed during the admission, and thus should not be in the model. If a patient had a hospital admission prior to the index admission for AMI and a diagnosis was noted during the prior admission that could be *either* acute or chronic, such as congestive heart failure, then one could feel comfortable in using that diagnosis as a risk factor in the subsequent index admission. If such a condition were noted only during the index admission, it would not be included in the standard, or Model A version. Some diagnoses, such as shock, are very powerful predictors of death, and are only relevant during the index admission. They were included in the Model B estimates, with the recognition that their inclusion might overcompensate for diagnoses that may actually have been complications.

When a patient has had prior admissions, it makes sense to include chronic conditions such as diabetes that appear on either record. There is a question, however, whether one should just add variables for the acute/chronic conditions, for example CHF, for those patients with prior admissions to a pooled model. Patients with multiple admissions may be different from those with just an index admission, and this may carry over to the effects of their chronic diseases. Thus, the sample was first split into patients with a prior admission in eight weeks and those without such a prior admission. Separate models were estimated for each subsample, both without and with the Model B variables representing conditions that may have been complications during the index admission. Thus, although there are four regressions, each patient received only two predicted probabilities, one from the A Model and one from the B Model, each with variables appropriate for whether the patient had prior admissions or not. The prior and no-prior groups were then melded together.

Table A1 includes the means of all the variables for FFS and HMO enrolled populations used in developing the risk models. The total number of cases is somewhat larger than the sum of enrollees in the plans indicated in the paper because cases were subsequently dropped because they were out of state or did not have both Part A and Part B Medicare coverage.

Table A1: Variables, Definitions, and Means Across Samples

Variable	Description	All Plans		FFS		HMO	
		Count	Mean	Count	Mean	Count	Mean
FFS	FFS coverage	68511	0.622	42599	1.000	25912	0.000
mortio30	Death within 30 days of admission	68511	0.174	42599	0.183	25912	0.159
npriors	Number of prior admissions	68511	0.313	42599	0.335	25912	0.276
iatxcabg	CABG in current or subsequent admission	68511	0.109	42599	0.111	25912	0.106
iatxptca	PTCA in current or subsequent admission	68511	0.174	42599	0.194	25912	0.141
priolagw	Weeks from most recent prior record	13484	9.146	8806	9.147	4678	9.145
sknulcrp	Chronic skin or ulcer condition	68511	0.005	42599	0.006	25912	0.004
sepsisi	Sepsis, bacteremia	68511	0.017	42599	0.019	25912	0.015
nopriors	No prior admissions	68511	0.803	42599	0.793	25912	0.819
female	Female	68511	0.447	42599	0.470	25912	0.409
iageyrs	Age in years	68511	76.442	42599	76.747	25912	75.941
siteant	Site: anterior	68511	0.290	42599	0.297	25912	0.279
siteinf	Site: inferior	68511	0.219	42599	0.218	25912	0.221
siteoi	Site: other	68511	0.078	42599	0.083	25912	0.068
prcabg	History of prior CABG	68511	0.010	42599	0.011	25912	0.007
iadm94	Admission in 1994	68511	0.338	42599	0.361	25912	0.300
iadm95	Admission in 1995	68511	0.341	42599	0.339	25912	0.345
chfb	Congestive heart failure	68511	0.401	42599	0.406	25912	0.393
chrrenab	Chronic hyperten renal failure, dialysis	68511	0.058	42599	0.062	25912	0.051
cnsdisb	Parkinsons, degenerative/demyelinating cns disorders	68511	0.019	42599	0.020	25912	0.017
dbtcmpb	Diabetes, complicated	68511	0.070	42599	0.073	25912	0.065
hrsecmab	History of primary or secondary malignant neoplasm	68511	0.017	42599	0.018	25912	0.015
htb	Hypertension with no note of renal or CHF	68511	0.453	42599	0.441	25912	0.473
thyroidb	Thyroid disease	68511	0.075	42599	0.074	25912	0.078
iagechf	Age * CHF	68511	31.223	42599	31.754	25912	30.350
iagefem	Age * Female	68511	34.750	42599	36.716	25912	31.519
iageinf	Age * Site inferior	68511	16.451	42599	16.419	25912	16.502
iagesit	Age * Site other	68511	6.110	42599	6.590	25912	5.320
iantchf	Anterior * CHF	68511	0.121	42599	0.124	25912	0.116
ichfcab	CHF * History of CABG	68511	0.004	42599	0.005	25912	0.003
ichffem	CHF * Female	68511	0.190	42599	0.203	25912	0.169
iinfchf	Inferior * CHF	68511	0.063	42599	0.064	25912	0.062
isitchf	Anterior * CHF	68511	0.041	42599	0.045	25912	0.035
ichfsho	CHF * History of CABG	68511	0.038	42599	0.039	25912	0.036
ishosep	Shock * Sepsis	68511	0.005	42599	0.005	25912	0.004

