REPORT FOR THE CALIFORNIA HOSPITAL OUTCOMES PROJECT COMMUNITY-ACQUIRED PNEUMONIA, 1996: MODEL DEVELOPMENT AND VALIDATION

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CHAPTER ONE: OVERVIEW—
REPORT ON COMMUNITY-ACQUIRED PNEUMONIA

The California Hospital Outcomes Project is an initiative mandated by the State of California and conducted by the Office of Statewide Health Planning and Development (OSHPD), to develop public reports comparing hospital outcomes for selected medical conditions and surgical procedures for patients treated in hospitals throughout California.

This technical report, prepared for OSHPD, summarizes the development and validation of a hospital-level risk-adjustment model intended, after modification, to assist in comparing hospital outcomes for patients with community-acquired pneumonia (CAP).

CAP was selected for this analysis because it is common, is associated with a substantial mortality rate, and because timely diagnosis and treatment are associated with improved outcomes.[1.1] Pneumonia is the sixth most common cause of mortality. Each year in the United States, there are over 5 million cases of community-acquired pneumonia.[1.2] This report details the development of a risk adjustment model for over 60,000 patients admitted to 399 California hospitals in 1996 with a diagnosis of community-acquired pneumonia. This sample includes over 7000 deaths.

This report summarizes the review of prior literature, model development, and the validation study for patients hospitalized with CAP. In particular, since this work utilized data from 1996, the first year that a 'condition present on admission' (CPAA) indicator was available in California, we present specific information about the validity of the coding of this information for patients with CAP. The report closes with recommendations for further evaluation and the feasibility of a public report for patients hospitalized with community-acquired pneumonia in California.

[1.1] Meehan TP, Fine MJ, Krumholz HM, et al. Quality of care, process, and outcomes in elderly patients with pneumonia. *JAMA*. 1997; 278(23):2080-4.
[1.2] National Center for Health Statistics, 2000.

CHAPTER TWO:
LITERATURE SUMMARY

An extensive review of the clinical literature pertaining to community-acquired pneumonia (CAP) was completed. The MEDLINE bibliographic database was searched for English language references since 1980 using relevant keywords. References were also identified through discussions with the Clinical Advisory Panel members and review of reference lists in reference books and meta-analyses. The literature review in this report is updated through June 2000.

IDENTIFICATION OF RISK FACTORS

All studies reporting on risk factors for in-hospital or 30-day mortality for CAP were obtained and reviewed. Studies from developing countries, and studies limited only to a specific etiologic organism for pneumonia (e.g., Legionella) or to the examination of specific therapies for pneumonia were set aside. Studies specific to nosocomial pneumonias, non-infectious pneumonia (e.g., lupus pneumonitis), pneumonia in patients with HIV infection, pneumonia in patients with immunosupression (e.g., cystic fibrosis, transplant) were also set aside, as were studies involving infants and children less than the age of 18 years.

Among the remaining studies, those with at least 250 observations were assigned a higher priority than those with fewer observations. Large cohort studies with multivariate models were given particular attention. Studies that were based solely on administrative data (e.g, discharge abstract data, Medicare claims data) were also given lower priority. Meta-analytic techniques were not applied.

Table 2.1 lists the major risk factors for in-hospital or 30-day mortality from CAP in the clinical literature. Each risk estimate in Table 2.1 represents the odds ratio or relative risk of death among patients with the characteristic, compared to those without the characteristic. Studies that did not report odds ratios or relative risks (or presented insufficient raw data to calculate these measures) are not shown. When a study reported an odds ratio or relative risk adjusted for other patient characteristics, these are presented in preference to unadjusted estimates. If several studies reported different risk estimates for the same risk factor, then the range of these estimates is shown.

APPLICATION OF THE LITERATURE SUMMARY

The literature summary was used to identify specific findings and conditions that are generally regarded as risk factors for death after CAP. These diagnoses were reviewed by the members of the Clinical Advisory Panel and then adapted to ICD-9-CM codes. The literature summary was also used to guide the development of the clinical validation tool for the medical record abstraction. For example, medical record data about the time to the administration of antibiotics was abstracted because of literature suggesting that timely administration is associated with lower mortality for patients with CAP. [23]

Table 2.1: Literature review of risk factors for in-hospital or 30-day mortality for an episode of community-acquired pneumonia.

Risk Factor	Risk Estimate[i]	Reference
Demographic factors		
Age:		
Per additional 10 years	1.2 – 3.3	[1-5]
> 65 years	2.1 – 6.6	[6, 7]
> 70 years	6.8 – 16.8	[8]
Male sex	1.2 – 1.3	[3, 9]
Comorbid illness		
Congestive heart failure	1.4 – 3.6	[1, 8, 10]
Chronic lung disease	0.8 – 2.2	[1, 10, 11]
Diabetes mellitus	1.8	[1]
History of diabetes mellitus	1.3	[9]
Neoplastic disease	1.3 – 7.9	[1, 3, 6-9, 12-14]
Chronic renal failure	1.7	[10]
Cerebrovascular disease	1.2 – 4.6	[1, 8-10, 13]
Poor functional status[ii]	1.2 – 5.0	[3, 13-15]
Current tobacco use	1.3 – 2.8	[1, 11]
Alcohol abuse	NS[iii]	[4, 16]
Recent use of antibiotics	3.1	[13]
Symptoms on Admission		
Pleuritic chest pain	0.4 – 0.5	[6, 7, 9]
Dyspnea	2.4	[4]
Physical findings on admission		
Fever[iv]	0.8 – 1.4	[3, 12, 17, 18]
Hypothermia [v]	1.4 – 5.0	[3, 9, 12, 17, 18]
Tachycardia	2.3 – 10.8	[7, 17]
Tachypnea		
≥ 30 breaths/ minute	1.2 – 3.8	[5, 8, 18, 19]
≥ 40 breaths/ minute	2.6 – 2.9	[4, 9, 12]
Systolic hypotension		
< 100 mm Hg	1.3 – 4.8	[7, 9, 15]
< 80 mm Hg	5.3	[8]
< 60 mm Hg	1.3	[19]
Shock	5.7	[10]
Cardiorespiratory arrest	6.4	[10]
Respiratory failure	5.7	[10]
Coma, stupor, lethargy, disorientation	1.8 – 4.2	[4-8, 12, 15]
Results of evaluation chest radiograph		
Multilobar infiltrate	1.1 – 3.1	[2-4, 9, 15]
Pleural effusion	1.2 – 7.0	[5, 10, 15, 17, 18, 20]
Hypernatremia[vi]	1.3	[18]
Hyponatremia[vii]	1.3 – 4.0	[5, 8, 12, 18]
Hyperkalemia	1.3	[14]

[1] Unless otherwise indicated, these figures represent the relative risk or odds ratio among patients with this risk factor compared to those without the risk factor, typically (although not exclusively) after multivariable adjustment.

Table 2.1: Literature review of risk factors for in-hospital or 30-day mortality for an episode of community-acquired pneumonia, *continued*.

Risk Factor	Risk Estimate*	Reference
Serum creatinine (≥ 1.5 mg/ dl)	1.5	[21]
Elevated blood urea nitrogen[viii]	1.4 – 5.2	[3, 4, 8, 12, 14, 15, 17, 19]
Serum albumin ≤ 2.4 g/dL	2.0 – 2.2	[1, 12, 15, 17, 22]
Bacteremia	1.1 – 2.8	[3, 9]
Leukocytosis		
> 10,000/ L	ORNA[ix]	[4]
> 15,000/ L	NS[x]	[12]
Leukopenia	2.5	[9]
Thrombocytopenia	1.8	[18]
Hypoxemia (pO_2 ≤ 60 mm Hg)	1.2 – 1.6	[12, 17, 18]
Acidosis[xi]	2.3 – 5.6	[8, 12, 17, 18]
Atrial fibrillation	1.4 – 1.8	[10, 18]
Elevated LDH	1.8	[18]
Pneumonia etiology		
"High risk" [xii]	1.8 – 2.8	[6, 7, 18]
Process of care		
'Do not resuscitate' order on admission	1.2 – 10.1	[3, 8, 18]
Initial antibiotics administered within 8 hours of hospital arrival	0.9	[23]
Blood culture obtained within 24 hours of admission	0.9	[23]
Oxygenation assessed within 24 hours of admission	1.2	[23]
Initial choice of antibiotics****	0.6 – 0.7	[24]

[1] Unless otherwise indicated, these figures represent the relative risk or odds ratio among patients with this risk factor compared to those without the risk factor, typically (although not exclusively) after multivariable adjustment.
[1] Assorted measures of functional status including: inability to walk, inability to bathe oneself.
[1] Examined and found to be not significant.
[1] Variably defined, most commonly > 38 C.
[1] Variably defined; typically < 35 C.
[1] > 145 mEq/ L
[1] < 130 or 135 mEq/ L depending on study.
[1] Variable degree of elevation.
[1] Odds Ratio Not Available (ORNA) – Odds ratio not displayed, only level of statistical significance.
[1] Not significant.
[1] Variable degree of abnormality. Typically pH < 7.35.
[1] High-risk etiology: gram-negative rods (*Klebsiella sp., Pseudomonas sp.), Staphylococus sp.* or aspiration pneumonia.
**** Second-generation cephalosporin with a macrolide, third generation cephalosporin plus a macrolide, or a fluroquinolone.

Table 2.2: References cited.

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3. **Daley J, Jencks S, Draper D, Lenhart G, Thomas N, Walker J.** Predicting hospital-associated mortality for Medicare patients. A method for patients with stroke, pneumonia, acute myocardial infarction, and congestive heart failure. *Jama*. 1988;260(24):3617-24.
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6. **Fine MJ, Singer DE, Hanusa BH, Lave JR, Kapoor WN.** Validation of a pneumonia prognostic index using the MedisGroups Comparative Hospital Database. *Am J Med*. 1993;94(2):153-9.
7. **Fine MJ, Orloff JJ, Arisumi D, et al.** Prognosis of patients hospitalized with community-acquired pneumonia. *Am J Med*. 1990;88(5N):1N-8N.
8. **Flanders WD, Tucker G, Krishnadasan A, Martin D, Honig E, McClellan WM.** Validation of the pneumonia severity index. Importance of study-specific recalibration. *J Gen Intern Med*. 1999;14(6):333-40.
9. **Fine MJ, Smith MA, Carson CA, et al.** Prognosis and outcomes of patients with community-acquired pneumonia. A meta-analysis. *Jama*. 1996;275(2):134-41.
10. **Iezzoni LI, Foley SM, Daley J, Hughes J, Fisher ES, Heeren T.** Comorbidities, complications, and coding bias. Does the number of diagnosis codes matter in predicting in-hospital mortality? *Jama*. 1992;267(16):2197-203.
11. **Almirall J, Bolibar I, Vidal J, et al.** Epidemiology of community-acquired pneumonia in adults: a population-based study. *Eur Respir J*. 2000;15(4):757-63.
12. **Iezzoni LI, Shwartz M, Ash AS, Mackiernan YD.** Using severity measures to predict the likelihood of death for pneumonia inpatients. *J Gen Intern Med*. 1996;11(1):23-31.
13. **Houston MS, Silverstein MD, Suman VJ.** Risk factors for 30-day mortality in elderly patients with lower respiratory tract infection. Community-based study. *Arch Intern Med*. 1997;157(19):2190-5.
14. **Davis RB, Iezzoni LI, Phillips RS, Reiley P, Coffman GA, Safran C.** Predicting in-hospital mortality. The importance of functional status information. *Med Care*. 1995;33(9):906-21.
15. **Kahn KL, Draper D, Keeler EB, et al.** *The effects of the DRG-based Prospective Payment System on Quality of Care for Hospitalized Medicare Patients: Final Report*. Vol. R-3931 Santa Monica, CA: RAND; 1992.
16. **Saitz R, Ghali WA, Moskowitz MA.** The impact of alcohol-related diagnoses on pneumonia outcomes. *Arch Intern Med*. 1997;157(13):1446-52.
17. **Fine MJ, Hanusa BH, Lave JR, et al.** Comparison of a disease-specific and a generic severity of illness measure for patients with community-acquired pneumonia. *J Gen Intern Med*. 1995;10(7):359-68.
18. **Rosenthal GE, Harper DL, Shah A, Covinsky KE.** A regional evaluation of variation in low-severity hospital admissions. *J Gen Intern Med*. 1997;12(7):416-22.
19. **Farr BM, Sloman AJ, Fisch MJ.** Predicting death in patients hospitalized for community-acquired pneumonia. *Ann Intern Med*. 1991;115(6):428-36.

Table 2.2: References cited, *continued*.

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21. **Conte HA, Chen YT, Mehal W, Scinto JD, Quagliarello VJ.** A prognostic rule for elderly patients admitted with community-acquired pneumonia. *Am J Med*. 1999;106(1):20-8.
22. **Ortqvist A, Hedlund J, Grillner L, et al.** Aetiology, outcome and prognostic factors in community-acquired pneumonia requiring hospitalization. *Eur Respir J*. 1990;3(10):1105-13.
23. **Meehan TP, Fine MJ, Krumholz HM, et al.** Quality of care, process, and outcomes in elderly patients with pneumonia. *Jama*. 1997;278(23):2080-4.
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CHAPTER THREE:
SELECTION CRITERIA

The intent of this analysis was to focus on patients admitted to an acute care hospital after developing community-acquired pneumonia (CAP). Patients with certain rare or unusual causes of pneumonia were not included in the analyses as these pneumonias present diagnostic and treatment issues clinically distinct from the majority of CAP cases. The inclusion and exclusion criteria discussed in this Chapter were developed after a careful review of the medical literature, and consultation with the Clinical Advisory Panel. The Panel included a pulmonologist, a nurse with a specialty in pulmonary care, two 'hospitalist' physicians, a clinical pharmacologist with expertise in the selection of antibiotics for CAP, and a credentialed coding expert.

