CCMRP

The California Report on Coronary Artery Bypass Graft Surgery

2000-2002 Hospital Data

California CABG Mortality Reporting Program

February 2005

PBGH
Pacific Business Group on Health

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The California Coronary Artery Bypass Graft Mortality Reporting Program

The Pacific Business Group on Health (PBGH) and the California Office of Statewide Health Planning and Development (OSHPD) are working together in a unique private-public sector partnership to develop the California CABG Mortality Reporting Program (CCMRP). The development of CCMRP reflects the commitment of both organizations to work with healthcare providers to improve the quality of care statewide.

PBGH is a statewide coalition of 50 public and private sector purchasers of care in California. PBGH's member organizations represent more than 3 million employees, dependents, and retirees, and they account for billions in annual healthcare expenditures. OSHPD is the State department that plans for and supports the development of health delivery systems that meet the current and future needs of the people of California. OSHPD conducts studies on access, cost, and quality, and is responsible for reporting risk-adjusted hospital outcomes data.

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Additional copies of the report can be obtained through the PBGH (www.pbgh.org) and OSHPD (www.oshpd.ca.gov) Web sites. PBGH posts the hospital performance results on its California Consumer HealthScope Web site (www.healthscope.org), a public source of information on healthcare quality for California consumers.

PREFACE

February 2005

We are pleased to release ***The California Report on Coronary Artery Bypass Graft Surgery 2000-2002 Hospital Data*****,** the third and final voluntary report from the California Coronary Artery Bypass Graft (CABG) Mortality Reporting Program (CCMRP). This report brings to a close an important partnership between the State of California, purchasers, and hospitals to voluntarily collect and release hospital performance data on mortality associated with heart bypass surgery.

Data on 77 of the 121 non-federal California hospitals that regularly performed heart bypass surgery during the 2000-2002 period are summarized in this report. These 77 hospitals performed approximately 73% of all isolated coronary artery bypass graft surgeries in California during this period, with an overall in-hospital death rate of 2.61%. The mortality rate for all California hospitals during this period was 2.84%.

All 77 participating hospitals are to be commended for their explicit commitment to quality improvement. Measurement and public accountability are requisite steps in the quality improvement process. The transparency of hospital performance information is critical to national efforts to close the quality gap identified in the Institute of Medicine's report *Crossing the Quality Chasm* (2001). Through concerted, collaborative efforts to measure and reduce performance variation, we take concrete steps to ensure that inpatient care is safe, effective, and efficiently delivered.

The important work of CCMRP over the last seven years has laid the foundation for public reporting of CABG outcomes and highlighted differences in death rates between participating and non-participating hospitals, which set the stage for compulsory reporting of heart bypass surgery outcomes for hospitals and surgeons in California. The passage of Senate Bill 680 (Chapter 898, Statutes of 2001) replaced the voluntary program with the California CABG Outcomes Reporting Program (CCORP), which began data collection in January 2003. The first CCORP hospital-level report is scheduled for release in the second half of 2005.

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SUMMARY

The CCMRP 2000-2002 Hospital Data Report presents findings for 77 of California's 121 non-federal hospitals that regularly performed adult CABG surgery during 2000-2002. The report uses risk-adjusted in-hospital mortality as the outcome measure.[1] The report includes results for calendar years 2000-2002 and all participating hospitals submitted at least one year of complete and continuous data during this period. This three-year analysis includes a total of 57,388 isolated CABG surgeries, making it one of the largest public reporting programs on CABG outcomes in the United States.[2] This report also provides information on performance over time for hospitals that submitted data from 1997 to 2002, and examines the relationship between hospital surgery volume and mortality.

Key findings from the 2000-2002 analyses are:

- The overall in-hospital death rate for isolated CABG surgery in California among participating hospitals was 2.61% for 2000-2002. This compares to 2.76% for participating hospitals in 1999. Among California hospitals that did not participate in CCMRP, the in-hospital death rate was 3.35% for 2000-2002.[3] For all non-federal California hospitals, the in-hospital death rate was 2.84% for the 2000-2002 period. Nationally, the Society of Thoracic Surgeons (STS) reports an "operative mortality" rate for isolated CABG surgery of 2.90% for 2000-2002.[4]

- Most participating hospitals performed within the range of what was expected. Sixty of the 77 hospitals performed "**as expected**," meaning that death rates at these institutions were within range of what was expected given the complexity of cases treated.