continued

Table A1: Continued

Variable	Description	All Plans		FFS		HMO	
		Count	Mean	Count	Mean	Count	Mean
atyper	Emergent admission	68511	0.849	42599	0.833	25912	0.875
paymcal	Payor source MediCal	68511	0.023	42599	0.036	25912	0.002
payunin	Payor source uninsured	68511	0.005	42599	0.004	25912	0.005
raceblk	Race/ethnicity black	68511	0.047	42599	0.049	25912	0.043
racehis	Race/ethnicity Hispanic	68511	0.044	42599	0.050	25912	0.033
shocki	Shock	68511	0.064	42599	0.067	25912	0.060
acrenali	Acute or unspecified renal failure	68511	0.053	42599	0.057	25912	0.045
comai	Coma	68511	0.013	42599	0.014	25912	0.010
othcvai	Other cerebrovascular disease	68511	0.026	42599	0.027	25912	0.023
puledemi	Pulmonary edema, adult respiratory distress	68511	0.078	42599	0.081	25912	0.075
epilepb	Epilepsy, convulsions	68511	0.021	42599	0.023	25912	0.018
coatrbli	Complete atrioventricular block	68511	0.033	42599	0.035	25912	0.030
pventaci	Paroxysmal ventricular tachycardia	68511	0.083	42599	0.085	25912	0.079
asppneui	Aspiration pneumonia	68511	0.016	42599	0.017	25912	0.014
amisequi	Catastrophic structural AMI compl	68511	0.003	42599	0.003	25912	0.003
vasinsui	Ischemic necrosis, infarct intestine/liver	68511	0.004	42599	0.004	25912	0.003
ishochf	Shock * CHF	68511	0.038	42599	0.039	25912	0.036
iacrchf	Acute renal failure * CHF	68511	0.036	42599	0.038	25912	0.032
icomage	Coma * Age	68511	0.964	42599	1.068	25912	0.792
icomchf	Coma * CHF	68511	0.006	42599	0.006	25912	0.005
ipulanti	Pulmonary edema * Anterior	68511	0.026	42599	0.027	25912	0.024
ipulchf	Pulmonary edema * CHF	68511	0.053	42599	0.053	25912	0.052
iepiage	Epilepsy * Age	68511	1.596	42599	1.735	25912	1.367
ishoacr	Shock * Acute renal failure	68511	0.014	42599	0.015	25912	0.012
ishocom	Shock * Coma	68511	0.002	42599	0.003	25912	0.002
ishooth	Shock * Other site	68511	0.002	42599	0.003	25912	0.002
ishopul	Shock * Pulmonary edema	68511	0.020	42599	0.021	25912	0.020
ishocoa	Shock * Complete atrioventricular block	68511	0.008	42599	0.009	25912	0.006
ishopve	Shock * Paroxysmal ventricular tachycardia	68511	0.011	42599	0.011	25912	0.011
ishoasp	Shock * Aspiration pneumonia	68511	0.003	42599	0.004	25912	0.003
ishoami	Shock * Catastrophic AMI	68511	0.001	42599	0.001	25912	0.001
iacroth	Acute renal failure * Other site	68511	0.003	42599	0.003	25912	0.003
icomoth	Coma * Other site	68511	0.002	42599	0.002	25912	0.002
icompul	Coma * Pulmonary edema	68511	0.004	42599	0.004	25912	0.003
icomepi	Coma * Epilepsy	68511	0.002	42599	0.002	25912	0.001
icomasp	Coma * Aspiration pneumonia	68511	0.001	42599	0.001	25912	0.001

continued

Table A1: Continued

Variable	Description	All Plans		FFS		HMO	
		Count	Mean	Count	Mean	Count	Mean
ipulasp	Pulmonary edema * Aspiration pneumonia	68511	0.007	42599	0.007	25912	0.006
icoapve	Complete atrioventricular block * Paroxysmal ventricular tachycardia	68511	0.004	42599	0.005	25912	0.004
priors	Prior admission	68511	0.197	42599	0.207	25912	0.181
OKplan	Case included in sample of plans after exclusions	64154	1.000	38319	1.000	25835	1.000

