

Appendix A: Technical Notes

Development of the risk-adjustment model involved selection of an outcome measure, selection of risk factors, estimation and testing of the model, and calculation of the outcome measures for CAP admissions. The full report on the data validation and model development, "Report for the California Hospital Outcomes Program, Community-Acquired Pneumonia, 1996: Model Development and Validation," is available on the OSHPD Web page: <http://www.oshpd.ca.gov>. The original model was developed using data collected in 1996. For the current report, risk factor coefficients were recalculated using the patient discharge data collected in 2003-2005.

A detailed description of the methodology employed for this analysis is available in the prior reports, "Community-Acquired Pneumonia: Hospital Outcomes in California 2002-2004," which is available at <http://www.oshpd.ca.gov>. The Technical Appendix of that report fully explains the record linkage process, use of the "Condition Present at Admission" (CPAA) flag, model diagnostics, and steps for calculating expected death rates. However, in the following Technical Notes we summarize the key information about the data sources that were used, criteria for selection of hospitals and patients for analysis, the mortality measure and risk factors, quality of the model, and limitations of the methods.

Data Sources

The primary data source for this report was the Patient Discharge Data (PDD) collected by OSHPD. For this report, CAP patients were selected from 2003, 2004, and 2005 PDD files, with a subsequent match to admissions reported in the 2002 file. If there were several CAP hospitalizations for a given patient, only the first (initial) was analyzed. This one is considered the "index" record. To identify deaths that occurred after discharge, the PDD was matched to the California death certificate files (Death Statistical Master Files) for 2003, 2004, and 2005, using Social Security Number as the identifier common to both datasets.

Selection of Hospitals and Patients

All acute care hospitals reporting patient discharge information to OSHPD were eligible for inclusion.¹ In cases of hospital consolidation, name change, and change of address, the discharges were attributed to the name of the hospital that was in effect at the time the services were provided. Patients selected for this analysis were required to meet all the following criteria to be included:

- A diagnosis of community-acquired pneumonia, either as principal diagnosis or as secondary diagnosis if the patient's principal diagnosis met specific criteria (Table A.1).
- Age at admission of 18 years or older.
- Source of admission was "Home." Patients were not included if they were admitted from "Residential Care Facilities," "Long-term Care" and "Other Inpatient Hospital Care," or from "Prison Jail" because they might have been exposed to organisms with different patterns of antibiotic resistance than individuals living in non-institutional settings. This would make their treatment more difficult.
- Date of discharge between January 1, 2003 and December 31, 2005 plus date of admission between November 1, 2002 and December 1, 2005.

¹ This involved selecting all CAP records with a "level of care" code indicating "General Acute Care."

Table A.1: CAP Diagnoses Included in the Analysis

ICD-9-CM Code	Principal Diagnosis	Principal CAP Codes	Non-CAP Principal Diagnosis Codes*
480.0	Pneumonia due to adenovirus	X	
480.1	Pneumonia due to respiratory syncytial virus	X	
480.2	Pneumonia due to parainfluenza virus	X	
480.8	Pneumonia due to other virus not elsewhere classified	X	
480.9	Viral pneumonia, unspecified	X	
481	Pneumococcal Pneumonia (<i>Streptococcus pneumoniae</i>)	X	
482.0	Pneumonia due to <i>klebsiella pneumoniae</i>	X	
482.1	Pneumonia due to <i>pseudomonas</i>	X	
482.2	Pneumonia due to <i>hemophilus influenza</i>	X	
482.30	Pneumonia due to <i>streptococcus</i> , unspecified	X	
482.31	Pneumonia due to <i>streptococcus</i> , Group A	X	
482.32	Pneumonia due to <i>streptococcus</i> , Group B	X	
482.39	Other <i>streptococcus</i> species	X	
482.4	Pneumonia due to <i>staphylococcus</i> species	X	
482.81	Pneumonia due to other specified bacteria - Anaerobes	X	
482.82	Pneumonia due to <i>escherichia coli</i> (E. Coli)	X	
482.83	Other gram negative bacteria	X	
482.84	Legionnaires' disease	X	
482.89	Other specified disease	X	
482.9	Bacterial pneumonia unspecified	X	
483.0	Pneumonia due to other specified organism - <i>mycoplasma</i>	X	
483.1	Pneumonia due to other specified organism - <i>chlamydia</i>	X	
483.8	Pneumonia due to other specified organism	X	
485	Bronchopneumonia, organism unspecified	X	
486	Pneumonia, organism unspecified	X	
487.0	Influenza with pneumonia	X	
510.0	Empyema with fistula		X
510.9	Empyema without fistula		X
511.0	Pleurisy without mention of effusion or current tuberculosis		X
511.1	Pleurisy with effusion, with bacterial cause other than tuberculosis		X
512.0	Spontaneous tension pneumothorax		X
512.1	Iatrogenic pneumothorax		X
512.8	Other spontaneous pneumothorax		X
513.0	Abscess of lung		X
518.0	Pulmonary collapse		X
518.81	Respiratory failure		X
518.82	Other pulmonary insufficiency, not elsewhere classified		X
785.5x	Shock without mention of trauma - shock unspecified		X
786.00	Dyspnea and respiratory abnormalities - respiratory abnormality, unspecified		X
786.09	Other dyspnea and respiratory abnormalities		X
786.2	Cough		X
786.3	Hemoptysis		X
786.4	Abnormal sputum		X
038.xx	Septicemia		X