INCLUSION CRITERIA

CAP cases were identified by reviewing the discharge abstracts from all California acute care hospitals that reported data to the Office of Statewide Health Planning and Development (OSHPD) in calendar year 1996. Patient discharge information from other levels of care, such as acute rehabilitation and skilled nursing facilities, was excluded. Information from facilities operated by the U.S. Department of Veterans Affairs and the Department of Defense was not available in these data, and thus not included. Cases selected for study were required to meet all inclusion criteria listed below.

1. **A principal diagnosis of community-acquired pneumonia or a specified pneumonia-related principal diagnoses with a secondary diagnosis of community-acquired pneumonia.**

   Although in 1996 hospitals were required to report whether or not the principal diagnosis and the secondary diagnoses were present on admission, this indicator was not reliably coded in many instances. Therefore, it was necessary to determine for each clinical risk factor whether or not the condition present at admission (CPAA) variable could be used in the analyses (Chapter 12). Consistent with previous California Hospital Outcomes Projects, a condition coded as a principal diagnosis was assumed present at admission regardless of the designation of the CPAA variable.

   Because the principal diagnosis is "the condition established, after study, to be the chief cause of the admission of the patient to the facility for care"[3.1], when CAP was the principal diagnosis it was assumed present at admission. For cases with CAP-related principal diagnoses (e.g., respiratory failure), the secondary diagnosis of CAP was also assumed present at admission based on the close clinical relationship of the two diagnoses. This

[3.1] Office of Statewide Health Planning and Development, June 1997. *1996 Discharge Data Fixed Length File Documentation.*

approach has been used in prior research on community-acquired pneumonia. [3.2]

Table 3.1 lists by ICD-9-CM code the principal CAP Diagnoses and the CAP- Related Principal Diagnoses that also require a secondary diagnosis of CAP. These conditions are defined to represent patients discharged with CAP.

2. **Age at admission is 18 years or greater.**

This study included adults only. The clinical spectrum of pneumonia for children is significantly different, and would therefore necessitate developing more than one risk adjustment system and validation instrument.

3. **Source of admission is home (1)**.

Because this study is focused on community-acquired pneumonia, the only source of admission for patients in the study was home. Patients admitted from Residential Care facilities (2) and Prison/Jail (8) were not included since patients who have been institutionalized may be exposed to organisms with different patterns of antibiotic resistance than individuals who live in a non-institutional setting.

Patients admitted from Acute Inpatient Hospital Care (5) were only included in the dataset for the first eligible pneumonia admission in a series of contiguous admissions. Any other subsequent, contiguous discharges for these patients were used to obtain outcome information. In our final sample, 1126 (1.9%) of patients were transferred to another acute care facility at the time of discharge. This procedure allowed the disposition of the hospital case to be properly assigned to the hospital that initially admitted the pneumonia patient.

Patients admitted from Long Term Care (4), and Other Inpatient Hospital Care (6) were not included because they are exposed to bacteria that do not typically exist in the community (i.e., they are exposed to bacteria that cause hospital-acquired pneumonia). Bacteria that cause hospital-acquired pneumonia have a different, often more severe, clinical course than bacteria that are typically associated with CAP. Patients transferred from a long-term care facility are also more likely to have a higher incidence of “Do Not Resuscitate” (DNR) orders. Patients with DNR orders have a higher risk of underlying medical conditions that may not be fully measured in a risk adjustment system using administrative data. In addition certain life-prolonging measures may not be used for patients with DNR orders, possibly introducing bias in the risk-adjustment development. Ambulatory Surgery (3) and Other (9) patients were also not included as it was not known where these patients normally resided. Newborns (7) were excluded based on age.

[3.2] Iezzoni LI, Shwartz M, Ash A, Mackiernan YD. Using severity measures to predict the likelihood of death for pneumonia inpatients. *J Gen Intern Med.* 1996; 11:23 – 31.

4. **Date of Discharge between 1/1/1996 - 12/31/1996 and Date of Admission between 11/1/1995 through 12/31/1996.**

Our analysis was designed to capture all patients with CAP discharged during 1996. We excluded patients admitted before 11/1/95 (n = 26) because this study was intended to capture patients primarily treated in calendar year 1996.

EXCLUSION CRITERIA

The exclusion criteria were designed to eliminate those pneumonia cases that did not represent community-acquired pneumonia. Cases with any of the following criteria were excluded:

1. **One or more acute inpatient hospitalizations for any reason within the 10 days preceding the CAP index admission.**

   Recent hospitalizations put a patient at risk for hospital-acquired pneumonia. The presence of pneumonia within 10 days of a hospital discharge is usually defined as a hospital-acquired pneumonia[3.3] Hospital-acquired pneumonia may be caused by different types of bacteria than CAP. Bacteria associated with hospital-acquired pneumonia may have greater resistance to antibiotics, and therefore may be more difficult to treat. 4363 discharges were excluded for this reason.

2. **An external cause-or-injury (E code) indicating a transport accident of any type (E800.x-E848).**

   These cases were excluded because it was highly likely that an accident victim would have acquired pneumonia in the hospital (n = 2574).

3. **We excluded discharges with diagnosis codes indicating that a patient had undergone organ transplant, had the human immunodeficiency virus or AIDS, had cystic fibrosis, tuberculosis, post-operative pneumonia or certain unusual pathogens as the cause of the pneumonia.**

   In addition to typical bacterial pathogens that cause CAP, individuals with AIDS or HIV infection are subject to a variety of HIV-related pathogens that are distinct from those underlying CAP. We therefore excluded 1,107 records indicating an HIV-related diagnosis. Similarly, since patients who have undergone an organ transplant receive medications to suppress their immune system, they are susceptible to bacteria and other organisms that do not cause CAP (138 discharges excluded). Patients with cystic fibrosis are not able to clear bacteria effectively from their lungs and are susceptible to frequent pneumonia. The frequency of pneumonia, and associated courses of antibiotics, also make them susceptible to antibiotic-resistant bacteria, thereby posing problems with treatment (262 discharges excluded). Patients with tuberculosis were excluded because this type of pneumonia requires specific antibiotics and has a very different clinical course than patients with CAP (2,562 patients excluded). Patients with postoperative pneumonia are clinically classified as having hospital-acquired pneumonia (434 discharges excluded). Some 'unusual' pneumonias (e.g., anthrax) were also excluded because these organisms are treated with

[3.3] Fang GD, Fine M, Orloff J, et al. New and Emerging Etiologies for Community-Acquired Pneumonia with Implications for Therapy: A Prospective Multicenter Study of 359 Cases. *Medicine.* 1990; 69:307-316.

specific antibiotics and have a different clinical course (606 discharges excluded). Table 3.2 lists the pneumonia diagnoses that were excluded because their etiologies and treatment regimes are clinically distinct from the majority of community-acquired pneumonias.

4. Other exclusions.

Finally, we excluded individuals with a sex that was not identified in the data as either male or female (n = 10). We also excluded discharges with missing or invalid social security numbers (n = 2,562) because a social security number is necessary to link information regarding a patient's prior hospitalization. This would ensure, for example, that the patient had not been discharged from the hospital within the preceding 10 days. In addition, we excluded 18 discharges with a date of admission that occurred after the date of death. Furthermore, we excluded 34 patients who were reported as dead but lacked information about the date of death. Consequently, we could not ascertain whether the death had occurred within 30 days of hospital admission.

Table 3.1 and Table 3.2 taken together represent those ICD-9-CM Diagnoses typically considered to represent community-acquired pneumonia[3.4]

[3.4] Fine M, Singer DE, Hanusa B, et al. Validation of a Pneumonia Prognostic Index Using the MedisGroups Comparative Hospital Database. *The American Journal of Medicine.* 1993; 94:153-159.

Table 3.1: CAP Diagnoses included in the analysis (Principal CAP and Principal CAP-Related with CAP Secondary).

ICD-9 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 (*Streptococcus pneumoniae*)	X	
482.0	Pneumonia due to *Klebsiella* pneumoniae	X	
482.1	Pneumonia due to *Pseudomonas*	X	
482.2	Pneumonia due to *Hemophilus influenza*	X	
482.30	Pneumonia due to *Streptococcus,* unspecified	X	
482.31	Pneumonia due to *Streptococcus*, Group A	X	
482.32	Pneumonia due to *Streptococcus*, Group B	X	
482.39	Other *Streptococcus* species	X	
482.4	Pneumonia due to *Staphylococcus* species	X	
482.81	Pneumonia due to other specified bacteria - Anaerobes	X	
482.82	Pneumonia due to *Escherichia coli* (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-*Mycoplasma*	X	
483.1	Pneumonia due to other specified organism -*Chlamydia*	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

* Secondary Pneumonia requires both the CAP-related Pneumonia code specified as the principal diagnosis and one of the Principal CAP codes in any secondary diagnosis code position.

Table 3.1: CAP Diagnoses included in the analysis (Principal CAP and Principal CAP-Related with CAP Secondary), *continued*.

ICD-9 Code	Principal Diagnosis	Principal CAP Codes	Non-CAP Principal Diagnosis Codes*
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

* Secondary Pneumonia requires both the CAP-related Pneumonia code specified as the principal diagnosis and one of the Principal CAP codes in any secondary diagnosis code position.

Table 3.2: Pneumonia diagnoses excluded from analyses.

ICD-9-CM Code	ICD-9-CM Description
Fungal Pneumonia	
112.4	Candida species
114.0	Primary Coccidioimycosis
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

CHAPTER FOUR:
DEFINITION OF OUTCOME: 30-DAY MORTALITY

Only one outcome for patients hospitalized with CAP was examined: death within 30 days of hospital admission. This outcome variable was selected for several reasons. First, 30-day mortality occurs at a substantial rate. Second, the outcome is reliably captured using OSHPD data. Third, death may be prevented by appropriate medical therapy such as the timely administration of antibiotics.[4.1]

This report uses death within 30 days, regardless of location, as the outcome. Deaths within 30 days of admission were ascertained by OSHPD by linking hospital discharge abstract data to vital statistics data using an established algorithm. Among 60,158 discharges for CAP in our final sample 7,274 (12.1%) were reported as 30-day deaths. Of the patients who died within 30-days of admission, 61.9% of the deaths occurred in the hospital. Deaths beyond 30 days following admission were not counted because these delayed deaths may have resulted from unrelated illness or complications. This 30-day limit was also adopted because it is consistent with previous research on patients with CAP, and because other California Hospital Outcomes Project reports have utilized this outcome variable.

For the 1,126 (1.9%) CAP patients who were transferred to another acute care facility from the original hospital of admittance, the outcome of each 'episode of care' was attributed to the hospital that originally admitted the patient. This attribution of the outcome to the initial hospital is necessary to prevent hospitals that transfer many of their patients, particularly their patients who are at higher risk of death, from having an artificially low risk-adjusted mortality.

[4.1] Meehan TP, Fine MJ, Krumholz HM, et al. Quality of care, process, and outcomes in elderly patients with pneumonia. *JAMA*. 1997; 278(23): 2080-4.

CHAPTER FIVE:
SELECTION AND EXCLUSION OF HOSPITALS

All acute care California hospitals that reported 1996 Community-Acquired Pneumonia (CAP) discharge information to OSHPD were potentially eligible for this study. Certain hospitals were excluded by OSHPD based on standard criteria (i.e., data modification and non-compliance). In addition, the coding of key risk factors and the accuracy of the coding of the Condition Present at Admission indicator (CPAA) was examined, by the research team, for each hospital and certain coding abnormalities were identified. Methods of addressing these abnormalities are presented and suggestions are also made for future evaluation.

HOSPITALS INITIALLY ELIGIBLE FOR STUDY

As described in Chapter 3, all acute care hospitals reporting discharge information to OSHPD for patients with CAP were initially eligible for inclusion (Level of Care = 1). Although some hospitals with distinct part psychiatric or alcohol and drug rehabilitation patients can report in this category, they would not have patients with principal diagnoses of CAP. Patients with the following reported levels of care were excluded: skilled nursing/intermediate care (3), rehabilitation (6), psychiatric (4) and Alcohol/Drug Rehabilitation (5).

CRITERIA FOR EXCLUDING HOSPITALS

OSHPD identified 19 hospitals that were excluded for data modification and non-compliance. An additional 25 hospitals were included in the study for some portion of the year, but had up to six months of data excluded for the same reasons.

We examined both the prevalence of key risk factors and the pattern of Condition Present at Admission coding for each hospital. Table 5.2 lists the risk factors examined, their statewide prevalence, and the prevalence range across hospitals. Initially a categorical cut-off for under or over coding based on clinical considerations was evaluated. After discussion, it was decided that there was no specific prevalence for these three risk factors that would clearly indicate that the hospital should be removed based on a categorical cut-off alone. The prevalence of these key risk factors was examined on a hospital-by-hospital basis. Since the validation study (see Chapter 12) suggests adequate accuracy of the coding of these variables overall and by outlier status, no hospitals were removed from the analysis based on the inaccurate coding of key risk factors. More information is needed to determine whether the coding of these key risk factors varies across hospitals and could therefore affect 30-day mortality comparisons.

Table 5.2: Key risk factor prevalence.