Table A2: Model A Logistic Regressions for Patients with No Prior Admissions

Patients ≥ 65 who had an HCFA match

Response Variable: MORTIO30 mortality w/in 30 days

Number of Observations: 55,465

Variable	Parameter Estimate	Standard Error	Wald Chi-Square	Prob > 0	Odds Ratio
INTERCPT	-8.3683	0.2480	1138.65	0.0001	
FEMALE	1.0751	0.2556	17.69	0.0001	2.93
IAGEYRS	0.0723	0.0031	534.99	0.0001	1.08
SITE_ANT	1.3369	0.0457	857.21	0.0001	3.81
SITE_INF	-0.2543	0.3171	0.64	0.4225	0.78
SITE_OI	4.3874	0.3805	132.97	0.0001	80.43
PRCABG	-0.4693	0.3212	2.13	0.1440	0.63
IADM94	0.0359	0.0301	1.42	0.2340	1.04
IADM95	0.0430	0.0299	2.06	0.1508	1.04
CHFB	2.6804	0.2638	103.27	0.0001	14.59
CHRENAB	0.5116	0.0543	88.83	0.0001	1.67
CNSDISB	0.2903	0.0857	11.46	0.0007	1.34
DBTCMPB	0.3428	0.0510	45.23	0.0001	1.41
HRSECMAB	0.8183	0.0944	75.14	0.0001	2.27
HTB	-0.4057	0.0258	247.56	0.0001	0.67
THYROIDB	-0.3820	0.0533	51.39	0.0001	0.68
I_AGECHF	-0.0218	0.0033	43.61	0.0001	0.98
I_AGEFEM	-0.0109	0.0033	11.27	0.0008	0.99
I_AGEINF	0.0162	0.0040	16.20	0.0001	1.02
I_AGESIT	-0.0295	0.0048	38.04	0.0001	0.97
I_ANTCHF	-0.4935	0.0628	61.82	0.0001	0.61
I_CHFCAB	0.6662	0.4276	2.43	0.1193	1.95
I_CHFFEM	-0.2992	0.0494	36.64	0.0001	0.74
I_INFCHF	-0.2719	0.0718	14.35	0.0002	0.76
I_SITCHF	-0.7748	0.0838	85.49	0.0001	0.46

Table A3: Model A Logistic Regressions for Patients with Prior Admissions
Patients ≥ 65 who had an HCFA match

Response Variable: MORTIO30 mortality w/in 30 days

Number of Observations: 13,573

<i>Variable</i>	<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>Wald Chi-Square</i>	<i>Prob > 0</i>	<i>Odds Ratio</i>
INTERCPT	- 6.1180	0.4048	228.44	0.0001	
FEMALE	0.2297	0.0745	9.52	0.0020	1.26
IAGEYRS	0.0485	0.0051	89.49	0.0001	1.05
SITE_ANT	1.1360	0.0544	436.74	0.0001	3.11
SITE_INF	0.9204	0.0640	207.08	0.0001	2.51
SITE_OI	1.7251	0.1119	237.81	0.0001	5.61
PRCABG	- 0.5503	0.1616	11.59	0.0007	0.58
PRIOLAGW	- 0.0153	0.0030	26.29	0.0001	0.99
IADM94	0.1093	0.0539	4.11	0.0426	1.12
IADM95	0.1341	0.0541	6.14	0.0132	1.14
CHFB	1.9824	0.4872	16.56	0.0001	7.26
CHRRENAB	0.4311	0.0652	43.79	0.0001	1.54
CNSDISB	0.1165	0.1240	0.88	0.3475	1.12
DBTCMPB	0.0645	0.0660	0.95	0.3287	1.07
HRSECMA	0.6754	0.0981	47.40	0.0001	1.97
HTB	- 0.2493	0.0465	28.77	0.0001	0.78
SKNULCRP	0.2272	0.1245	3.33	0.0681	1.26
I_AGECHF	- 0.0159	0.0063	6.44	0.0112	0.98
I_CHFFEM	- 0.3281	0.0923	12.63	0.0004	0.72
I_SITCHF	- 0.3039	0.1289	5.56	0.0184	0.74

Of the total number of patients, 55,467 had no prior admissions for non-AMI reasons within eight weeks, and 13,573 had a prior admission, allowing the identification of additional risk factors.