- Eight of the 77 hospitals performed significantly "**better than expected**," meaning that their actual death rate was lower than expected given the complexity of cases they treated. The eight hospitals were:

Hoag Memorial Hospital Presbyterian	**Orange County**
Loma Linda University Medical Center	**Inland Empire, Riverside, and San Bernardino**
Mercy General Hospital	**Sacramento Valley and Northern California**
Mills-Peninsula Hospital	**San Francisco Bay Area and San Jose**
Sequoia Hospital	**San Francisco Bay Area and San Jose**
Summit Medical Center	**San Francisco Bay Area and San Jose**
Sutter Memorial Hospital	**Sacramento Valley and Northern California**
Torrance Memorial Medical Center	**Greater Los Angeles**

[1] Risk adjustment is a statistical technique that allows for fair comparison of hospital mortality rates even though some have sicker or healthier patients than average. In-hospital mortality means that the patient expired prior to discharge from the hospital that performed the operation, regardless of length of stay. Deaths are not counted after discharge. If a patient is transferred post-operatively to rehabilitation or a transitional care facility and dies before going home, this death is not counted.

[2] 57,388 cases were used in the analysis, including six hospitals that provided data but did not want their results published. Their 4,198 cases are included in the risk-adjustment model even though they are not listed as participants.

[3] OSHPD, Patient Discharge Data, 2000-2002.

[4] Operative mortality refers to patient death up to 30 days after surgery, regardless of patient location. Most deaths "in hospital" occur within 30 days. The "operative mortality" rate is somewhat higher than the "in hospital" mortality rate.

- Nine of the 77 hospitals performed significantly "**worse than expected**," meaning their actual death rate was higher than expected given the complexity of cases they treated. The nine hospitals were:

Alta Bates Medical Center	**San Francisco Bay Area and San Jose**
Alvarado Hospital Medical Center	**Greater San Diego**
California Pacific Medical Center - Pacific Campus	**San Francisco Bay Area and San Jose**
Desert Regional Medical Center	**Inland Empire, Riverside, and San Bernardino**
Glendale Adventist Medical Center - Wilson Terrace	**San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara**
Providence Holy Cross Medical Center	**San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara**
San Jose Medical Center	**San Francisco Bay Area and San Jose**
Scripps Mercy	**Greater San Diego**
Valley Presbyterian Hospital	**San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara**

- Of the 77 hospitals participating in 2000-2002, 25 have participated in this program every year since 1997. Of these, four had Observed to Expected (O/E) mortality ratios below 1.0 throughout the six-year period, meaning their actual death rates were below their expected death rates. One hospital had an O/E ratio above 1.0 for the entire six-year period, meaning its observed death rate was consistently higher than its expected rate. For the remaining 20 hospitals, performance was not consistent over time though patterns of improvement and decline were seen in some cases.

Other major findings in this report include:

- The expected death rate ranged from 1.6% to 5.3%, revealing wide variation among California hospitals with respect to the average pre-operative risk of patients they treat. This variation underscores the importance of adjusting for differences in case mix to produce comparative outcome scores.

- There was close agreement between the actual number of deaths and the predicted numbers of deaths from the risk-adjustment model, especially for the most severely ill patients. This means that the risk model gives hospitals appropriate credit for treating more clinically complex cases. Consequently, hospitals and surgeons should not exclude high-risk patients from appropriate CABG surgeries as a means to improve performance scores.

- Higher volume hospitals were found to have lower risk-adjusted in-hospital mortality rates, on average, than low volume hospitals, and this finding was statistically significant. The volume-outcome relationship, however, was not extremely strong. For example, if all isolated CABG patients were sent to hospitals with an annual volume of >=250 cases, the model predicts an overall reduction in predicted mortality of 0.51%. In other words, assuming 25,000 CABG procedures are performed each year, 50 lives would be saved annually. If all CABG patients went to hospitals with annual volume >=450 cases, a reduction in predicted mortality of 0.64% would result, or 110 lives saved annually. These projections assume, among other things, that higher-volume hospitals would continue to perform at their current standard of quality despite increased volume. However, it should be noted that some low-volume hospitals have very low risk-adjusted mortality rates.