Risk factor	Statewide prevalence	Range across hospitals
CHF	24.8%	4.3% - 45.9%
Respiratory Failure	11.4%	2.2% - 36.0%
Septicemia	9.8%	1.2% - 23.4%

Similarly, several hospitals were identified that coded no secondary diagnoses as present on admission (n = 7 hospitals), or, conversely, coded all of the secondary diagnoses as present on admission (n = 53 hospitals). In addition, 5 hospitals had no secondary diagnoses coded at all for over 20% of their discharges with community- acquired pneumonia. A list of these hospitals has been provided separately to OSHPD staff. While it is clinically unlikely that either all or none of the secondary diagnoses at a hospital would be present on admission, we did not remove these hospitals from the risk adjustment model on the basis of this coding because we were concerned that we were making this assessment on the basis of relatively few discharges (i.e., based on discharges for patients with community-acquired pneumonia instead of on the basis of a hospital's overall coding pattern across all of their discharges). Rather, we left them in our analysis file, but the subset of these hospitals that had at least 80 CAP discharges in 1996 were not eligible for risk adjustment using the full set of variables in our final model (n = 20). Only those hospitals with at least 80 discharges were treated differently in the risk adjustment process because this was the minimum number of discharges necessary to determine that their coding practices were statistically unlikely to be observed by chance. Because of these apparent abnormalities in the coding of the Condition Present at Admission indicator, these hospitals were not eligible for risk adjustment using the three clinical risk factors that required this indicator in our final model (i.e., respiratory failure, coagulation deficit, acute cerebrovascular accident). These hospitals were eligible for risk adjustment using age and the chronic clinical conditions that were included in the model.

In summary, 399 California hospitals were included in our final risk assessment model using discharge data from at least part of 1996. Twenty of these hospitals were felt to have extreme coding abnormalities of the Condition Present at Admission indicator. For these 20 hospitals, risk-adjustment was performed only using chronic clinical conditions and demographic characteristics that do not depend on the accuracy of this information.

On the basis of these analyses, we recommend that two things be examined further before the development of a public report for CAP:

1. Because several of these hospitals had relatively few CAP discharges in a single year, it is recommended that this issue be addressed further in multiple years of data to determine which hospitals are outliers because of abnormal coding or physician documentation.

2. We recommend that further work be undertaken to examine whether certain hospitals have aberrant coding of the Condition Present at Admission indicator and should therefore be

removed from the risk adjustment model until their coding accuracy improves. Because pneumonia discharges are only a subset of a hospital's patient panel, we suggest that hospital Condition Present at Admission coding be examined on all medical discharges (as opposed to discharges for patients with only community-acquired pneumonia). If hospitals display overall patterns of high or low coding of the Condition Present at Admission indicator, these hospitals should be removed from further risk adjustment efforts until the abnormalities are corrected. Because 1996 was the first year that the Condition Present at Admission indicator was used, this issue should be examined in subsequent years of data, and trends in accuracy should be examined. Alternatively, hospitals that have aberrant coding of the Condition Present at Admission indicator could be included in the risk adjustment model, but not given 'credit' for any risk factors that depend on the Condition Present at Admission identification. This second approach is similar to the one presented in this report.

CHAPTER SIX:
DEFINITIONS AND PREVALENCE OF RISK FACTORS

The purpose of the CAP risk-adjustment model is to provide a method of quantifying the risk of death within 30 days of a hospital admission for patients with CAP. This information can then be used to compare risk-adjusted death rates for California CAP patients, and could facilitate an evaluation of the quality of care for these patients. To develop a useful risk-adjustment system, it is first necessary to identify key clinical and demographic information (risk factors) about each patient that can help to define the extent and severity of both their acute and chronic illnesses. Risk factors used in this risk-adjustment process are defined as patient characteristics or conditions that were probably present at the time of admission, and that may have influenced the 30-day mortality of CAP patients.

A comprehensive literature review (Chapter 2), and suggestions of the Clinical Advisory Panel were the main methods used to compile an initial list of risk factors for further evaluation. Only those risk factors that were reported to OSHPD in the discharge abstract could be used in the risk-adjustment models. For example, the presence of a "Do Not Resuscitate" order has been shown to be a risk factor for mortality among patients with CAP. However, this information was not reported to OSHPD in 1996. Risk factors that have previously been identified in the literature, but are not reported in the OSHPD data were set aside during the development of the risk-adjustment model, but were evaluated during the validation phase of this project (i.e., based on data from medical record abstraction). In order to capture all risk factors available in the administrative data, the initial risk factor list was supplemented with any additional risk factors with prevalence greater than 1% that were shown to be significantly associated with 30-day mortality in our sample. The reported risk factors include demographic and clinical information.

This chapter describes how the reported risk factors were defined. Chapter 7 describes the use of these risk factors in model development.

SOURCES OF RISK MEASURED AND LIMITATIONS

Indicators of age, gender, race/ ethnicity, principal and secondary diagnoses and their severity, clinical "fragility", and principal and secondary procedures were evaluated as potential risk factors. Table 6.1 lists the information in the OSHPD data used to define the risk factors that were evaluated.

Clinical information was reported by hospitals using the ICD-9-CM codes. Clinical risk factors were converted to ICD-9-CM codes using the *International Classification of Diseases, Ninth Revision, Clinical Modifications.* In addition, relevant *Coding Clinics* were reviewed, and three coding professionals reviewed, and edited, the risk factor conversions.

It is not possible to measure all sources of risk for patients with community-acquired pneumonia. Some common sources of risk measurement such as detailed clinical information, cultural and attitudinal biases about preferred health outcomes, and a patient's functional level are not available in this dataset. In addition, for those risk factors available in the OSHPD data, the indicators used may not adequately measure the risk factor. For example, although there is an ICD-9-CM code for volume depletion (dehydration), the severity of this condition might be better captured by a lab test result.

Table 6.1: Risk factors by data source.

Patient Risk Category	Discharge Abstract Data Source
Demographic Characteristics	
Age	Chronological Age
Gender	Male/Female
Race-Ethnicity	Hispanic/Non-Hispanic & Race
Insurance Status	Expected Payer Status
Clinical Characteristics	
Principal Diagnosis and Severity	ICD-9-CM for Principal Diagnosis
Pre-Existing Comorbid Conditions	ICD-9-CM for up to 24 Secondary Diagnoses (either clinically assumed to be chronic or with reliable CPAA indicator)
Clinical "Stability"	Number of Prior Hospitalizations
Procedure Use	Selected ICD-9-CM Codes for Principal and Secondary Procedures

OTHER CRITERIA FOR RISK FACTOR INCLUSION:

1. Reliable Coding of the Presence of the Risk Factor

Only risk factors shown to be reliably coded in the validation study were eligible for inclusion in the risk-adjustment model. ICD-9-CM codes are complex to determine and require a level of judgement and experience that may not always be available to every hospital for every chart that is coded. As described in more detail in Chapter 12, a risk factor had to show an adequate kappa, sensitivity and specificity using the re-abstracted data as the "gold standard". Many risk factors that were statistically associated with mortality had to be excluded because of unreliable coding.

2. Timing of Risk Factors

Reliable Coding of the 'Condition Present At Admission' (CPAA) Variable for Conditions that Could Have Developed Before or After Admission.

The CAP risk-adjustment model is intended to capture only those conditions that were present at the time of hospital admission. Conditions that arise after admission may be related to the type of care rendered by the hospital and should therefore be excluded from a risk-adjustment model developed to detect differences in the quality of care across hospitals. Chronic conditions, CAP principal diagnoses, and CAP secondary diagnoses paired with CAP-related principal diagnoses were assumed to be present on admission.

For risk factors that could be either acute or chronic, the CPAA variable, first reported in 1996, was examined to determine if it was reliably coded. For most of the key risk factors analyzed, extreme variation was seen in the CPAA coding when comparing the hospital data reported to OSHPD to the re-coded data from the validation study. Only three risk factors, stroke, respiratory failure and coagulation defects, were shown to meet minimum standards for CPAA coding reliability (see Chapter 12). Minimum CPAA standards included determining that the kappa for the presence of the risk factor was acceptable, in addition to an acceptable kappa for the timing of the condition (present at admission or not). This kappa compared patients reported in both the OSHPD data and the re-abstracted data as having the risk factor being studied, using the reabstracted data as the "gold standard". As more fully described in Chapter 8, the risk factors included in the final model include predominantly chronic conditions, and CAP-related diagnoses (e.g., the type of bacteria identified as the cause of the pneumonia). The model also includes the three eligible risk factors that require the use of the CPAA variable (i.e., respiratory failure, stroke and coagulation deficits). As described in Chapter 5, the expected mortality of patients in hospitals that demonstrated extreme variation in their CPAA coding was calculated without using the three variables that were dependent on the CPAA indicator.

3. Statistical Significance

A broad set of potential risk factors was examined. These variables are displayed in Tables 6.3 (for variables included in the final model) and 6.4 (for variables that were not included in the final model), with their ICD-9-CM definition. As described further in Chapter 7, some variables that were statistically associated with mortality in bivariate comparisons were not included in the final model because they did not enter a substantial number of the bootstrap samples.

Using Prior Hospitalizations to Capture Increased Risk

Because 26.3% of CAP patients had a prior hospitalization within the preceding six months, information about the number of prior hospitalizations was used to capture the clinical "fragility" of the patient. CAP patients who have a prior hospitalization may be more debilitated and therefore be more predisposed to complications from pneumonia than patients without a prior hospitalization. In addition to including information in the risk-adjustment model about the number of prior hospitalizations (if any), information about chronic conditions captured only in prior hospitalizations was used to supplement the coding of chronic risk factors identified during the index CAP hospitalization.

Table 6.2 lists the demographic and hospitalization characteristics of the patients in the final sample.

Any clinical risk factors included in the final model, and their ICD-9-CM descriptions, are listed in Table 6.3. Clinical risk factors considered but not included in the final model (with their ICD-9-CM descriptions) are listed in Table 6.4.

Table 6.2: Demographic and hospitalization characteristics of CAP discharges (after exclusions).

Characteristics	Number CAP Discharges	Percent CAP Discharges
Total	60,158	100.0
Demographic Data		
Sex		
Male	28,417	47.2
Female	31,741	52.8
Race		
White	41,612	69.2
Black	4,733	7.9
Hispanic	7,972	13.3
Native American	151	0.3
Asian	3,534	5.9
Other	638	1.1
Missing/Unknown	1,518	2.5
Age		
Mean	68.5 years	
Std. Deviation	17.5 years	
Expected Payment Source		
Medicare	37,583	62.5
Medi-Cal	6,753	11.2
Worker's Compensation	68	0.1
Indigent Program	1,321	2.2
Other Government	268	0.4
HMO	7,962	13.2
PPO	2,837	4.7
Private Insurance	1,935	3.2
Self Pay, Charity, No Charge	1,393	2.3
Other Non-Government	38	0.1
Hospitalization Characteristics		
Admission Type		
Scheduled	1,949	3.2
Unscheduled	58,078	96.5
Unknown	131	0.2

Table 6.3: ICD-9-CM codes for clinical risk factors included in the CAP risk-adjustment model.

ICD-9-CM Code	ICD-9-CM Description	Source of Data*	Eligible Positions for Index Admission
	Respiratory Failure	Index Only	Principal or Secondary
518.81	Respiratory failure		
518.82	Other pulmonary insufficiency NEC		
	Solid Non-Lung Cancer	Index or Prior	Secondary
140.x - 160.x	Malignant neoplasm of head, neck, digestive organs and peritoneum		
170.x-172.x	Malignant neoplasm of bone, connective tissue, malignant melanoma of skin		
174.x	Malignant neoplasm of female breast		
179.x-189.x	Malignant neoplasm of genitourinary organs		
191.x-192.x	Malignant neoplasm of brain and other CNS		
193.x-195.x	Malignant neoplasm of thyroid, endocrine glands		
196.x-199.x	Secondary malignant neoplasm		
V10.0x	Personal history of malignant neoplasm		
	Septicemia	Index Only	Principal Only
038.xx	Septicemia		(CPAA coding not accurate enough to include if coded in Secondary position)
790.7	Bacteremia		
	Lung Cancer	Index or Prior	Secondary
162.x	Malignant neoplasm of trachea, bronchus, and lung		
163.x	Malignant neoplasm of pleura		
165.x	Malignant neoplasm of other respiratory site		
	Chronic Liver Disease	Index or Prior	Secondary
571.x	Chronic liver disease and cirrhosis		
572.x-573.x	Liver abscess and sequelae of chronic liver disease, other disorders of the liver		
070.22, 070.32, 070.44, 070.54	Chronic hepatitis		
	Blood Cancer	Index or Prior	Secondary
200.x-203.x	Lymphosarcoma and reticulosarcoma, Hodgkin's disease, other malignant neoplasms of lymphoid & histiocytic tissue, multiple myeloma and histiocytic tissue, multiple myeloma and immunoproliferative neoplasms		

* Index hospitalization only or also includes data from prior hospitalizations (if any).

Table 6.3: ICD-9-CM codes for clinical risk factors included in the CAP risk-adjustment model, *continued*.

ICD-9-CM Code	ICD-9-CM Description	Source of Data*	Eligible Positions for Index Admission
204.xx-208.xx	Leukemia		
284.x, 273.8	Aplastic anemia, other disorders of plasma protein metabolism		
	Chronic Renal Disease	Index or Prior	Secondary
585	Chronic renal failure		
403.91	Unspecified hypertensive renal disease with renal failure		
403.01, 403.11	Malignant, benign hypertensive renal disease with renal failure		
404.02, 404.12, 404.92	Malignant, benign, unspecified hypertensive heart and renal disease with renal failure		
996.73	Other complications of internal prosthetic device, implant, & graft due to renal dialysis device		
V45.1	Renal dialysis status		
	Coagulopathy	Index Only	Secondary
287.4, 287.5, 287.9	Secondary thrombocytopenia, unspecified thrombocytopenia, unspecified hemorrhagic conditions		
286.6, 286.7, 286.9	Defibrination syndrome, acquired coagulation factor deficiency, other and unspecified coagulation defects		
	Staphylococcus Pneumonia	Index Only	Principal or Secondary
482.4	Pneumonia due to Staphylococcus species		
	Congestive Heart Failure (CHF)	Index or Prior	Secondary
398.91	Rheumatic heart failure (congestive)		
402.91	Unspecified hypertensive heart disease with CHF		
404.01, 404.11, 404.91	Malignant, benign, and unspecified hypertensive heart and renal disease with CHF		
404.03, 404.13, 404.93	Malignant, benign, and unspecified heart and renal disease with CHF and renal failure		
425.x	Cardiomyopathy		
428.x	Heart Failure		

* Index hospitalization only or also includes data from prior hospitalizations (if any).