The logistic regressions for the priors and no-priors patients using Models A and B are shown in Tables A2–A5. There are no substantial differences in the coefficients for these regressions relative to those estimated by the CHOP team on all AMI patients with the exception of the UNDER35 age variable that obviously was excluded from these models.

C-statistics for Model A were .730 and .713 for patients with prior admissions and without prior admissions, respectively. For Model B, the corresponding c-statistics were .816 and .789. More important for the purposes of this study than the c-statistics is the calibration of the model. Rather than just relying on the Hosmer-Lemeshow statistic, which, with a very large number of observations can yield significant chi-square values that are

Table A4: Model B Logistic Regressions for Patients with No Prior Admissions

Patients ≥ 65 who had an HCFA match

Response Variable: MORTIO30 mortality w/in 30 days

Number of Observations: 55,027

WARNING: 440 observation(s) were deleted due to missing values for the explanatory variables.

<i>Variable</i>	<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>Wald Chi-Square</i>	<i>Prob > 0</i>	<i>Odds Ratio</i>
INTERCPT	-9.5181	0.2802	1153.58	0.0001	
FEMALE	0.8290	0.2795	8.80	0.0030	2.29
IAGEYRS	0.0789	0.0035	516.59	0.0001	1.08
IADM94	0.1300	0.0364	12.79	0.0003	1.14
IADM95	0.0296	0.0328	0.82	0.3660	1.03
SITE_ANT	1.1675	0.0502	541.42	0.0001	3.21
SITE_INF	-0.4932	0.3498	1.99	0.1586	0.61
SITE_OI	4.2539	0.4213	101.95	0.0001	70.38
PRCABG	-0.3291	0.3366	0.96	0.3283	0.72
CHFB	1.8885	0.2947	41.05	0.0001	6.61
CHRRENAB	0.2656	0.0610	18.94	0.0001	1.30
CNSDISB	0.2414	0.0935	6.66	0.0098	1.27
DBTCMPB	0.1528	0.0572	7.13	0.0076	1.17
HRSECMA	0.9207	0.1013	82.68	0.0001	2.51
HTB	-0.2955	0.0282	110.19	0.0001	0.74
THYROIDB	-0.3368	0.0574	34.40	0.0001	0.71
I_AGECHF	-0.0129	0.0037	12.50	0.0004	0.99
I_AGEFEM	-0.0078	0.0036	4.86	0.0275	0.99
I_AGEINF	0.0163	0.0044	13.55	0.0002	1.02
I_AGESIT	-0.0301	0.0053	32.51	0.0001	0.97
I_ANTCHF	-0.5330	0.0683	60.85	0.0001	0.59
I_CHFCAB	0.3345	0.4564	0.54	0.4637	1.40
I_CHFFEM	-0.2685	0.0541	24.63	0.0001	0.77
I_INFCHF	-0.3663	0.0784	21.82	0.0001	0.69
I_SITCHF	-0.7395	0.0915	65.32	0.0001	0.48
ATYP_ER	0.2049	0.0444	21.33	0.0001	1.23
PAY_MCAL	-0.1207	0.0950	1.62	0.2038	0.89
PAY_UNIN	0.4282	0.1757	5.94	0.0148	1.54
RACE_BLK	-0.2253	0.0708	10.12	0.0015	0.80
RACE_HIS	0.0411	0.0676	0.37	0.5430	1.04
SHOCKI	2.8182	0.0705	1597.81	0.0001	16.75
I_SHOCHF	-0.6027	0.0855	49.66	0.0001	0.55
ACRENALI	1.1272	0.0876	165.54	0.0001	3.09
I_ACRCHF	-0.1430	0.1009	2.01	0.1564	0.87
COMAI	7.2841	0.9412	59.89	0.0001	999.00
I_COMAGE	-0.0647	0.0120	28.97	0.0001	0.94