* To be used as an inclusion criterion, a non-CAP principal diagnosis must occur with a secondary diagnosis of CAP.

Cases with any one of the following characteristics were excluded:

- One or more prior admissions to acute inpatient hospital care within 10 days before the index CAP admission.
- Any diagnosis code on the index hospital record indicating trauma.
- A diagnosis code indicating that the patient had undergone organ transplant, had human immunodeficiency virus (HIV) or AIDS, had cystic fibrosis, tuberculosis, post-operative pneumonia, certain unusual pathogens as the cause of the pneumonia, or other diagnoses identified by clinical consultants to OSHPD (See Table A.2).
- Data-related exclusions. Patients were also excluded if they had unusable data reported for Social Security Number, gender, date of death, and California residence.

Table A.2: CAP Diagnoses Excluded from Analysis

ICD-9-CM Code	ICD-9-CM Description
Fungal Pneumonia	
112.4	Candida species
114.0	Primary Coccidioidmycosis
115.05, 115.15, 115.95	Histoplasmosis Pneumonia
484.6	Aspergillosis Pneumonia
484.7	Pneumonia from Other Systemic Mycoses
Other Miscellaneous Pneumonias	
136.3	Pneumocystis carinii
484.1	Pneumonia from Cytomegalovirus
484.3	Pneumonia from Whooping Cough
484.5	Pneumonia from Anthrax
484.8	Pneumonia in other Infectious Disease
73.0	Ornithosis with Pneumonia
39.1	Primary Actinomycosis
55.1	Post-Measles Pneumonia
003.22	Salmonella Pneumonia
130.4	Pneumonia Due to Toxoplasmosis
21.2	Pulmonary Tularemia
52.1	Varicella Pneumonitis

*To be used as an inclusion criterion, a non-CAP principal diagnosis must occur with a secondary diagnosis of CAP.

Outcome Measure: 30-Day Mortality

Mortality was chosen as the outcome for this report because it is important, definitive, readily available, and because prevention of some of the deaths is possible through medical interventions. Therapies that have been shown to be useful in prevention of death for CAP patients include appropriate use of antibiotics and performance of sputum cultures at admission.

The thirty-day death rate is used as the outcome measure because it is a more robust and complete measure than the in-hospital death rate. It is not biased by variation among facilities in how decisions are made about the timing of patient discharge; the use of in-hospital death rate would undercount deaths for hospitals that discharged ill patients early.

Dates of death were determined by linking the hospital discharge records to the vital statistics records (death certificates).

Risk Factors Selected for the CAP Model

Risk factors are patient factors that exist at the time of admission that may significantly influence the patient's outcome. Hospitals in which a high percentage of the patients had these risk factors (that is, hospitals with a high risk case mix) would be likely to have higher death rates, regardless of the quality of care provided.

Three types of risk factors were considered: Patient demographic characteristics such as age (Table A.3), hospitalization characteristics such as number of prior admissions (Table A.4), and clinical risk factors such as chronic liver disease (Table A.5). Acute clinical factors, such as respiratory failure or acute cerebrovascular accident, were used in the risk-adjustment model only if they were reported as present at the time of the patient's admission.

Table A.3 details the demographic characteristics of the CAP patients selected for the analysis. Of these characteristics gender and age are included in the risk-adjustment model.