ACKNOWLEDGEMENTS

Funding for CCMRP was provided by the Office of Statewide Health Planning and Development and the Pacific Business Group on Health's Quality Improvement Fund.

Important contributions were made by a host of individuals in each of the participating hospitals who dedicated their scarce time and resources to collect and clean the data for analysis. Participating hospitals provided ongoing feedback on the design of the program, which was vital to its success. Members of the CCMRP/CCORP Clinical Advisory Panel also made substantial contributions, providing oversight and policy guidance in the collection, analysis, and presentation of the results. CCMRP also continued to collaborate with the Society of Thoracic Surgeons and its California Chapter to coordinate and improve data collection efforts.

The California CABG Mortality Reporting Program reflects the efforts and significant contributions of numerous individuals, including:

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GLOSSARY OF FREQUENTLY USED ACRONYMS

BMI	Body mass index
BSA	Body surface area
CABG	Coronary artery bypass graft
CAP	Clinical Advisory Panel
CASTS	California Society of Thoracic Surgeons
CCMRP	California CABG Mortality Reporting Program (Voluntary)
CCORP	California CABG Outcomes Reporting Program (Mandatory)
CHF	Congestive heart failure
COPD	Chronic obstructive pulmonary disease
ICD-9-CM	International Classification of Diseases, 9th Revision, Clinical Modification
MDC 5	Major Diagnostic Category 5 (Diseases and Disorders of Circulatory System)
MI	Myocardial infarction
NYHA	New York Heart Association
O/E ratio	Observed to expected ratio
OSHPD	Office of Statewide Health Planning and Development
PBGH	Pacific Business Group on Health
PCI	Percutaneous coronary intervention
PDD	Patient Discharge Data (OSHPD)
PTCA	Percutaneous transluminal coronary angioplasty
STS	Society of Thoracic Surgeons

I. INTRODUCTION

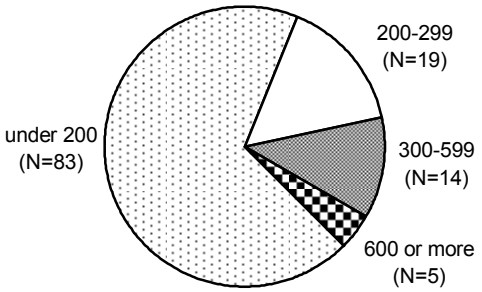
Each year, approximately 25,000 Californians with advanced heart disease undergo a major surgical procedure known as coronary artery bypass graft (CABG) surgery. A CABG surgery reroutes or "bypasses" blockages in the arteries and improves the supply of oxygenated blood to the heart. In California, 121 non-federal hospitals offer bypass surgery to adult patients. Prior to the establishment of the California CABG Mortality Reporting Program (CCMRP) and the release of its first report in July 2001, little was known about how well California hospitals performed this surgery. Such information is critical for hospital quality improvement efforts and assisting patients and their families in making informed decisions about where to receive the best care. Making quality performance information transparent is central to efforts to close the national quality gap.

In 1995, the Pacific Business Group on Health (PBGH) and the California Office of Statewide Health Planning and Development (OSHPD) established a voluntary statewide reporting program to collect mortality data from California hospitals and to publicly report the performance results on this key marker of clinical quality. The *CCMRP 2000-2002 Hospital Data Report* is the third and final report in the series of voluntary public reports showing comparative performance results for California hospitals that perform bypass surgery.

This report presents findings from analyses of data collected from 77 of California's 121 hospitals that regularly performed CABG surgery and uses in-hospital mortality as the key outcome measure. The report includes results for a total of 57,388 cases from hospitals that submitted data to CCMRP during the 2000-2002 period. The report also includes a graphical presentation of participating hospitals' performance over time during the 1997-2002 period and an analysis of the relationship between hospital CABG surgery volume and outcomes.

Figure 1 shows the number and percentage of California hospitals performing different levels of isolated CABG surgery volume in 2002. As seen in the pie chart, 83 out of 121 California hospitals (68.6%) performed 200 or fewer surgeries. Compared to other states, California has a large percentage of hospitals performing relatively low volumes of CABG surgery. Of the other states with public CABG quality reporting programs, New Jersey had one hospital (7%) with case volume under 200, New York had four hospitals (11%), Pennsylvania had 25 hospitals (41%), and Massachusetts had four hospitals (31%).