continued

Table A4: Continued

<i>Variable</i>	<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>Wald Chi-Square</i>	<i>Prob > 0</i>	<i>Odds Ratio</i>
I_COMCHF	-0.7079	0.1845	14.73	0.0001	0.49
OTHCVAI	1.2842	0.0704	332.94	0.0001	3.61
PULEDEMI	1.5044	0.0768	383.45	0.0001	4.50
I_PULANT	-0.1401	0.0811	2.99	0.0840	0.87
I_PULCHF	-0.6582	0.0839	61.58	0.0001	0.52
EPILEPB	2.8005	0.8776	10.18	0.0014	16.45
I_EPIAGE	-0.0264	0.0114	5.32	0.0211	0.97
COATRBLI	0.8428	0.0717	138.21	0.0001	2.32
PVENTACI	0.4769	0.0481	98.18	0.0001	1.61
ASPPNEUI	0.7838	0.1168	45.06	0.0001	2.19
AMISEQUI	1.2271	0.2367	26.87	0.0001	3.41
VASINSUI	0.9499	0.1774	28.69	0.0001	2.59
I_SHOACR	-0.4031	0.1114	13.08	0.0003	0.67
I_SHOCOM	-0.6338	0.2883	4.83	0.0279	0.53
I_SHOOTH	-1.0470	0.2048	26.13	0.0001	0.35
I_SHOPUL	-0.9836	0.0965	103.88	0.0001	0.37
I_SHOCOA	-0.9412	0.1290	53.20	0.0001	0.39
I_SHOPVE	-0.5491	0.1070	26.32	0.0001	0.58
I_SHOASP	-1.0333	0.1918	29.04	0.0001	0.36
I_SHOAMI	-0.9784	0.3476	7.92	0.0049	0.38
I_ACROTH	-0.7548	0.1936	15.20	0.0001	0.47
I_COMOTH	-0.6923	0.2505	7.64	0.0057	0.50
I_COMFUL	-0.7858	0.2115	13.80	0.0002	0.46
I_COMEPI	-0.4325	0.2931	2.18	0.1400	0.65
I_COMASP	-0.2260	0.3074	0.54	0.4623	0.80
I_PULASP	-0.5189	0.1640	10.01	0.0016	0.60
I_COAPVE	-0.1897	0.1625	1.36	0.2430	0.83

not particularly meaningful, plots of the observed and predicted results are more informative. Given the large number of cases, to provide even more resolution, 20 cells are used, rather than the 10 in the classic Hosmer-Lemeshow approach. Cases are ordered by the predicted value and for each 20th of the dataset, the observed and predicted values are plotted.

Figures A1 and A2 present the calibration curves for Models A and B, respectively. Both models exhibit a very wide range of predicted values, and these match the observed values quite well. As would be expected, because Model B includes some variables that may have been complications, its top range of predicted values was even higher with the top 5 percent of cases having an average value of 0.752 and an observed death rate of .721 (the

Table A5: Model B Logistic Regressions for Patients with Prior Admissions
Response Variable: MORTIO30 mortality w/in 30 days

Number of Observations: 13,484

WARNING: 89 observation(s) were deleted due to missing values for the explanatory variables.