Table A.3: Demographic Characteristics of CAP Patients (after exclusions)

Characteristic	2003		2004		2005 (Jan-Nov)	
	Number	Percent	Number	Percent	Number	Percent
Total Patients	78,592		66,152		64,093	
Gender						
Male	37,290	47.5	31,630	47.8	30,641	47.8
Female	41,302	52.6	34,522	52.2	33,452	52.2
Race/Ethnicity						
White	51,655	65.7	43,584	65.9	41,301	64.4
African American	6,501	8.3	5,337	8.1	5,318	8.3
Latino	12,475	15.9	10,336	15.6	10,424	16.3
Native American	220	0.3	167	0.3	155	0.2
Asian/Pacific Islander	5,893	7.5	5,150	7.8	5,153	8.0
Other	1,412	1.8	1,195	1.8	1,315	2.1
Missing	436	0.6	383	0.6	427	0.7
Age						
Mean	69.6		69.8		69.6	
Standard Deviation	17.0		16.8		17.0	

Table A.4 provides hospitalization characteristics of the CAP patients. Of these, only the number of prior discharges within the previous six months is included in the risk-adjustment model.

Clinical risk factors for the CAP model were identified through a review of recent medical literature, input from a clinical advisory panel, empirical analyses of data for CAP patients, and if the 1996 validation study found them to be reliably coded in the PDD. The clinical risk factors selected for use in the model are shown in Table A.5.

Table A.4: Hospitalization Characteristics of CAP Patients (after exclusions)

Characteristic	2003		2004		2005(Jan-Nov)	
	Number	Percent	Number	Percent	Number	Percent
Total Patients	78,592		66,152		64,093	
Admission Type						
Scheduled	1,902	2.4	1,459	2.2	1,410	2.2
Unscheduled	76,559	97.4	64,651	97.7	62,645	97.7
Missing/Unknown	128	0.2	42	0.1	38	0.1
Payment Source						
Missing	7	0.0	15	0.0	3	0.0
Medicare	52,307	66.6	44,005	66.5	42,404	66.2
Medi-Cal	9,165	11.7	7,484	11.3	7,092	11.1
Private Coverage	13,154	16.7	11,052	16.7	11,227	17.5
Worker Compensation	64	0.1	70	0.1	59	0.1
County Indigent Programs	1,266	1.6	1,057	1.6	1,013	1.6
Other Government	348	0.4	318	0.5	288	0.5
Other Indigent Coverage	203	0.3	192	0.3	148	0.2
Self Pay	1,841	2.3	1,672	2.5	1,687	2.6
Other Payers	237	0.3	287	0.4	172	0.3
Number of Prior Discharges						
Mean	0.6		0.5		0.5	
Standard Deviation	1.1		1.0		1.0	

Table A.5: Prevalence of Clinical Risk Factors in CAP Patients

Risk Factor	Prevalence (%)
Congestive Heart Failure	30.84
Asthma	12.98
Respiratory Failure	10.85
Chronic Renal Failure	8.03
Septicemia	7.74
Solid Non-Lung Cancer	7.01
Late Effects of Stroke	4.94
Blood Cancer	4.91
Chronic Liver Disease	4.50
Coagulation Defects	3.53
Staphylococcus Infection	3.46
Lung Cancer	2.67
Infection with Gram Negative Bacteria	2.17
Parkinson's Disease	2.11
Cerebrovascular Disease	1.29

The Risk-Adjustment Model

Table A.6 shows the parameter estimates, odds ratios (ORs), and confidence intervals (CIs) for the risk factors in the 2003-05 CAP risk-adjustment model. All of the risk factors were found to be statistically significant predictors of mortality except infection due to gram negative species.

The strongest predictors of death in the model were: having a diagnosis of respiratory failure (OR = 5.05), followed by diagnoses of lung cancer, non-lung solid cancer, and septicemia. The remaining predictors had odds ratios that were significant but were less than 2.0. Asthma had a protective effect (OR = 0.52). Possibly patients with both asthma and CAP are treated more aggressively and have a lower threshold for hospital admission.