Table 6.3: ICD-9-CM codes for clinical risk factors included in the CAP risk-adjustment model, *continued*.

ICD-9-CM Code	ICD-9-CM Description	Source of Data*	Eligible Positions for Index Admissions
482.0, 482.1, 482.82	**Gram Negative Pneumonia** Pneumonia due to Klebsiella pneumoniae, pneumonia due to Pseudomonas, pneumonia due to Escherichia coli	Index Only	Principal or Secondary
342xx 438.xx	**Late Effects of Stroke/ Hemiplegia** Hemiplegia and hemiparesis Late effects of cerebrovascular disease	Index or Prior	Secondary
493.xx	**Asthma** Asthma	Index or Prior	Secondary
430; 431; 432.x-435.x; 436; 437.1	**Acute Cerebrovascular Accident** Subarachnoid hemorrhage; intracerebral hemorrhage; other and unspecified intracranial hemorrhage, occlusion and stenosis of precerebral arteries, occlusion of cerebral arteries, transient cerebral ischemia; acute but ill-defined cerebrovascular disease; other generalized ischemic cerebrovascular disease	Index Only	Secondary
332.x	**Parkinson's Disease** Paralysis agitans, secondary parkinsonism	Index or Prior	Secondary

* Index hospitalization only or also includes data from prior hospitalizations (if any).

Table 6.4: ICD-9-CM codes for risk factors considered, but not included in final model.

ICD-9-CM Code	ICD-9-CM Description
	Acidosis
276.2	Acidosis
	Acute Renal Failure
584.x	Acute renal failure
	Airway Obstruction, Chronic
491.x; 492.x; 496	Emphysema; chronic airway obstruction not elsewhere classified
	Alcohol Use
291.x, 357.5x, 303.x, 305.0x, 571.2x, 571.1x, 571.3x, 571.0x, 425.5x, V11.3	Assorted complications of alcohol abuse
	Anemia
280.x, 281.x, 282.x, 283.x, 285.x	Assorted causes of anemia
	Aspiration Pneumonia
507.x	Pneumonitis due to inhalation of food or vomitus, due to inhalation of oils and essences, due to other solids and liquids
	Anoxic Brain Damage
348.1	Anoxic brain damage
	Atrial Fibrillation
427.3x	Atrial fibrillation and flutter
	Cardiac Arrest
427.5	Cardiac arrest
	Cardiac Dysrhythmia, Other
427.8x, 427.9	Other specified cardiac dysrhythmias, unspecified cardiac dysrhythmia
	Coma
780.01	Coma
	Decubiti
707.0	Decubitus ulcer
	Dementia
290.xx; 294.x; 331.xx	Senile and presenile organic psychotic conditions, other specified senile psychotic conditions, unspecified senile psychotic condition; other organic psychotic conditions (chronic); other cerebral degeneration

Table 6.4: ICD-9-CM codes for risk factors considered, but not included in final model, *continued*.

ICD-9-CM Code	ICD-9-CM Description
	Diabetes Mellitus -complicated
250.1x, 250.2x, 250.3x, 250.4x, 250.5x, 250.6x, 250.7x, 250.8x, 250.9x	Assorted complications of diabetes mellitus
	Dysphasia
787.2	Dysphasia
	Electrolyte Disorders, Misc.
275.4x; 276.9	Disorders of calcium metabolism; electrolyte imbalance, hyperchloremia, hypochloremia
	Encephalopathy
348.3	Unspecified encephalopathy
	Empyema
510.x	Empyema
	Fibrosis, Post-Inflammatory
515	Postinflammatory pulmonary fibrosis
	Gastrointestinal Hemorrhage
578.9	Unspecified hemorrhage of gastrointestinal tract
	Gastrostomy Status
V44.1; V55.1	Artificial opening status of gastrostomy; attention to artificial openings during gastrostomy
	Hemophilus Influenza
482.2	Hemophilus influenza
	Hyperosmolality
276.0	Hyperosmolality and/or hypernatremia
	Hypertension - complicated
401.0x, 401.9x, 402.00, 402.10, 402.90, 403.00, 403.10, 403.90, 404.00, 404.10, 404.90, 437.2x	Assorted complications of hypertension
	Hyperpotassemia
276.7	Hyperpotassemia
	Hypoosmolality
276.1	Hyposmolality and/or hyponatremia
	Ischemic Heart Disease
410.x – 414.x	Assorted manifestations of ischemic heart disease

Table 6.4: ICD-9-CM codes for risk factors considered, but not included in final model, *continued*.

ICD-9-CM Code	ICD-9-CM Description
	Kidney Disorder, Unspecified
593.xx	Other disorders of kidney and ureter
	Mixed Acid/ Base Disorder
276.4	Mixed acid/ base disorder
	Nutritional Deficiency
260-262; 263.X-266.X; 267; 268.x-269.x; 799.4	Kwashiorkor, nutritional marasmus, other severe protein-calorie malnutrition, vitamin A deficiency, thiamine and niacin deficiency states, deficiency of B-complex components; ascorbic acid deficiency; vitamin D deficiency, other nutritional deficiencies; cachexia
	Pacemaker
V45.01	Cardiac pacemaker *in situ*
	Paroxysmal Ventricular Tachycardia
427.0, 427.1	Paroxysmal supraventricular tachycardia, paroxysmal ventricular tachycardia
	Peripheral Vascular Disease
440.xx; 441.xx; 442.xx; 443.xx	Atherosclerosis; aortic aneurysm and dissection; other aneurysm; other peripheral vascular disease
	Pleurisy
511.1, 511.8, 511.9	Pleurisy with effusion (with mention of a bacterial cause other than tuberculosis), other unspecified forms of effusion except tuberculosis, unspecified pleural effusion
	Pneumococcal pneumonia
481	Pneumococcal pneumonia
	Pregnancy
640.x-677.x	Assorted conditions associated with pregnancy
	Renal Failure
586	Unspecified renal failure
	Rheumatologic Conditions
710.x, 714.xx	Diffuse disease of the connective tissue including systemic lupus erythematosus and rheumatoid arthritis
	Seizure Disorder
345.xx; 780.3x	Epilepsy, other forms of epilepsy, unspecified epilepsy; febrile convulsions, other convulsions

Table 6.4: ICD-9-CM codes for risk factors considered, but not included in final model, *continued*.

ICD-9-CM Code	ICD-9-CM Description
	Shock
785.5x; 458.0, 458.9	Shock without mention of trauma: unspecified shock, cardiogenic shock, other shock, enlargement of lymph nodes, other symptoms involving cardiovascular system; orthostatic hypotension, unspecified hypotension
	Streptococcus species
482.3x	Streptococcus unspecified, group A, group B, other
	Urinary Tract Infection
599.0	Urinary tract infection, site not specified
	Valvular Heart Disease
394.x, 395.x, 396.x, 397.x	Assorted causes of valvular heart disease
	Viral Pneumonia
480.x; 487.0	Viral Pneumonia due to adenovirus, due to respiratory syncytial virus, due to parainfluenza virus, due to other virus, unspecified; influenza with pneumonia
	Volume Depletion
276.5	Volume depletion
	White Blood Cell Dysfunction
288.x	Diseases of white blood cells

CHAPTER SEVEN:
PROCEDURE FOR DEVELOPING THE RISK-ADJUSTMENT MODELS

This chapter describes the analytical steps and statistical methods used to develop the risk-adjustment model for the CAP report.

Step 1: Review of Potential Clinical Risk Factors
The potential clinical risk factors listed in Chapter 6 were reviewed to identify important subsets and groups. Some clinically or statistically important variables were ultimately not considered because the validation study suggested that they were not reliably coded.

Step 2: **Preliminary Analyses of Clinical Risk Factors**
These analyses were designed to describe the frequency distributions of each clinical risk factor, detect potential risk factors with too few observations or deaths, evaluate the unadjusted bivariate association between each risk factor and death, and summarize multi-level clinical risk factors in a manner appropriate for logistic regression modeling.

2.1 The frequency distribution of each clinical risk factor was determined and low frequency risk factors were aggregated as appropriate.
Binary risk factors present in less than 1% of all cases were examined carefully. Whenever possible, these risk factors were aggregated with physiologically related risk factors that showed a similar association with mortality.

2.2 Risk factors not associated with mortality were identified and eliminated from further consideration to improve the efficiency of subsequent modeling.
The bivariate relationship between each clinical risk factor and mortality was summarized using relative risk estimate and a p-value from a chi-square statistic. Risk factors without even a marginal association with death ($p > 0.10$) were eliminated from further consideration. Similar to other California Hospital Outcome Projects, this cut-off was selected to screen out risk factors unlikely to contribute significantly to the multivariate model. Many of the risk factors eliminated for this reason are included in Table 6.4.

2.3 Risk factors that had counter-intuitive associations with mortality were identified and evaluated.
The direction of all statistically significant associations between potential risk factors and mortality were examined. Risk factors that appeared to lower the risk of death were eliminated from further analysis unless prior literature or clinical experience suggested a reason for this relationship. Asthma was the only clinical condition with a counter-intuitive association that was included in the final model. Because clinicians perceive patients with asthma to be at greater risk of complications from CAP, it is possible that these patients are admitted to the hospital when they are less severely ill, for more intensive observation and more aggressive treatment.

2.4 Multi-level clinical risk factors were summarized as multiple (dichotomous) variables.

Two clinical risk factors were divided into multiple severity categories based on the fourth or fifth digit of the ICD-9-CM code or the presence of certain associated conditions. For example, diabetes could be classified as complicated if it was associated with ketoacidosis, coma, or end organ damage. Hypertension could be classified as complicated if it was associated with kidney or heart disease. To determine how to model the effects of these multi-level variables, unadjusted associations were assessed using relative risk estimates and p-values derived from chi-square tests. These analyses suggested that hypertension and diabetes, whether complicated or uncomplicated, did not convey significant risk of mortality for patients hospitalized with CAP.

2.5 'Condition Present At Admission' (CPAA) indicator

Based on the results of the validation study, it was determined that only three non-chronic risk factors had reasonably accurate coding of the CPAA indicator (i.e., respiratory failure, coagulation deficit, stroke). The overall accuracy of the coding of the CPAA indicator was examined at the hospital level. If it appeared that a hospital was grossly unable to accurately code the CPAA indicator (i.e., 0%, or > 99.5% of secondary diagnoses were coded as present on admission and the hospital had at least 80 discharges of patients with CAP), then these three risk factors were not used in the risk-adjustment process for these hospitals (i.e., risk-adjustment for these hospitals was performed using demographic characteristics, chronic clinical conditions and non-clinical factors).

2.6 Information about chronic conditions was obtained from prior hospitalizations

For patients with a prior hospitalization within six months of admission, supplemental information was obtained for clinically important chronic risk factors. If, for example, a patient had a prior hospitalization that indicated an ICD-9-CM code for chronic renal failure but this code was not indicated during the index CAP hospitalization, then the information about chronic renal failure from the prior hospitalization was incorporated into the model. Table 7.1 displays the prevalence of chronic risk factors indicated during the index CAP hospitalization alone, and the somewhat higher rates after incorporating data from both index and prior hospitalizations (if any).

Step 3: Preliminary Analyses of Non-Clinical Risk Factors

These analyses were designed to describe the distributions of all non-clinical risk factors and 30-day mortality, and to select the appropriate specification for these variables.

3.1 The distributions of age and other continuous predictors and the associations between these predictors and mortality were evaluated.

Scatter plots of the logit outcome (log[p/ (1 – p)]) as a function of age were used to determine the best fitting relationship between age and 30-day mortality. Age was examined in both 1-year and 5-year increments. Piecewise components of the age-mortality relationship were tested using 5-year cut-offs. As a result of these analyses, age was categorized as a linear predictor. Because of a small number of outliers, age was truncated at 100 years.

The same approach was taken to examine the relationship between the number of prior hospitalizations and death. In scatter plots, the number of prior hospitalizations appeared to have a linear relationship with the risk of mortality. As a result of these analyses, the number of prior hospitalizations was categorized as a linear predictor.

3.2 The distribution of categorical non-clinical variables and the associations between these variables and mortality were evaluated.
Contingency tables were used to evaluate the relationship between each categorical demographic variable (e.g., sex, race, expected payer source) and mortality. Race was categorized as: white, African-American, Latino, Asian American, and 'other.' Both African-Americans and Latinos had lower unadjusted mortality rates than non-Latino whites (9.6%, 9.7% and 12.9%, respectively). Race was not included in the multivariate models because of the concern that this association may be related to differences in the clinical threshold for admission that may not be adequately captured in administrative data.[7.1] Four categories of expected payer were used: Medi-Cal, Medicare, uninsured (including self-pay, no charge, and section 17000 indigent services), and insured (including Blue Cross/ Blue Shield, fee-for-service, health maintenance organization, Worker's Compensation, Title V, and other government payers). Patients with Medicare had higher mortality (14.5%) than the rest of the sample related to the older age of this population. Because uninsured patients and those with Medi-Cal had lower than expected mortality (8.0% and 4.2%, respectively), and again we believed that this may be related to different thresholds for admission that may not be adequately reflected in administrative data, we did not include payer in the multivariate models. Also, because we only had information about principal payer, we could not adequately define patients who were dually eligible for Medi-Cal and Medicare. We examined whether the patient's zip code of residence suggested homelessness (i.e., zip code coded as 'ZZZZZ' or '00000'), but this was only reported in 201 patients (0.3% of the sample).