<i>Variable</i>	<i>Parameter Estimate</i>	<i>Standard Error</i>	<i>Wald Chi-Square</i>	<i>Prob > 0</i>	<i>Odds Ratio</i>
INTERCPT	-6.8449	0.4466	234.94	0.0001	
FEMALE	0.2471	0.0808	9.35	0.0022	1.28
IAGEYRS	0.0530	0.0056	90.63	0.0001	1.05
IADM94	0.1418	0.0648	4.79	0.0285	1.15
IADM95	0.1248	0.0584	4.57	0.0326	1.13
PRIOLAGW	-0.0129	0.0032	16.22	0.0001	0.99
SITE_ANT	0.9547	0.0586	265.02	0.0001	2.60
SITE_INF	0.7382	0.0690	114.31	0.0001	2.09
SITE_OI	1.6008	0.1208	175.60	0.0001	4.96
PRCABG	-0.5097	0.1760	8.39	0.0038	0.60
CHFB	1.5094	0.5304	8.10	0.0044	4.52
CHRRENAB	0.3648	0.0711	26.30	0.0001	1.44
CNSDISB	0.0400	0.1351	0.09	0.7670	1.04
DBTCMPB	-0.0017	0.0719	0.00	0.9813	1.00
HRSECMAB	0.8307	0.1028	65.31	0.0001	2.30
HTB	-0.2050	0.0500	16.81	0.0001	0.82
SKNULCRP	0.0921	0.1361	0.46	0.4986	1.10
I_AGECHF	-0.0114	0.0068	2.85	0.0917	0.99
I_CHFFEM	-0.2957	0.0996	8.81	0.0030	0.74
I_SITCHF	-0.2684	0.1396	3.70	0.0544	0.77
ATYP_ER	0.0426	0.0743	0.33	0.5659	1.04
PAY_MCAL	-0.2416	0.1486	2.64	0.1040	0.79
PAY_UNIN	-0.5729	0.4031	2.02	0.1552	0.56
RACE_BLK	-0.3119	0.1093	8.14	0.0043	0.73
RACE_HIS	-0.0029	0.1084	0.00	0.9786	1.00
ACRENALI	0.8620	0.0892	93.39	0.0001	2.37
ASPPNEUI	0.4763	0.1664	8.20	0.0042	1.61
COMAI	1.8419	0.1751	110.62	0.0001	6.31
EPILEPB	0.5464	0.1121	23.78	0.0001	1.73
OTHCVAI	0.9144	0.1292	50.08	0.0001	2.50
PULEDEMI	0.9513	0.0777	149.92	0.0001	2.59
PVENTACI	0.3618	0.0819	19.54	0.0001	1.44
SEPSISI	0.1666	0.1525	1.19	0.2746	1.18
SHOCKI	2.8194	0.1664	286.93	0.0001	16.77
I_CHFSHO	-0.7239	0.1865	15.07	0.0001	0.49
I_SHOACR	-0.6352	0.2205	8.30	0.0040	0.53
I_SHOASP	-0.6712	0.4053	2.74	0.0977	0.51
I_SHOCOM	0.0984	0.6506	0.02	0.8798	1.10
I_SHOOTH	-0.7722	0.5231	2.18	0.1398	0.46
I_SHOPUL	-1.0039	0.1893	28.12	0.0001	0.37
I_SHOSEP	-0.4413	0.3149	1.96	0.1610	0.64

Figure A1: Observed versus Predicted Mortality-Model A, Arranged by Predicted Mortality

Figure A2: Observed versus Predicted Mortality-Model B, Grouped into 20ths by Predicted Mortality

Figure A3: Observed versus Predicted Mortality-Model A, Adjusted with a Cubic Transformation, Grouped into 20ths by Predicted Mortality

Figure A4: Observed versus Predicted Revascularization Rates (CABG and/or PTCA within 30 Days), Grouped into 20ths by Predicted Rates

Figure A5: Observed versus Predicted Index LOS, Arranged by Predicted Index LOS

Figure A6: Observed versus Predicted Total LOS, Arranged by Predicted LOS

maximum predicted was actually 0.990736!). As is often the case with the logistic link, the predicted values at the very high and very low ends of the spectrum were somewhat higher than they “should be.” Since HMOs tend to have a somewhat lower-risk enrollee base there is a concern that this may account for their better than expected results. To test this, the predicted mortality rates were replaced by new predicted values derived from a regression of the 30-day death variable on the predicted, predicted squared, and predicted cubed terms. This allowed an even closer fit at the tails of the distribution. The lowest 5 percent of cases had a predicted rate of .0237 and an observed rate of .0231 while the next 5 percent had predicted and observed rates of .0362 and .0379. Likewise, the top two categories had predicted and observed rates of .3843 versus .3821 and .4606 versus .4696. The results of this calibration are shown in Figure A3. This much closer fit of predicted to observed risks made no difference in the results when aggregated to the plan level. The largest difference was .0005 relative to a risk level of .1771 in a small plan.

Figure A4 presents the calibration results for the probability of any revascularization within 30 days of the AMI.

Although not technically appropriate for the Hosmer-Lemeshow test, the approach can be also be used for the results of LOS estimates. For length of stay, the distribution of predicted values was narrower, but the fit was nonetheless quite precise. These results are shown in Figures A5 and A6 for total and index lengths of stay.