Table A.6: Parameters for Model

Risk Factor	Parameter Estimates	P Value	Odds Ratio	95% CL for Odds Ratio	
Intercept	-5.9928	<.0001			
Age (per year)	0.0427	<.0001	1.044	1.042	1.045
Male	0.0709	<.0001	1.073	1.041	1.107
Septicemia	1.1265	<.0001	3.085	2.956	3.220
Respiratory failure	1.6191	<.0001	5.048	4.864	5.239
Staphylococcal pneumonia	0.3668	<.0001	1.443	1.349	1.544
Chronic liver disease	0.6071	<.0001	1.835	1.716	1.962
Lung cancer	1.2108	<.0001	3.356	3.132	3.596
Solid cancer, non-lung	0.9554	<.0001	2.600	2.481	2.724
Hematologic cancers	0.5133	<.0001	1.671	1.577	1.770
Chronic renal failure	0.2820	<.0001	1.326	1.263	1.392
Late effects of cerebrovascular accident (CVA)	0.2503	<.0001	1.284	1.211	1.362
Coagulopathy	0.6492	<.0001	1.914	1.795	2.041
Gram negative species	-0.0292	0.5424	0.971	0.884	1.067
Congestive heart failure	0.1866	<.0001	1.205	1.167	1.245
Parkinson's disease	0.2072	<.0001	1.230	1.127	1.343
Acute CVA	0.2564	<.0001	1.292	1.161	1.439
Asthma	-0.6490	<.0001	0.523	0.492	0.555
Number of prior discharges	0.1365	<.0001	1.146	1.132	1.161

Internal Validity of Risk-Adjustment Models

For this report, internal validity is defined as how well the model controls for differences in patient characteristics that would otherwise confound outcome comparisons across hospitals. Not adequately controlling for such differences may generate biased and misleading estimates of death rates. Internal validity was assessed in three ways: face validity, discrimination, and goodness of fit (i.e., calibration).

As shown in Table A.7, the current model's C-statistic was 0.80. This is similar to the C-statistics obtained in the original validation study (C-statistic = 0.79), as well as in the CAP reports for 1999-2001 (C-statistic = 0.79 without DNR and C-statistic = 0.82 with DNR) and for 2002-2004 (C-statistic = 0.80 without DNR and C-statistic = 0.82 with DNR). The goodness-of-fit statistic is significant, which reflects the large sample size and does not indicate a problem with over-dispersion.

Table A.7: Discrimination and Goodness-of-Fit Tests for Re-Estimated CAP Risk-Adjusted 30-Day Mortality Model

Number of Cases	208,837
Number of Deaths	25,389
Statewide 30-day Death rate	12.16%
C-statistic (Discrimination)	0.802
χ^2 (Goodness of Fit Statistic)	
Over-dispersion Estimate	1.2696
p-value	<.0001

There was no evidence of unusual coding practices that would seriously distort comparisons of risk-adjusted death rates across hospitals. However, we excluded three acute clinical risk factors (congestive heart failure, septicemia, and respiratory failure) from a hospital's risk-adjustment in any of the semi-annual reporting periods for that hospital when the hospital coded either all or none of these conditions as present at admission (where there were 80 or more such admissions in a six-month reporting period). These are indicated by "E" in Table A.8.

Additionally, the Patient Data Section, Healthcare Information Division, of OSHPD reported that some hospitals exhibited unacceptable CPAA indicator coding. We also excluded these hospitals from full risk-adjustment during each six-month period with problematic data. These are indicated by "X" in Table A.8.

Table A.8: Hospitals Excluded from Full Risk-Adjustment

Hospital Name	Reporting Period (Year - 1st or 2nd Half)					
	2003-1	2003-2	2004-1	2004-2	2005-1	2005-2
Bakersfield Heart Hospital						E
Barstow Community Hospital	XE					
Coastal Communities Hospital		E	E			
Colorado River Medical Center						X
Emanuel Medical Center			E	E	E	E
Encino Tarzana Regional Mc - Encino	E					
Fairchild Medical Center			E			
Fallbrook Hospital District			E			
Foothill Presbyterian Hospital					E	E
Good Samaritan Hospital - Bakersfield	XE				E	
Granada Hills Community Hospital		X				
Hanford Community Hospital					E	
Hollywood Community Hosp of Hollywood					E	
Long Beach Community Medical Center			E	E		
Los Angeles Co Harbor - UCLA Medical Center			E	E	E	

Hospital Name, Continued	2003-1	2003-2	2004-1	2004-2	2005-1	2005-2
Los Angeles Community Hospital	E		E			
Los Angeles Metropolitan Medical Center	E					
Madera Community Hospital	XE					
Mayers Memorial Hospital	X	X				
Mission Community Hospital - Panorama	E					
Mountains Community Hospital		X				
Norwalk Community Hospital					E	
Palomar Medical Center	E	E	E			
Paradise Valley Hospital				E		
Parkview Community Hospital	E	E		E		
Pomerado Hospital		E				
Ridgecrest Community Hospital	E	E	E		E	E
Riverside County Regional Medical Center						E
Santa Marta Hospital	E	XE	X			
Selma District Hospital	E	E				
Simi Valley Hosp & Hlth Svcs - Sycamore				E		
South Coast Medical Center		E				
Sutter Davis Hospital	E					
Temple Community Hospital	E					
Tulare District Hospital		E	E	E	E	E

Key: X = Inaccuracies noted by the Patient Data Section, Healthcare Information Division of OSHPD.
E = Possible inaccuracies detected by empirical analysis according to the criteria described above.