Figure 1: California Hospital Isolated CABG Surgery Volumes, 2002 OSHPD Patient Discharge Data



The total number of isolated CABG surgeries performed has also been declining over recent years, both at the national and state level. Between 2000 and 2002 the total number of isolated CABG surgeries performed in California dropped by 11.6% (from 27,830 cases in 2000 to 24,593 cases in 2002), while percutaneous coronary intervention (PCI) volume increased by 8.4% (from 50,110 in 2000 to 54,298 in 2002).[5] PCIs include balloon angioplasty and (drug-coated) stents, which have replaced isolated CABG surgery in many less complex cases. As the total volume of CABG surgeries continues to fall, many small-volume hospitals may face tough questions regarding the viability of their heart bypass surgery programs.

[5] OSHPD, Patient Discharge Data, 2000-2002.

II. HOSPITAL PARTICIPATION

Table 1 lists the 121 hospitals in California that performed more than two adult isolated CABG surgeries in calendar year 2002 and their participation status in the CCMRP 2000-2002 public report. The number of heart procedures and isolated CABG surgeries shown in Table 1 is derived from OSHPD's hospital patient discharge data (PDD), using definitions based on International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes. The number of isolated CABG surgeries in Table 1 may not match those provided to CCMRP by participating hospitals, since submissions to CCMRP were based on a clinical definition of isolated CABG surgery (See Appendix A).

The following categories were used to define participation status for the 2000-2002 data-reporting period. The table also shows the number and percentage of hospitals and isolated CABG surgeries that fall into each category.

Key to Table 1

Participation Status	Definition	Number of Hospitals (Percentage)	Number of Isolated CABG* (Percentage)
Participating	Hospital submitted a minimum of one full year of data during 2000-2002 and agreed to public release of results.	77 (64%)	17,583 (73%)
Not Participating	Hospital did not participate in the 2000-2002 public reporting period.	44 (36%)	6,572 (27%)
Total Number of CABG Hospitals		121 (100%)	24,155 (100%)

* Source: OSHPD, Patient Discharge Data, 2002.

**Table 1: California Hospitals that Perform Adult CABG Surgeries:
2000-2002 CCMRP Participation Status and Volume of Heart and Isolated CABG Surgeries in 2002**

Hospital	CCMRP Participation Status	Region	Number of Heart Surgeries	Number of Isolated CABG Surgeries	Isolated CABG as % of Heart Surgeries
Alta Bates Medical Center	Participating	San Francisco Bay Area and San Jose	74	52	70.3
Alvarado Hospital Medical Center	Participating	Greater San Diego	135	92	68.1
Anaheim Memorial Medical Center	Participating	Orange County	279	215	77.1
Antelope Valley Hospital and Medical Center	Not Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	85	62	72.9
Bakersfield Heart Hospital	Not Participating	Central California	294	196	66.7
Bakersfield Memorial Hospital	Not Participating	Central California	448	352	78.6
Beverly Hospital	Not Participating	Greater Los Angeles	32	28	87.5
Brotman Medical Center	Participating	Greater Los Angeles	85	70	82.4
CA Pacific Medical Center - Pacific Campus	Participating	San Francisco Bay Area and San Jose	276	183	66.3
Cedars-Sinai Medical Center	Participating	Greater Los Angeles	654	291	44.5
Centinela Hospital and Medical Center	Participating	Greater Los Angeles	246	184	74.8
Community Memorial Hosp. of San Buenaventura	Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	250	182	72.8
Dameron Hospital	Participating	Central California	115	97	84.3
Daniel Freeman Memorial Hospital	Participating	Greater Los Angeles	17	9	52.9
Desert Regional Medical Center	Participating	Inland Empire, Riverside, and San Bernardino	300	222	74.0
Doctor's Medical Center - Modesto	Not Participating	Central California	676	513	75.9
Doctor's Medical Center - San Pablo	Participating	San Francisco Bay Area and San Jose	64	48	75.0
Dominican Hospital	Participating	San Francisco Bay Area and San Jose	144	109	75.7
Downey Community Hospital	Not Participating	Greater Los Angeles	70	62	88.6