Step 4: Division of Data into Separate Samples for Estimation and Validation
The dataset was split into an estimation and a validation sample by randomly selecting 60% of the original cases for the estimation sample and setting aside the remaining 40% for the validation sample. This procedure made it possible to develop risk-adjustment models on the estimation sample and then assess these models in a separate validation sample. This technique is more rigorous than one that uses the same sample for estimation and validation. Sampling was stratified by outcome status (death) to ensure that the overall probability of death was the same in both the estimation and the validation samples.

Step 5: Selection of the Main Effects Risk Factors
Because of the availability of the CPAA indicator in 1996, a single model was estimated that contained clinical risk factors that could be assumed chronic and therefore present on admission (e.g., lung cancer, chronic renal failure), and conditions that could be acute and the validation study suggested that the CPAA indicator was generally reliable (e.g., respiratory failure, cerebrovascular accident, and coagulation deficits). As described further in Chapter 12, many conditions that could not be assumed chronic (i.e., atrial fibrillation, acute renal failure) could not be used in the model because the validation study suggested that the CPAA indicator was not reliably recorded.

[7.1] Rosenthal GE, Harper DL, Quinn LM, Cooper GS. Severity-adjusted mortality and length of stay in teaching and non-teaching hospitals. Results of a regional study. *JAMA*. 1997; 278:485-490.

For patients with a prior hospitalization, we incorporated the "supplemented" rates of the chronic risk factors into the risk-adjustment model. For each patient in our primary CAP dataset we searched for prior hospitalizations for any reason during the six months prior to the date of admission. From these hospitalizations, we collected information about chronic conditions that were coded during these prior hospitalizations. For these conditions, we made the assumption that if they had been present during the prior hospitalization then the condition would still be present during the CAP hospitalization. For example, if a patient had been hospitalized during the prior six months and the prior record indicated a diagnosis of lung cancer in either the principal or a secondary position, then lung cancer was assumed to be present even if it was not coded during the index CAP hospitalization. Of the variables in the final model, chronic liver disease, malignancies, chronic renal failure, late effects of stroke, congestive heart failure, Parkinson's disease and asthma were "supplemented" in this manner.

The goal of Step 5 was to generate a single best set of robust, significant predictors of death. To this end, 100 bootstrap sub-samples of the estimation sample were randomly generated with replacement, and covariate selection procedures were completed in each sub-sample. The results of this process were reviewed to determine the best set of predictors, while minimizing overfilling related to the characteristics of a particular sample.

5.1 One hundred random sub-samples were generated, with replacement, using a sampling fraction of 50%, from the 60% estimation sample.
Sampling with replacement means that the same case could have been selected multiple times for some of the sub-samples. Sampling with replacement offers the advantage of allowing a sub-sample to contain more cases of an uncommon risk factor than the population from which the sample was drawn.

5.2 The best set of risk factors for each sub-sample was determined by stepwise logistic regression.
A multivariate logistic regression model was fit using stepwise selection with the significance level for selection set at 0.01.

5.3 The results of the sub-samples were summarized to determine the final main effects variables.
All risk factors that were significant at the $p < 0.01$ level in 50 or more of the 100 bootstrap samples were retained as main effects for the construction of the risk-adjustment model. The risk factors that were eliminated at this stage are shown in Table 6.4.

Step 6: Examination of Risk Factor Interaction Terms
The number of main effects selected for the risk-adjustment model in Step 5 was too large to consider all two-way interactions or higher order interactions. A selective approach for testing interaction terms was based on the premise that only clinically or statistically important main effects would contribute in an important way to the development of the risk-adjustment model. We therefore evaluated interaction terms involving: age with respiratory failure, age with lung cancer, age with septicemia, age with chronic liver disease, respiratory failure with lung cancer, and respiratory failure with septicemia.

These two-way interactions were tested using 100 randomly generated sub-samples, also with replacement. For each bootstrap sub-sample, a multivariate logistic regression model was fit with the significance level set to 0.01 for the interaction terms. All of the important main effects selected above were forced into the model. Interaction terms that were significant at the $p < 0.01$ level in 40 or more of the 100 sub-samples were used in the construction of the risk-adjustment model. Of the interaction terms evaluated, only age with chronic liver failure entered at least 40 of the sub-samples.

Step 7: Internal Validation and Refinement of the Risk-Adjustment Model
To validate the model selected above, the parameter estimates from the 60% estimation sample was compared with the parameter estimates obtained by fitting the same model in the 40% validation sample. The parameter estimates from the 60% sample generally fell within the 95% confidence intervals of the parameter estimates from the 40% sample for all of the variables included in our final model except in two instances: asthma and the number of prior hospitalizations. Because these estimates in the 60% sample were close to the bounds of the confidence interval for these two variables, and within the bounds of the confidence intervals for all of the other variables, the validity of the model was considered to be adequate.

Step 8: Re-Estimation of the Final Model Using All Cases
The 60% sample and the 40% sample were re-combined into the full dataset. The model was then re-run on the full sample to determine the final parameter estimate for each variable. This final model was used to calculate the predicted probability of death for each case. These predicted probabilities were used in the preliminary analyses of hospital mortality rates.

Table 7.1: Prevalence of Chronic Risk Factors: Index Hospitalization Alone and Incorporating Information Prior Hospitalizations (within 6 months of admission for CAP).

Conditions	Index of Hospitalization	Index of Hospitalization and Prior Hospitalizations
Chronic liver disease	2.4%	2.7%
Lung cancer	2.2%	2.4%
Solid cancer, non-lung	5.5%	6.2%
Hematologic malignancies	4.1%	4.5%
Chronic renal failure	4.3%	4.8%
Late effects of CVA	4.2%	5.0%
CHF	26.2%	28.2%
Parkinson's disease	1.8%	2.0%
Asthma	7.4%	8.3%

CHAPTER EIGHT:
PRESENTATION AND INTERPRETATION OF FINAL MODELS

In this chapter the final risk-adjustment model developed through the process described in Chapter 7 is presented.

Because of the availability of the Condition Present at Admission Indicator (CPAA) in 1996, we present a single model that incorporates both chronic conditions and those that could be acute or chronic but were indicated to have been present on admission. This approach is different than what has been used in prior California Hospital Outcomes Project reports because of the recent availability of this indicator. Prior projects have relied on a Model A (i.e., a model that only includes variables with a high likelihood of having been present on admission) and a Model B (i.e., a model that also includes variables that are less likely to have been present on admission).

For those 15,805 (26.3%) of patients with one or more hospitalizations that occurred more than ten days before the index hospitalization and within six months, we collected supplemental information about comorbid conditions that were reported in the prior hospitalization (as previously described).

As in prior reports, the general format of these logistic regression models is:

$$\text{Log}\ (p/\ 1 - p) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots + \beta_q x_q$$

Table 8.1 shows the CAP risk-adjustment model for the overall sample. This model incorporates the 'supplemented' information about chronic risk factors for those patients with a prior hospitalization.

Table 8.1: CAP Risk-Adjustment Model – Overall Sample (n = 60,158).

Variable	Parameter Estimate	Lower CI for Odds Ratio	Odds Ratio	Upper CI for Odds Ratio
Age	0.039	1.04	1.04	1.04
Male	0.191	1.15	1.21	1.28
Septicemia	0.868	2.18	2.38	2.61
Respiratory failure	1.510	4.24	4.52	4.83
Staph. pneumonia	0.659	1.73	1.93	2.16
Chronic liver disease	0.779	1.56	2.18	3.05
Lung cancer	1.090	2.61	2.97	3.38
Solid cancer, non-lung	0.937	2.34	2.55	2.78
Hematologic cancers	0.669	1.76	1.95	2.16
Chronic renal failure	0.477	1.45	1.61	1.79
Late effects of CVA	0.388	1.33	1.48	1.63
Coagulopathy	0.791	1.92	2.21	2.54
Gram negative species	0.439	1.41	1.55	1.70
CHF	0.277	1.25	1.32	1.40
Parkinson's disease	0.337	1.20	1.40	1.64
Acute CVA	0.349	1.16	1.42	1.73
Asthma	-0.638	0.47	0.53	0.61
Age*Liver interaction	0.003	1.00	1.00	1.01
Number of prior discharges	0.125	1.11	1.13	1.16

CHAPTER NINE: TESTING THE INTERNAL VALIDITY OF THE RISK-ADJUSTMENT MODELS

The validity of the final risk-adjustment models was assessed using a similar approach to other California Hospital Outcomes Project (CHOP) reports.

CONTENT VALIDITY

The parameter estimates for each risk factor were compared to the estimates that have been presented in the prior literature and were found to be consistent. The risk factors included in the final model were believed to be clinically important risk factors for mortality by the members of the Clinical Advisory Panel.

MODEL DISCRIMINATION

The c-statistic was used as a measure of model discrimination (i.e., the model's ability to accurately discriminate patients with poor outcomes from those with good outcomes). A c-statistic can range from 0 to 1.0, with a value of 0.5 representing discrimination that could be obtained from random selection.

Table 9.1 shows the c-statistic for the CAP model. C-statistic for AMI models have been in the 0.75 – 0.77 range for Model A, and the 0.82 – 0.85 range for Model B. This statistic suggests that the discrimination of the CAP model is comparable to the other CHOP projects.

GOODNESS OF FIT

Goodness of fit was assessed by the Pearson chi-square statistic and the corresponding estimate of overdispersion.[9-1] This test is comparable to the Hosmer-Lemeshow test, except that it does not collapse subjects into only ten groups, instead using as many different groups as there are unique predictor profiles. Like the Hosmer-Lemeshow test, it provides an overall test of all model assumptions about linearity and lack of interactions. A drawback of such procedures is that very large studies, such as this one, can show statistically significant "lack of fit" even though departures from model assumptions are small.

Table 9.1 shows a $p < 0.0001$ for the goodness of fit test, indicating that some additional interactions or non-linearity are likely to be present. Adding a quadratic term for age or several other two-way interactions, however, did not produce any statistically significant improvement in the overall model, suggesting that very subtle features such as higher order interactions account

[9.1] McCullagh P, Nelder JA. *Generalized Linear Models, Second Edition*. London: Chapman and Hall, 1989, pp. 124-128.

for the small overall p-value. Any such additional terms would be very difficult to interpret, and choosing the right one(s) would require starting with a large pool of candidate variables, which would create serious overfitting problems. In addition, the estimated overdispersion was only 1.18, indicating very minor departures from model assumptions. The usual method to adjust for overdispersion is to multiply estimated variances by the overdispersion factor.[9-2] For the overall model, this increases the widths of confidence intervals by only 9% and does not produce any qualitative changes in the report's findings. Thus, there appears to be no need for additional terms to model interactions or nonlinearity.

In summary, the CAP model has adequate discrimination. Future CAP risk-adjustment models should be improved by incorporating multiple years of data. A larger sample size would possibly allow a greater number of interaction terms to be incorporated into the model. As discussed in Chapter 12, the validation study suggests that the addition of clinical data elements also significantly improves the estimation of the CAP risk-adjustment model.

Table 9.1: Goodness of Fit Tests for the CAP model.

		Overall Model
Number of cases (discharges)		60158
Number of deaths		7274
Death rate		12.10%
C-statistic		
	Estimation sample (60%)	0.79
	Validation sample (40%)	0.79
	Overall	0.79
Pearson Goodness of Fit Statistic		
	Overdispersion	1.18
	p-value	0.0001

[9. 2] McCullagh P, Nelder JA. *Generalized Linear Models, Second Edition*. London: Chapman and Hall, 1989, pp. 124-128.

CHAPTER TEN: VALIDATION STUDY OF COMMUNITY-ACQUIRED PNEUMONIA – INTRODUCTION AND PURPOSE

The primary purpose of the validation study was to evaluate the impact of systematic errors on the risk-adjustment model and to explore the effect of supplemental clinical information on the predictive validity of the model. The validation study was also designed to provide some information about whether the differences in the process of care explain, in part, observed differences in risk-adjusted mortality.

The validation study was designed to assess the effect of systematic error, thereby providing useful information to be used in interpreting the risk-adjustment models using the OSHPD data. This chapter outlines the research questions addressed by this study. Chapter 11 describes the methodology of the validation study including sampling, data collection and data analysis. Chapter 12 reports the key findings of the CAP validation study.

Question 1. What percentage of CAP discharges reported to OSHPD should have been excluded because CAP was incorrectly reported or diagnosed?

Using the selection criteria described in Chapter 3, CAP discharges were identified based on the OSHPD data. In the validation study, two levels of analysis were completed to determine if patients defined as having CAP using the study algorithm actually had community-acquired pneumonia on admission. First, the medical record of each patient in the validation study was recoded by a panel of expert coders. It was then possible to identify those patients who should not have been identified as having CAP using the 1996 ICD-9-CM coding rules and conventions. In addition, the same charts were abstracted by health care professionals to determine if there was clinical information in the medical records to "confirm" a diagnosis of community-acquired pneumonia on admission. Clinical signs and symptoms (fever $\geq$ 101°F, WBC $\geq$15,000, WBC differential $\geq$15% bands, new onset of cough or sputum production), a chest x-ray within 48 hours of admission that confirmed pneumonia or infiltrates, and a physician's diagnosis of CAP were used to confirm the presence of CAP.

Question 2. What is the statewide reporting accuracy for risk factors in the risk-adjustment models?