Calculation of Hospital Outcome Measures

The number of observed deaths equals the total number of CAP patient deaths that occurred within 30 days after the index admission, expressed as a percentage. The number of expected deaths at a hospital is obtained by applying the parameters (coefficients) produced by the model to each patient's data to produce a "probability of death." The sum of these probabilities across all the patients for a given hospital makes up the expected number of deaths for the hospital.

The risk-adjusted (or indirectly standardized) death rate at a hospital equals the statewide rate, multiplied by the ratio of the number of observed deaths to the number of expected deaths at that hospital (O/E ratio). The O/E ratio provides a quick assessment of that hospital's performance. A ratio that is less than one indicates there were fewer actual deaths than expected (a good result) while a ratio greater than one indicates that there were more deaths than would be expected, given the level of risk in the patient mix.

Confidence Limits for Risk-Adjusted Death Rates

Confidence limits are indicators of the reliability of a hospital's risk-adjusted death rate. In this report, there is a 98% chance that the true risk-adjusted death rate falls within the confidence limits, assuming that the model is valid. In general, when the upper and lower confidence limits are far apart (a wide confidence interval), there is more uncertainty about the specific risk-adjusted death rate that is calculated. A wide confidence interval occurs if there is wide variation among the hospital's patients and/or if the hospital reports only a small number of patients.

The exact probability of the number of observed deaths (or a more extreme number) occurring by chance, given the number of expected deaths at a hospital, was used to identify outlier hospitals. This approach differs from the more widely used normal approximation in that it relies on fewer distributional assumptions and gives better estimates for hospitals with relatively few expected deaths. If the number of observed deaths exceeded the number of expected deaths, an upper probability (p) value was computed. If the number of observed deaths was less than or equal to the number of expected deaths, a lower probability (p) value was computed. Hospitals classified as significantly “better than expected” had fewer deaths than expected and a p-value less than 0.01. Hospitals rated as significantly “worse than expected” had more deaths than expected and a p-value less than 0.01. This is equivalent to a two-tailed significance test based on a 98% confidence interval.

Results: Risk-Adjusted CAP Death Rates

As shown in Table A.9, a total of 48 hospitals were found to have significantly “better than expected” (lower) risk-adjusted death rates (RADRs), 47 had significantly “worse than expected” (higher) rates, and 259 had RADRs that were “as expected” (not statistically different from the statewide rate of 12.16%).

Table A.9: Number of Hospitals with Better than Expected, Worse than Expected, and As Expected Ratings

Hospital Ratings	Frequency
Better than Expected (+)	48
As Expected	259
Worse than Expected (-)	47
Total	354

The results obtained for all of the individual hospitals are shown in Chart 1. This chart compares the risk-adjusted death rates of hospitals to the statewide rate. There were 30 hospitals that admitted fewer than 30 CAP patients during the three-year period of this report and were excluded from the chart. These small numbers often resulted in extremely wide confidence intervals that could not be meaningfully interpreted. They are listed in Table 3 in the main section of the report.

Limitations of the Data and the Model

Quality of care is one reason a hospital’s death rate may be unusually high or low. However, there are additional factors that may contribute to the results.

Additional factors might include the following:

- Unmeasured risk. Risk factors that might be important but are not reported in the patient discharge records could not be included in the model. If these additional factors had been available, it is possible that a model could have been developed to fully account for differences in the severity of patient risk across the hospitals.
- Problems with data quality. Hospitals that failed to report important risk factors or had other data quality problems could have received too little “credit” for their patient risk in the risk adjustment process. Also, if there were patients admitted from facilities such as board and care

homes or skilled nursing facilities who were erroneously reported to OSHPD as “admissions from home” they would have met the CAP definition and been included in this report.

- Limited outcome measure. This report focuses on a single measure of outcome: 30-day mortality. It does not address other outcomes such as a patient’s quality of life after discharge or likelihood of having subsequent hospital readmissions. Other organizations that monitor different aspects of healthcare quality are listed in Appendix C with contact information.

Note that this report provides information on only the care of patients with community-acquired pneumonia. It does not address the quality of care for other conditions.