Table 1: California Hospitals that Perform Adult CABG Surgeries: 2000-2002 CCMRP Participation Status and Volume of Heart and Isolated CABG Surgeries in 2002 (Continued)

Hospital	CCMRP Participation Status	Region	Number of Heart Surgeries	Number of Isolated CABG Surgeries	Isolated CABG as % of Heart Surgeries
Eisenhower Memorial Hospital	Not Participating	Inland Empire, Riverside, and San Bernardino	317	211	66.6
El Camino Hospital	Participating	San Francisco Bay Area and San Jose	131	99	75.6
Encino Tarzana Regional Medical Center	Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	227	160	70.5
Enloe Medical Center	Participating	Sacramento Valley and Northern California	325	241	74.2
Fountain Valley Regional Hospital	Participating	Orange County	213	167	78.4
French Hospital - San Luis Obispo	Not Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	214	159	74.3
Fresno Community Hospital and Medical Center	Not Participating	Central California	447	318	71.1
Garfield Medical Center	Not Participating	Greater Los Angeles	149	121	81.2
Glendale Adventist Med Center - Wilson Terrace	Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	210	175	83.3
Glendale Memorial Hospital and Health Center	Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	247	198	80.2
Good Samaritan Hospital	Not Participating	San Francisco Bay Area and San Jose	324	249	76.9
Granada Hills Community Hospital	Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	33	30	90.9
Hoag Memorial Hospital Presbyterian	Participating	Orange County	405	254	62.7
Huntington Memorial Hospital	Participating	Greater Los Angeles	295	171	58.0
Intercommunity/Citrus Valley Medical Center	Not Participating	Greater Los Angeles	229	196	85.6

Table 1: California Hospitals that Perform Adult CABG Surgeries: 2000-2002 CCMRP Participation Status and Volume of Heart and Isolated CABG Surgeries in 2002 (Continued)

Hospital	CCMRP Participation Status	Region	Number of Heart Surgeries	Number of Isolated CABG Surgeries	Isolated CABG as % of Heart Surgeries
John Muir Medical Center	Participating	San Francisco Bay Area and San Jose	182	135	74.2
Kaiser Foundation Hospital - Los Angeles	Participating	Greater Los Angeles	1,531	1,051	68.6
Kaiser Foundation Hospital - San Francisco	Participating	San Francisco Bay Area and San Jose	1,450	996	68.7
Kaweah Delta Hospital	Participating	Central California	445	337	75.7
LA County Harbor - UCLA Med. Center	Not Participating	Greater Los Angeles	222	146	65.8
LA County/USC Med. Center	Not Participating	Greater Los Angeles	337	167	49.6
Lakewood Regional Medical Center	Participating	Greater Los Angeles	179	133	74.3
Lancaster Community Hospital	Not Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	31	23	74.2
Little Company of Mary Hospital	Not Participating	Greater Los Angeles	154	100	64.9
Loma Linda University Medical Center	Participating	Inland Empire, Riverside, and San Bernardino	565	307	54.3
Long Beach Memorial Medical Center	Participating	Greater Los Angeles	508	361	71.1
Los Robles Regional Medical Center	Not Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	311	231	74.3
Marian Medical Center	Not Participating	Central California	144	117	81.3
Marin General Hospital	Participating	San Francisco Bay Area and San Jose	53	40	75.5
Memorial Medical Center of Modesto	Participating	Central California	463	366	79.0
Mercy General Hospital	Participating	Sacramento Valley and Northern California	1,400	948	67.7
Mercy Medical Center - Redding	Participating	Sacramento Valley and Northern California	378	288	76.2

**Table 1: California Hospitals that Perform Adult CABG Surgeries:
2000-2002 CCMRP Participation Status and Volume of Heart and Isolated CABG Surgeries in 2002 (Continued)**