Previous CHOP validation projects[10.1] have demonstrated that the reliability and validity of risk factors can vary significantly. These analyses confirm that there are both over- and under-coding of important risk factors defined using the OSHPD data compared with re-coded data abstracted by an expert panel of coders. To identify coding irregularities likely to affect the reliability and validity of risk factors, coding experts completed a blind re-coding of each discharge in the validation study. These results were then compared to the information in the OSHPD data on a patient by patient basis. The accuracy of each key risk factor was then evaluated. This process also included an analysis of the coding of the CPAA indicator. These

[10.1] Report of the California Hospital Outcomes Project – Acute Myocardial Infarction, Volume Two: Technical Appendix, 1996, pp21-1 - 12-2.

analyses could result in the removal of inaccurately coded variables from the final version of the risk assessment model.

Question 3. Is there a significant difference in the coding of important risk factors when comparing low, average, and high mortality hospitals?

The consistency of ICD-9-CM coding of all key risk factors was examined by hospital outlier status to determine if between group variation might affect the accuracy of risk-adjustment. For example, there is some indication in the AMI CHOP validation study that "low mortality" hospitals (i.e., lower than expected 30-day mortality after risk-adjustment) as a group tend to code more risk factors that are not supported on recoding than average or high mortality hospitals. This tendency did not result in changing the mortality status of the "low mortality" hospitals when recoded data was used. It does, however, illustrate the need to determine the effect of variability in coding accuracy by outlier status.

Question 4. How does the risk-adjustment model change when additional clinical variables are used as risk factors?

As discussed in Chapter 6, administrative datasets provide limited data, based on ICD-9-CM codes, to fully quantify known clinical risk factors. To assess how much the administrative risk-adjustment model using the OSHPD data could be improved through supplementation of more detailed clinical data, the validation study collected specific clinical information from the medical records. The additional clinical variables were identified through the literature survey and in conjunction with the Clinical Advisory Panel. For each patient in the validation study, medical professionals abstracted these additional clinical variables from the medical record. The clinical abstractors were medical students who had finished the clinical training for their M.D. degree, physicians, or experienced nurses. After special training, they reviewed all portions of the medical record, including Emergency Department notes, physician notes, nursing notes, discharge summaries, operative reports, laboratory reports, x-ray reports, and special tests and studies. Key clinical risk factor information was abstracted. This information was then used, in part, to determine if more complete clinical information would improve the validity of the CAP risk-adjustment model. As part of this assessment, it was determined whether the use of clinical variables would change the performance classification of individual hospitals.

Question 5. Is there a difference in the process of care between low and high mortality hospitals?

After review of the prior literature and discussion with the Clinical Advisory Panel, we identified several process of care indicators that may reflect the quality of hospital care, and therefore reflect differences in 30-day mortality, for patients with CAP. We defined a set of indicators that were likely to be reliably identified through medical record review. For example, the time from arrival at the hospital to the first dose of antibiotics has been shown to be associated with 30-day mortality.[10.1] These processes of care were then analyzed to determine if there was a relationship between "good" processes of care and hospital mortality status.

[10.1] Meehan TP, Fine MJ, Krumholz HM, Scinto JD, Galusha DH, Mockalis JT, Weber GF, Petrillo MK, Houck PM, Fine, MJ. Quality of care, process, and outcomes in elderly patients with pneumonia. *JAMA*. 1997; 278: 2080-4.

CHAPTER ELEVEN: VALIDATION STUDY OF COMMUNITY-ACQUIRED PNEUMONIA — METHODOLOGY

The CAP validation study included 1,032 discharges of patients with CAP hospitalized in 1996 at 82 large- and medium-volume California hospitals. The hospitals selected were randomly sampled from all hospitals included in the development of the CAP risk-adjustment model.

All CAP patient information used in the validation study was re-abstracted from copies of the original patient medical record. Participating hospitals were asked to submit a complete copy of each sampled patient's record. Information about each patient was then abstracted from the charts by two different groups of professionals. Medical records professionals abstracted key demographic information and recoded the principal and secondary diagnoses and procedures using ICD-9-CM codes. This information was then compared to the discharge abstract and used to determine whether the principal diagnoses and co-morbid conditions (risk factors) were reliably coded. This information was the basis for answering Questions 2,3, and part of Question 1 as defined in Chapter 10. Experienced medical professionals abstracted key demographic, clinical, and process of care information, which provided the basis for answering Questions 4, 5, and the remainder of Question 1. The entire chart abstraction process, blind recoding and clinical abstraction, averaged about 90 minutes per chart.

All data abstractors were given detailed written instructions, received on-site training and supervision, passed initial reliability screening, and were monitored on-site through daily clinical and process supervision and 5% over-reading.

The analyses were completed as described in Chapter 12. The study protocol was approved by the Committee on Human Research at the University of California, San Francisco. All records were stored safely and were not accessible to persons outside of the California Hospital Outcomes Project staff.

The following is a discussion of the sampling frame, data abstraction tool development and data collection methods.

SAMPLING AND SAMPLE SIZE

The CAP validation study was a retrospective cross sectional study stratified on two variables: hospital mortality status (three strata) and number of CAP discharges in 1996 (two strata). Because hospitals must volunteer to participate in the validation study, the sample was stratified to assure that the hospitals sampled included good representation of the three mortality categories and were large enough to meet the statistical thresholds for outlier status. This strategy produced a sampling frame with 6 cells defined by combinations of the strata values as shown in Table 11.1.

Hospital Sample – Phase 1 and 2

The hospital sample was selected in two separate groups at two different points in time (Phase 1 and 2). Following suggestions from the Technical Advisory Committee and OSHPD staff, a proprietary risk-adjustment system (i.e., APR-DRG) was used to select a portion of the hospitals for the validation study before the CHOP Pneumonia (CHOPP) risk-adjustment system was developed. This two-phase sampling method was intended to expedite the selection of hospitals for the validation study. The APR-DRG risk-adjustment software was used to identify the first group of hospitals by mortality status. Hospitals were assigned, by using the APR-DRG software, to high, average or low risk–adjusted mortality groups. Within the average mortality category, hospitals were further divided into high average, average or low average mortality groups.

Once the mortality status of each hospital was determined, the minimum number of CAP patient discharges in 1996 that would allow a hospital to be a low outlier with 0 deaths was calculated. That minimum is 3.7 /E, where E is the expected death rate for that hospital, expressed as a proportion. The smallest size that met that criterion in both the Phase 1 and Phase 2 samples was 78 CAP patient discharges. Hospitals with less than 78 CAP discharges were not included in the validation sample. Hospitals with 78 or more CAP discharges, were stratified into medium (78 to 219) and large (≥ 220) hospitals). Forty hospitals were sampled in Phase 1. In order to increase the opportunity for overlapping outliers in the Phase 2 sample, all outliers were sampled in Phase 1. Patients were sampled as described below from the 40 hospitals chosen. The charts of these hospital patients were then abstracted while the CAP risk-adjustment system was being developed.

After the development of the CAP risk-adjustment model, the entire group of eligible hospitals was re-sampled and hospitals that had already been abstracted were assigned to a final mortality group determined by the CAP risk-adjustment model developed in Phase 2. In this process, nine hospitals initially selected by the APR-DRG software algorithm for the Phase 1 group of validation hospitals were dropped from further consideration for the validation study due to extreme variability in key risk factor or CPAA coding. The remaining 31 hospitals were included in the Phase 2 sample. The Phase 2 CAP risk-adjustment model provided the basis for the validation study analyses described in Chapter 12.

As shown in Table 11.1, 251 hospitals were eligible for inclusion in the validation study. Of the 87 hospitals (including the 31 hospitals carried over from Phase I) selected in the Phase 2 sampling, 82 (94%) agreed to participate. All 16 'high mortality' and 19 'low mortality' hospitals were sampled. One large low mortality hospital did not participate. The average mortality hospital category included 73% of the hospitals and patients in the validation sample. To provide a representative sample of hospitals with "average" risk adjusted mortality, these hospitals were first rank ordered by risk-adjusted mortality using a z-score. The hospitals were then sub-divided into three groups, high average, average and low average mortality. The remaining hospitals were then randomly selected from within these 3 groups to get approximately equal numbers of patients from each average mortality group.

PATIENT SAMPLING

The second stage of sampling involved sampling patients within each selected hospital. In both Phase 1 and 2 hospitals, 15 patient charts, stratified by mortality (11 survivors and 4 deaths), were randomly selected for each hospital. Deaths were oversampled at twice the statewide death rate for CAP during the study period (i.e., 24.1%). The oversampling of deaths was

intended to insure that each hospital stratum contained enough high-risk patients who might be more subject to coding errors or unmeasured risk factors and could, therefore, affect the predicted probability of death.

From the 15 requested patient charts, a second random sample selected 9 survivors and 3 deaths from each validation study hospital for inclusion in the study. The remaining three charts were set aside for potential replacement of charts within the same stratum that could not be located or were too incomplete for study inclusion.

DATA COLLECTION

Data Elements and Tool Development

In addition to the risk factors in the risk-adjustment model fully described in Chapter 6, key clinical risk factors and process variables were abstracted from the medical record. These additional clinical and process variables were identified through literature review and consultation with the Clinical Review Panel.

The clinical items and the process of care variables included in the clinical data abstraction instrument were developed in consultation with the Clinical Advisory Panel. The structure of the instrument and the data definitions were modeled substantially on the National Pneumonia Study data collection instrument provided by CMRI. The tool had extremely detailed guidelines, instructions, and data definitions. The instruction manual specified the allowable data sources for each question, the hierarchy of data sources with conflicting information, allowable synonyms, and constraints on the timing of physical findings, laboratory values, and process of care variables. During a 4-week period the CAP clinical abstraction tool (CAPCAT) was pilot tested by medical professionals who would participate in the clinical abstraction. Both the tool and instructions were revised as needed based on this additional information. A copy of CAPCAT and the accompanying instruction manual is provided to OSHPD with this report.

Direct data entry software was developed for the CAPCAT which included default values, precoded response options, range checks on dates and physiologic variables, and relational logic checks. In addition, the information entered was periodically screened for illogical data values.

A second instrument was developed for the re-coding of each medical record. Certified Coding Specialists, with a minimum of 10 years training, entered demographic information and the ICD-9-CM Diagnosis and Procedures codes and their CPAA status directly into a data entry screen. The codes submitted to OSHPD through the discharge abstract were removed from the charts before the coders received them.

Training

For the clinical data abstraction, each clinical abstractor participated in an extensive training process that included an overview of the CHOP Pneumonia project, principles of reliable data abstraction, and an item by item review of the CAPCAT using the CAPCAT Manual. After the training process was completed, each data abstractor was required to successfully complete the reabstraction of two training charts. These charts had been previously abstracted by a physician experienced in pneumonia diagnosis and treatment. The purpose of this process was to determine if the clinical abstractor could both apply the guidelines and instructions correctly

as well as demonstrate the clinical knowledge necessary to competently abstract CAP patient medical records. After successful completion of the training charts, each abstractor had daily on-site clinical and process supervision and was subject to periodic review of the charts being abstracted through the 5% overread.

Certified coding specialists were required to code consistent with the guidelines published in *Coding Clinic for ICD-9-CM*, *Official Coding Guidelines*, and the American Hospital Association's ICD-9-CM Coding Handbook. They also participated in a training process that included an overview of the CHOP Pneumonia project, principles of reliable data abstraction, a review of the relevant coding clinics, and review of the CPAA guidelines developed by OSHPD. To be included in the coding process, coding specialists were required to maintain 95% reliability across five test charts on principal diagnosis to the 5th digit, and to maintain 95% reliability across five test charts on secondary diagnoses to the 3rd digit. Coders were also subject to reliability checks using the 5% overread of the records. All coders who participated in this project were credentialled, considered expert coders within the contracting company and exceeded the project experience requirements.

Recruitment and Record Submission

The Chief Executive and the Director of Medical Records of each sampled hospital received a recruitment letter from the study Principal Investigator and a letter from the Director of the Office of Statewide Health Planning and Development. These letters outlined the purpose of the validation study, the process for maintaining the confidentiality of the patients and hospitals participating, the importance and use of the validation study information, the expectations of participants, and the benefits of participation. The Chief Executive also received a letter supporting participation in the project from the Chief Executive of the California Association of Hospital and Health Systems. A follow-up telephone call was made within three weeks to obtain verbal confirmation of the hospital administration's willingness to participate.

After agreement to participate, each hospital's Medical Records department received a list of the 15 sampled patient charts. This list included the patient's social security number, hospital medical record number (if known), gender, age, date of birth, admission and discharge dates, principal and secondary diagnoses. Copies of the full patient chart for the index CAP admission was requested including but not limited to: ambulance records, emergency department notes, admission notes, physician and nursing progress notes, nursing flow sheets or graphic records, physician orders, laboratory and radiology reports, other special medical studies, medication administration records, demographic data forms, and consultation reports. Each hospital also received instructions about what information was needed, how to provide the information, and how to be reimbursed for the copying and mailing of the medical record.

Although each participating hospital was asked to provide 15 Medical Records, a total of 1,230 charts (82 x 15), only 1,032 charts were needed for the validation study. This included 12 charts (9 deaths and 3 survivors) for each of the original 87 hospitals sampled. For the five hospitals unable to participate and in the instances when participating hospitals were unable to locate all of the targeted 12 records, the randomly sampled additional records from other hospitals within that stratum were used for replacement.

Table 11.2 lists the number of validation sample charts originally requested and received (of the 12 targeted for inclusion for each hospital) in each strata, the percent received, and the number of replacement charts in each stratum. Of the 82 hospitals participating, 67 hospitals supplied 12 or more complete medical records. Of the remaining 15 hospitals, 12 supplied 11 records, 2

supplied 10 records, and 1 supplied 5 records. Every attempt was made to get 12 of the sampled records from each hospital, 9 deaths and 3 survivors. Because of the three year time lag between the request for the record and the patient admit date, almost all of the requested medical records were being stored off-site. This off-site storage caused both delays in getting some records and an inability to get other records for reasons such as a record being out to be micro-filmed or difficulty getting needed compliance from off-site storage facilities. Even with these challenges, hospital medical records department were generally able to supply the needed records.

Of the 12 records from each hospital actually needed for the study, 97.7% were received. Of the 15 records originally requested per hospital, 95.9% were received. The slightly lower percentage for the 15 records, in part, reflects the method of follow-up used for missing medical records. All hospitals were contacted if they did not send the initial 15 records requested. However, those hospitals that did not send all of the 12 charts actually targeted for inclusion in the study were part of an aggressive follow-up to obtain the needed 12 charts.

Table 11.1: Number of hospitals selected from those eligible for CAP validation study by sampling strata. (Phase 1 and Phase 2).

Hospitals by Volume	Hospital Risk-Adjusted Mortality			
	Better than Expected	As Expected	Worse than Expected	Total
Medium (78–219 pts.)				
Eligible	10	134	5	149
Selected	10	24[11.1]	5	39
Large (220 or more pts.)				
Eligible	9	82	11	102
Selected	8[11.2]	24[11.1]	11	43
Total				
Eligible	19	216	16	251
Selected	18	48	16	82

[11.1] Two hospitals in this category were initially selected but were unwilling to participate.

[11.2] One hospital in this category was initially selected but was unwilling to participate.

Table 11.2: Number of records received for CAP validation study by sampling strata.

Hospital Volume	Hospital Risk-Adjusted Mortality: Better than Expected	Neither better nor worse	Worse than Expected	Total
Medium (78–219 pts.)				
Requested	150	360	75	585
Received	145	346	72	563
% Rcvd from Requested	96.7%	96.1%	96.0%	96.2%
Needed for Stratum	120	300	60	480
Large (220 or more pts.)				
Requested	120	360	165	645
Received	116	343	157	616
% Rcvd from Requested	96.7%	95.2%	95.2%	95.5%
Needed for Stratum	108	312	132	552

CHAPTER TWELVE: VALIDATION STUDY OF COMMUNITY-ACQUIRED PNEUMONIA– RESULTS

This chapter summarizes the key findings of the CAP validation study.

1. What proportion of cases included in the 1996 CAP study should have been excluded because CAP was incorrectly reported or incorrectly coded?

Among the 1032 records included in the validation sample, we examined the issue of whether some of the patients did not have clinically documented CAP at the time of admission to the hospital, yet were included in our sample on the basis of ICD-9-CM coding. Clinical data were used to define a standard for comparison. Definite CAP was considered present if the patient had a diagnosis of CAP and there was a documented radiographic infiltrate that was not known to be old. These data had to be confirmed by at least one of the following: the documented presence of a new onset of cough or sputum production, fever, a white blood cell count of > 15,000 or greater than 15% band forms on differential. Possible CAP was considered present if the treating physician or radiologists noted pneumonia or the presence of a radiographic infiltrate that was not known to be old. A physician's diagnosis of CAP with confirmatory signs (listed above) was considered possible CAP in the absence of a documented radiographic infiltrate. For the pneumonia to be considered present at admission, the clinical signs had to be documented within 24 hours of admission, and the confirming chest x-ray had to be taken within a 48 hour time period immediately before or after admission. Table 1 shows the unweighted and weighted findings:

Table 12.1: Accuracy of CAP based on clinical data.

	Unweighted	Weighted
Definite CAP on admission	605 (58.6%)	58.6%
Possible CAP on admission	329 (31.9%)	32.2%
No CAP on admission	98 (9.5%)	9.3%

Of the 98 discharges without CAP: 59 had insufficient documentation of pneumonia of any type, 34 had pneumonia with insufficient documentation to determine whether it was present on admission, and 5 had pneumonia that clearly developed after admission.

Although we had excluded ICD-9-CM codes that indicated HIV infection or AIDS, 14 patients (1.4%) were felt by the clinical abstractors to have these conditions. Similarly, 5 discharges (0.5%) indicated that a patient was status post an organ transplant. Among the 98 patients without CAP, the principal ICD-9-CM code from the re-coded data indicated: pneumonia NOS (21.4%), acute respiratory failure (9.2%), septicemia (8.2%), congestive heart failure

(5.1%), acute bronchitis (4.1%), chronic obstructive pulmonary disease (4.1%), urinary tract infection (3.1%), asthma (3.0%) and the remainder a variety of single ICD-9-CM codes.

The discharges without clinical documentation of CAP were distributed across 63 hospitals with 1 to 5 cases at each hospital. There was no significant difference in the prevalence of discharges without documentation of CAP across hospitals by outlier status ('good' outlier 9.7%, 'bad' outlier 10.2%, inlier 9.1%, p = 0.89). There was also no difference in weighted (or unweighted) mortality rate by whether a patient was classified as definite, possible or no pneumonia (12.2%, 11.4%, 10.9%, p = 0.76)

2. What is the statewide reporting accuracy for important risk factors included in the risk-adjustment models?

All risk factors used in the final CAP model demonstrated kappa's of 0.5 or greater for presence of the risk factor in a comparison between the original OSHPD data and the recoded "gold standard" data. Those risk factors with kappa's of 0.5 or greater also had to demonstrate a specificity of 0.6 or better. All risk factors included in the final model, except one, Pneumonia NOS, demonstrated a specificity of 0.95 or better. In addition, those risk factors that are potentially acute in nature and could have either been present at admission or developed after hospitalization had to demonstrate a kappa of 0.5 or greater on agreement of the CPAA status for inclusion.

The risk factors shown in Table 12.2, 12.3, and 12.4 were key risk factors considered for inclusion in the final models. Six risk factors (viral pneumonia, aspiration pneumonia, acidosis, hyperosmolality, shock, nutritional deficit) were removed as candidate variables due to inaccurate coding of the presence of the risk factor. These risk factors had sensitivities ranging from 19.4% to 49.1%. A sensitivity of less than 50% would indicate under-coding of the risk factor.

Only one risk factor had an unacceptably low positive predictive value (hyperosmolality—30.8). A PV+ of 30.8 would indicate that only 30.8% of cases reported to OSHPD with hyperosmolality should have been reported when compared to the gold standard coding (i.e., over-coding). The sample size was too small (n = 4) to draw any conclusions about coding of this risk factor. Of interest is the relatively low PV+ of *Staphylococcal* species pneumonia (55.0), indicating that there may have been over-coding of this ICD-9-CM Code in 1996. Risk factors with a PV+ above 0.50 were eligible for inclusion.

The problem of inaccurate CPAA coding can be seen by examining Table 12.3, Column 6, "Kappa for CPAA Among Patients with Condition in Both Datasets". There were only three key non-chronic conditions with adequate presence of the condition coding that had a kappa of 0.5 or better when considering agreement of the CPAA status. These risk factors were stroke, coagulation defects and respiratory failure. It should be noted that because these analyses are based on 1,032 charts, some rarer conditions have small sample sizes. Also, for those risk factors based on more than 30 cases and that show a high per cent of agreement on the CPAA variable (Table 12.3, Column 6), but a low kappa (e.g., volume depletion, septicemia), the actual number of cases about which they disagree could be relatively small.

Inaccurate CPAA coding did limit the use of risk factors that would be useful predictors.

Table 12.2: Comparison of "Gold Standard" and OSHPD data on selected diagnoses.

Selected Conditions	Number in OSHPD Data	Number in Coders' Data	Number in Both	KAPPA on Condition
Staph. Species	40	32	22	0.60
Viral Pneumonia	10	15	6	0.47
Gram negative Pneumonia	73	61	47	0.68
Pneumonia NOS	683	657	558	0.52
Pneumococcal Pneumonia	71	68	47	0.65
Aspiration Pneumonia	9	36	7	0.30
Acidosis	27	63	20	0.42
Coagulopathy	34	41	25	0.65
Decubiti	31	30	21	0.68
Hyperosmolality	13	12	4	0.31
Stroke	18	27	14	0.61
Septicemia	141	138	100	0.67
Hyperpotassemia	44	39	27	0.64
Acute renal failure	50	58	41	0.75
Atrial fibrilation	170	182	160	0.89
Shock	49	55	27	0.49
Respiratory failure	176	181	147	0.79
Volume depletion	191	219	155	0.70
Rheumatic condition	37	43	36	0.90
Chronic liver disease	28	38	23	0.69
Solid non-lung cancer	64	78	55	0.76
Lung cancer	30	27	23	0.80
Blood cancer	49	55	40	0.76
Chronic renal disease	41	42	29	0.69
Late effects of stroke	43	48	30	0.64
Asthma	76	94	56	0.63
Nutritional deficit	55	81	36	0.50
Dementia	78	92	69	0.80
Congestive Heart Failure	293	327	257	0.76
Parkinson's disease	16	19	15	0.86

Table 12.3: Comparison of "Gold Standard" and OSHPD data on CPAA and CPAA plus presence of the condition for selected diagnoses.

Selected Conditions	% CPAA in OSHPD Data	% CPAA in GS Coders' Data	# in Both Datasets w/ Condition	% Agreement on CPAA-Both	KAPPA for CPAA*
Staph. Species Pneumonia	97.5	96.9	22	95.5	-
Viral Pneumonia	100.0	100.0	6	100.0	-
Gram negative pneumonia	93.2	93.4	47	89.4	0.23
Pneumonia NOS	97.8	97.3	558	96.2	0.20
Pneumococcal pneumonia	100.0	97.1	47	97.9	-
Aspiration Pneumonia	55.6	88.9	7	57.2	0.09
Acidosis	77.8	65.1	20	60.0	-0.07
Coagulopathy	76.5	70.7	25	84.0	0.57
Decubiti	90.3	80.0	21	85.7	0.32
Hyperosmolality	84.6	50.0	4	75.0	0.50
Stroke	72.2	81.5	14	85.7	0.69
Septicemia	92.9	87.0	100	92.0	0.39
Hyperpotassemia	72.7	61.5	27	66.7	0.18
Acute renal failure	62.0	55.2	41	56.1	0.12
Atrial fibrilation	90.6	84.6	160	85.0	0.32
Shock	83.7	74.5	27	85.2	0.26
Respiratory failure	80.7	69.1	147	79.6	0.47
Volume depletion	95.8	95.9	155	93.6	0.13
Rheumatic condition	94.6	100.0	36	94.4	-

* Among patients with the condition in both datasets.

Table 12.4: Sensitivity and specificity on the presence of selected conditions, assuming coders' data are true.

Selected Conditions	Specificity on Condition	Sensitivity on Condition	Likelihood Ratio (Sens/100-Spec)	Predictive Value Positive
Staph. Species	98.2	68.8	38.2	55.0
Viral Pneumonia	99.6	40.0	100.0	60.0
Gram negative pneumonia	97.3	77.1	28.6	64.4
Pneumonia NOS	66.7	84.9	2.5	81.7
Pneumococcal pneumonia	97.5	69.1	27.6	66.2
Aspiration Pneumonia	99.8	19.4	97.0	77.8
Acidosis	99.3	31.8	45.4	74.1
Coagulopathy	99.1	61.0	67.8	73.5
Decubiti	99.0	70.0	70.0	67.7
Hyperosmolality	99.1	33.3	37.0	30.8
Stroke	99.6	51.9	129.7	77.8
Septicemia	95.4	72.5	15.8	70.9
Hyperpotassemia	98.3	69.2	40.7	61.4
Acute renal failure	99.1	70.7	78.6	82.0
Atrial fibrilation	98.8	87.9	73.2	94.1
Shock	97.8	49.1	22.3	55.1
Respiratory failure	96.6	81.2	23.9	83.5
Volume depletion	95.6	70.8	16.1	81.2
Rheumatic condition	99.9	83.7	837.0	97.3
Chronic liver disease	99.5	60.5	121.0	82.1
Solid non-lung cancer	99.1	70.5	78.3	85.9
Lung cancer	99.3	85.2	121.7	76.7
Blood cancer	99.1	72.7	80.8	81.6
Chronic renal disease	98.8	69.1	57.6	70.7
Late effects of stroke	98.7	62.5	48.1	69.8
Asthma	97.9	59.6	28.4	73.7
Nutritional deficit	98.0	44.4	22.2	65.5
Dementia	99.0	75.0	75.0	88.5
Congestive Heart Failure	94.9	78.6	15.4	87.7
Parkinson's disease	99.9	79.0	790.0	93.8

3. **Is there a significant difference in the coding of important risk factors when comparing low, average and high mortality hospitals?**

Overall, 24.6% of discharges had at least one risk factor documented on recoding that was not originally coded in the OSHPD data. 76 hospitals had at least one discharge with a missing risk factor (range: 1 – 7 discharges/ per hospital). Conversely, 20.8% of discharges indicated at least one risk factor that was unsubstantiated on re-coding. 72 hospitals had at least one unsubstantiated risk factor (range: 1 – 6 discharges/ per hospital).

Hospitals labeled as 'good' outliers were not statistically more likely to 'over-code' (i.e., have unsubstantiated coding) than either 'bad' outliers or inliers (21.1%, 16.2%, 22.2% respectively, $p = 0.18$). Hospitals labeled as 'bad outliers were not statistically more likely to 'under-code' (i.e., have more missed coding) than either 'good' outliers or inliers (20.8%, 24.6%, 25.8% respectively, $p = 0.38$).