Hospital	CCMRP Participation Status	Region	Number of Heart Surgeries	Number of Isolated CABG Surgeries	Isolated CABG as % of Heart Surgeries
Mercy San Juan Hospital	Participating	Sacramento Valley and Northern California	171	119	69.6
Methodist Hospital of Southern California	Participating	Greater Los Angeles	188	142	75.5
Mills-Peninsula Hospital	Participating	San Francisco Bay Area and San Jose	139	88	63.3
Mission Hospital and Regional Medical Center	Participating	Orange County	237	197	83.1
Mt. Diablo Medical Center	Not Participating	San Francisco Bay Area and San Jose	389	320	82.3
Northridge Hospital Medical Center	Not Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	175	123	70.3
O'Connor Hospital	Not Participating	San Francisco Bay Area and San Jose	128	98	76.6
Palomar Medical Center	Participating	Greater San Diego	210	159	75.7
Pomona Valley Hospital and Medical Center	Not Participating	Inland Empire, Riverside, and San Bernardino	221	167	75.6
Presbyterian Intercommunity Hospital	Participating	Greater Los Angeles	87	82	94.3
Providence Holy Cross Medical Center	Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	187	124	66.3
Providence St. Joseph Medical Center	Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	162	98	60.5
Queen of the Valley Hospital	Not Participating	San Francisco Bay Area and San Jose	181	154	85.1
Redding Medical Center*	Participating	Sacramento Valley and Northern California	872	681	78.1

Table 1: California Hospitals that Perform Adult CABG Surgeries: 2000-2002 CCMRP Participation Status and Volume of Heart and Isolated CABG Surgeries in 2002 (Continued)

Hospital	CCMRP Participation Status	Region	Number of Heart Surgeries	Number of Isolated CABG Surgeries	Isolated CABG as % of Heart Surgeries
Rideout Memorial Hospital	Not Participating	Sacramento Valley and Northern California	108	89	82.4
Riverside Community Hospital Med Center	Not Participating	Inland Empire, Riverside, and San Bernardino	357	290	81.2
Saddleback Memorial Medical Center	Participating	Orange County	158	116	73.4
Salinas Valley Memorial Hospital	Participating	San Francisco Bay Area and San Jose	347	274	79.0
San Antonio Community Hospital	Not Participating	Inland Empire, Riverside, and San Bernardino	125	93	74.4
San Joaquin Community Hospital	Not Participating	Central California	158	121	76.6
San Jose Medical Center	Participating	San Francisco Bay Area and San Jose	54	44	81.5
San Ramon Regional Medical Center	Not Participating	San Francisco Bay Area and San Jose	129	95	73.6
Santa Barbara Cottage Hospital	Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	334	236	70.7
Santa Clara Valley Medical Center	Not Participating	San Francisco Bay Area and San Jose	86	57	66.3
Santa Monica - UCLA Medical Center	Not Participating	Greater Los Angeles	71	41	57.7
Santa Rosa Memorial Hospital	Participating	San Francisco Bay Area and San Jose	210	140	66.7
Scripps Green Hospital	Participating	Greater San Diego	218	157	72.0
Scripps Memorial Hospital - La Jolla	Participating	Greater San Diego	624	389	62.3
Scripps Mercy	Participating	Greater San Diego	230	156	67.8

**Table 1: California Hospitals that Perform Adult CABG Surgeries:
2000-2002 CCMRP Participation Status and Volume of Heart and Isolated CABG Surgeries in 2002 (Continued)**

Hospital	CCMRP Participation Status	Region	Number of Heart Surgeries	Number of Isolated CABG Surgeries	Isolated CABG as % of Heart Surgeries
Sequoia Hospital	Participating	San Francisco Bay Area and San Jose	549	176	32.1
Seton Medical Center - Heart Institute	Participating	San Francisco Bay Area and San Jose	289	225	77.9
Sharp Chula Vista Medical Center	Participating	Greater San Diego	403	324	80.4
Sharp Grossmont Hospital	Participating	Greater San Diego	283	207	73.1
Sharp Memorial Hospital	Participating	Greater San Diego	480	262	54.6
Sierra Vista Regional Medical Center	Not Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	41	34	82.9
St. Agnes Medical Center	Not Participating	Central California	627	480	76.6
St. Bernardine Medical Center	Participating	Inland Empire, Riverside, and San Bernardino	663	546	82.4
St. Francis Medical Center	Participating	Greater Los Angeles	143	119	83.2
St. Helena Hospital	Participating	San Francisco Bay Area and San Jose	198	166	83.8
St. John's Hospital and Health Center	Participating	Greater Los Angeles	161	112	69.6
St. John's Regional Medical Center	Not Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	206	154	74.8
St. Joseph Hospital - Eureka	Not Participating	Sacramento Valley and Northern California	111	84	75.7
St. Joseph Hospital - Orange	Participating	Orange County	309	242	78.3
St. Joseph's Medical Center of Stockton	Participating	Central California	376	277	73.7
St. Jude Medical Center	Participating	Orange County	280	215	76.8
St. Mary Medical Center	Not Participating	Greater Los Angeles	90	66	73.3
St. Mary's Hospital and Medical Center	Participating	San Francisco Bay Area and San Jose	114	72	63.2