We evaluated the aggregate impact of under- and over-coding by calculating expected mortality rates using data from the gold-standard coders and using the original OSHPD codes. We then compared the differences in the mean expected mortality for each of these two data sources. There was no statistically significant difference for the expected mortality derived from these two sources suggesting that under- or over-coding does not result in statistically significant differences in outlier assignment.

4. **How does the risk assessment model change when additional clinical variables are used as risk factors?**

Extensive clinical record reviews were completed as part of the validation study. This data abstraction process included all components of the medical record (i.e., ED notes, history and physical examination, laboratory results, radiology results, operative notes, nursing notes, discharge summaries). Based on review of the literature and the input of the clinical advisory panel the following clinical factors were evaluated as potential risk factors for 30-day mortality from CAP:

1. Admission temperature
2. Admission systolic blood pressure
3. Admission heart rate
4. Admission respiratory rate
5. Admission level of oxygenation by pulse oximetry
6. Initial amount of oxygen supplementation
7. Initial serum pH
8. Initial white blood cell count
9. Initial serum sodium less than 130 mEq/ l
10. Initial serum creatinine
11. Initial serum BUN
12. Initial chest X-ray indicates a multilobar pneumonia
13. Do-not-resuscitate order within the first 24 hours of the hospital stay

Bivariate chi-square tests and plots of the continuous variables by the logit(mortality) were used to determine the best specifications for these clinical risk factors. Multivariate logistic regression models were used that forced in the variables in the CAP risk-adjustment model

and then used a backward selection procedure (p to exit = 0.10). These procedures identified six promising clinical risk factors. These variables are:

1. Admission temperature (converted to Fahrenheit) – First temperature recorded within the first 24 hours of the hospitalization.
2. Admission systolic blood pressure (in mmHg) – First systolic blood pressure noted within the first 24 hours of the hospital stay.
3. Admission heart rate (in beats per minute) – First heart rate noted within the first 24 hours of the hospital stay.
4. Admission serum sodium less than 130 mEq/ l- Whether a serum sodium of less than 130 mEq/ l was documented within the first 24 hours of the hospital stay.
5. Multi-lobar pneumonia – Whether an X-ray performed within 24 hours of admission indicated that the pneumonia involved more than one lobe of the lung.
6. Do-not-resuscitate order noted within the first 24 hours of the hospital stay.

This final set of clinical risk factors was then added to the multivariate models. Table 12.5 shows how adding the additional clinical characteristics affect the performance characteristics of the risk-adjustment model depending on whether the original OSHPD codes were used or the re-abstracted data.

Table 12.5: CAP models with and without additional clinical data.

	OSHPD Data No additional clinical variables	OSHPD Data All additional clinical variables	Re-coded Data No additional clinical variables	Re-coded Data All additional clinical variables
	Odds Ratios			
Age	1.04	1.02	1.04	1.02
Male	1.06	1.14	1.14	1.16
Septicemia	2.18	2.22	2.09	2.07
Respiratory failure	6.68	3.44	6.94	4.02
Staph. Organisms	4.37	2.73	3.28	2.15
Chronic liver disease	9.92	490.82	80.04	29.0
Lung cancer	1.95	1.93	1.35	1.64
Solid, non-lung cancer	2.85	2.12	4.03	3.38
Hematologic malignancy	1.79	3.48	2.17	2.96
Chronic renal failure	3.04	3.65	1.73	2.01
Late effects of stroke	1.49	1.34	1.64	1.26
Coagulopathy	2.87	2.84	3.88	2.91
Gram negative organism	2.1	1.57	1.48	1.85
Congestive Heart Failure	1.16	1.15	1.31	1.32
Parkinson's disease	3.69	2.74	1.69	1.46
Stroke	1.28	1.30	1.60	1.71
Asthma	0.63	1.06	0.58	1.08
Age*liver interaction	0.98	0.93	0.95	0.97
Number of prior discharges	1.22	1.06	1.22	1.09
Temperature		0.71		0.74
Systolic blood pressure		0.98		0.99
Heart rate		1.01		1.01
Sodium <130 mEq/l		2.33		2.44
Multi-lobar pneumonia		2.32		1.90
DNR order		17.31		16.61
c-statistic	0.80	0.91	0.80	0.91

Several things are worth noting from these data. First, the odds ratios derived from the regression coefficients based on the OSHPD data are similar to those based on the gold-standard data. Importantly, the significant differences in the coefficient for chronic liver disease are probably related to the small number of people with this condition in the validation dataset (n = 26). Second, the addition of clinical data substantially improves both the model estimation. The addition of clinical data substantially diminishes the effect of respiratory failure using either the OSHPD data or the re-coded data. The addition of clinical data also brings the odds ratio for asthma closer to 1.0, such that the effect of an asthma diagnosis is no longer 'protective.'

5. Is there a difference in the process of care between low and high mortality hospitals?

Based on review of the literature and the input of the clinical advisory panel the following clinical factors were evaluated as potential risk factors associated with 30-day mortality from CAP:

1. Time from arrival at the ED to the first dose of antibiotics – this was examined both as a continuous predictor as well as in categories that have been evaluated by other investigators (e.g., antibiotics were administered within 6 hours of arrival).
2. Mechanical ventilation
3. The completion of a sputum culture within 24 hours of admission.
4. Performance of a blood culture within 24 hours of admission.
5. Initial triage to an intensive care unit.

Table 12.6 shows the relationship between several of these process of care indicators and hospital mortality status in a weighted analysis.

Table 12.6: Weighted process of care characteristics by hospital mortality and volume category.

Process of Care Indicator	Hospital Mortality Category			
	Better	Worse	Neither	p-value
Sputum culture performed	54.3%	45.3%	47.3%	0.16
Mechanical ventilation	7.3%	11.0%	10.1%	0.41
Admitted to ICU	15.5%	16.6%	13.2%	0.38
Time to antibiotics (hours)	8.4 ± 14.8	7.6 ± 12.2	9.3 ± 26.1	0.59

There is no significant association between mechanical ventilation or admission to an ICU and hospital mortality category. Both mechanical ventilation and admission to the ICU probably reflect unmeasured severity of illness and are therefore not ideal measures of the process of care. There is a trend (although not statistically significant) towards greater use of sputum cultures in hospitals that are 'good outliers' compared with other hospital mortality categories. There is not a significant association between hospital mortality status and the time to the administration of antibiotics.

Because 27% of patients in the validation data set had received a 'do not resuscitate order' and because these patients may receive less aggressive care, we also specifically looked at the process of care indicators for patients who did not have this order written within the first 24 hours of their hospital stay. Patients with a DNR order may receive less aggressive care. Among these patients who were not DNR, patients with CAP hospitalized in a hospital with a worse than expected mortality rate were significantly less likely to receive a sputum culture than were patients in a hospital with better than expected mortality (44.5% vs. 56.9%, $p < 0.05$). There was, however, no significant difference in time to the administration of antibiotics.

Similarly, we also looked at time to the use of antibiotics among patients who were most severely ill at the time of admission using clinical risk factors. These patients were defined as those with an admission blood pressure less than 100 mm Hg, an admission heart rate $\geq$ 140 beats per minute, an admission sodium less than 130, or multi-lobar pneumonia. 451 patients

(44%) of the validation sample fit this definition. Among these patients, the average time to the administration of antibiotics among patients was 7.1 hours in hospitals with greater than expected mortality and 5.3 hours among hospitals with better than expected mortality, and 5.8 hours in the average mortality group (p = 0.18). There were no significant differences in the performance of sputum cultures by hospital status among this sub-group of patients.

Table 12.7 shows the CAP model with the addition of our process of care indicator (i.e., the receipt of a sputum culture). Both models (using the OSHPD data and the re-coded data) suggest that the receipt of a sputum culture is protective of mortality from CAP.

Table 12.7: CAP models with and without process of care data

	OSHPD Data No process	OSHPD Data with Process of Care	Re-coded Data No process	Re-coded Data with Process of Care
	Odds Ratios			
Age	1.04	1.04	1.04	1.04
Male	1.06	1.01	1.14	1.18
Septicemia	2.18	2.35	2.09	2.03
Respiratory failure	6.68	7.53	6.94	8.17
Staph. Organisms	4.37	8.08	3.28	3.90
Chronic liver disease	9.92	4.26	80.04	81.40
Lung cancer	1.95	3.28	1.35	1.38
Solid, non-lung cancer	2.85	2.38	4.03	3.88
Hematologic malignancy	1.79	2.02	2.17	2.26
Chronic renal failure	3.04	2.81	1.73	1.63
Late effects of stroke	1.49	1.40	1.64	1.65
Coagulopathy	2.87	2.50	3.88	3.72
Gram negative organism	2.10	2.42	1.48	1.7
Congestive Heart Failure	1.16	1.18	1.31	1.32
Parkinson's disease	3.69	3.63	1.69	1.61
Stroke	1.28	1.26	1.60	1.45
Asthma	0.63	0.76	0.58	0.61
Age*liver interaction	0.98	1.00	0.95	0.95
Number of prior discharges	1.22	1.28	1.22	1.21
Recived sputum culture		0.57		0.63
c-statistic	0.80	0.80	0.80	0.80

CHAPTER THIRTEEN: VALIDATION STUDY OF COMMUNITY-ACQUIRED PNEUMONIA— CONCLUSIONS

This chapter briefly summarizes the key findings of the CAP validation study.

1. What proportion of cases included in the 1996 CAP study should have been excluded because CAP was incorrectly reported or incorrectly coded?

- A total of 98 cases from the validation sample of 1032 charts (9.5%) did not have evidence of CAP on admission. This number is similar to what has been reported in other CHOP reports.
- 90.5% of cases met definite (58.6%) or possible (31.9%) clinical criteria for CAP.
- Note that this validation study cannot address the number of discharges with true CAP that were missed because of lack of documentation by physicians.

2. What is the statewide reporting accuracy for important risk factors included in the risk-adjustment models?

- The validity and reliability of coding were adequate for the presence of many important risk factors (Staph. species, gram negative pneumonia, pneumococcal pneumonia, coagulation deficits, stroke, septicemia, hyperpotassemia, acute renal failure, atrial fibrillation, respiratory failure, volume depletion, rheumatologic condition, chronic liver disease, malignancies, chronic renal disease, late effects of stroke, asthma, dementia, congestive heart failure, Parkinson's disease.
- However, the validity and reliability of CPAA coding was only adequate for three non-chronic risk factors (i.e., respiratory failure, coagulation defects, stroke).
- These results should be used for educational efforts designed to improve the reporting of conditions as CPAA. Inaccurate CPAA coding severely limited the use of risk factors that cannot be assumed to be present at admission.
- Since 1996 was the first year that the CPAA variable was available, the accuracy of this variable should be assessed over time and for all conditions (i.e., not just CAP).

3. **Is there a significant difference in the coding of important risk factors when comparing low, average and high mortality hospitals?**

   - There were no significant differences in the coding of key risk factors across hospital mortality and volume categories, although there was some observed variation.

   - Overall, 24.6% of discharges had at least one 'missing' clinical risk factor (i.e., "under-coding"). There was no significant variation in missing risk factors across hospital mortality and volume categories.

   - Overall, 20.8% of discharges had at least one additional clinical risk factor (i.e., "over-coding"). There was no significant variation in additional risk factors across hospital mortality and volume categories.

4. **How does the risk assessment model change when additional clinical variables are used as risk factors?**

   - Clinical variables substantially improved the risk-adjustment models. These clinical variables are: temperature, systolic blood pressure, heart rate, sodium less than 130 mEq/ l, the presence of a multi-lobar infiltrate on chest X-ray, and the documentation of a 'do not resuscitate' order.

   - The CAP validation study demonstrates that a better risk-adjustment system for CAP mortality could be developed if additional clinical information was routinely collected.

5. **Is there a difference in the process of care between low and high mortality hospitals?**

   - We were able to identify a limited number of process of care indicators for CAP patients (i.e, performance of a sputum culture, time to initial antibiotics, admission to the ICU, and use of mechanical ventilation). Of these, two (i.e., admission to the ICU, and use of mechanical ventilation) probably better reflect unmeasured severity of illness rather than more appropriate process of care.

   - There was a trend toward greater use of sputum cultures in 'lower than expected mortality' hospitals in the weighted analysis. The performance of sputum cultures was significantly protective against mortality in our risk-adjustment model. Sputum culture has been associated with better outcomes in prior studies.[13.1] While the performance of a sputum culture may result directly in better care through a more tailored choice of antibiotics, the effect of this variable most likely represents a proxy for 'more conscientious' care that we cannot measure. This study did not confirm a significant association between the timeliness of antibiotic administration that has been observed in prior work.[13.1]

   - Because 27% of patients in the validation data set had received a 'do not resuscitate order' within 24 hours of admission, and because these patients may receive less aggressive care, this may make it more difficult to examine the link between hospital

[13.1] Meehan TP, Fine MJ, Krumholz HM, Scinto JD, Galusha DH, Mockalis JT, Weber GF, Petrillo MK, Houck PM, Fine, MJ. Quality of care, process, and outcomes in elderly patients with pneumonia. *JAMA*. 1997;278: 2080-4.

outlier status and the process of care. The number of discharges who were candidates for "aggressive" care was smaller than we anticipated, and may not be adequate to find differences in process that truly exist. We did examine process of care among the subset of patients without a DNR order and among those who were more severely ill on admission. We found that those patients who were hospitalized in a "higher than expected" mortality hospital were less likely to receive a sputum culture within the first 24 hours of hospitalization than patients hospitalized in a hospital with a "lower than expected" mortality. There were no significant differences in the time to administration of antibiotics in this sub-group.

- We also examined the subset of patients who were most severely ill at the time of admission based on clinical risk factors. In this sub-group there was a trend toward more timely administration of antibiotics in hospitals with lower than expected mortality compared with hospitals with higher than expected mortality.