**Table 1: California Hospitals that Perform Adult CABG Surgeries:
2000-2002 CCMRP Participation Status and Volume of Heart and Isolated CABG Surgeries in 2002 (Continued)**

Hospital	CCMRP Participation Status	Region	Number of Heart Surgeries	Number of Isolated CABG Surgeries	Isolated CABG as % of Heart Surgeries
St. Mary's Regional Medical Center	Not Participating	Inland Empire, Riverside, and San Bernardino	203	173	85.2
St. Vincent Medical Center	Participating	Greater Los Angeles	312	194	62.2
Stanford University Hospital	Not Participating	San Francisco Bay Area and San Jose	636	184	28.9
Summit Medical Center	Participating	San Francisco Bay Area and San Jose	1,025	767	74.8
Sutter Medical Center of Santa Rosa	Not Participating	San Francisco Bay Area and San Jose	176	123	69.9
Sutter Memorial Hospital	Participating	Sacramento Valley and Northern California	895	592	66.1
The Hospital of the Good Samaritan	Participating	Greater Los Angeles	510	349	68.4
Torrance Memorial Medical Center	Participating	Greater Los Angeles	308	179	58.1
Tri-City Medical Center	Participating	Greater San Diego	216	153	70.8
UC Irvine Medical Center	Participating	Orange County	89	56	62.9
UCD Medical Center	Participating	Sacramento Valley and Northern California	276	172	62.3
UCLA Medical Center	Participating	Greater Los Angeles	433	106	24.5
UCSD Medical Center - Hillcrest	Not Participating	Greater San Diego	126	52	41.3
UCSD Medical Center - Thornton	Not Participating	Greater San Diego	211	42	19.9
UCSF Medical Center	Participating	San Francisco Bay Area and San Jose	287	127	44.3
USC University Hospital	Not Participating	Greater Los Angeles	302	97	32.1

Table 1: California Hospitals that Perform Adult CABG Surgeries: 2000-2002 CCMRP Participation Status and Volume of Heart and Isolated CABG Surgeries in 2002 (Continued)

Hospital	CCMRP Participation Status	Region	Number of Heart Surgeries	Number of Isolated CABG Surgeries	Isolated CABG as % of Heart Surgeries
Valley Presbyterian Hospital	Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	36	33	91.7
Washington Hospital - Fremont	Participating	San Francisco Bay Area and San Jose	165	124	75.2
West Anaheim Medical Center	Not Participating	Orange County	44	42	95.5
West Hills Regional Medical Center	Not Participating	San Fernando Valley, Antelope Valley, Ventura, and Santa Barbara	61	47	77.0
Western Medical Center - Anaheim	Participating	Orange County	298	242	81.2
Western Medical Center - Santa Ana	Participating	Orange County	173	133	76.9
White Memorial Medical Center	Not Participating	Greater Los Angeles	123	95	77.2
All Hospitals			**35,147**	**24,155**	**68.7**

Note: Excludes three Veterans Administration Hospitals in Los Angeles, San Diego, and San Francisco that also perform CABG surgeries. For this table, counts of surgical procedures are calculated from the patient's date of discharge from a hospital (that is, a patient receiving a CABG surgery on December 30, 2000, who was discharged on January 3, 2001 is counted among the 2001 discharges). The source of the numbers listed in the table above is the Office of Statewide Health Planning and Development's (OSHPD) Patient Discharge Data. These numbers may not match the number of isolated CABG surgeries submitted to CCMRP by hospitals, which are based on a clinical definition of isolated CABG surgery.

Number of Heart Surgeries calculated using the following ICD-9-CM codes: 35.10, 35.11, 35.12, 35.14, 35.20, 35.21, 35.22, 35.23, 35.24, 35.27, 35.28, 35.31, 35.32, 35.33, 35.39, 35.51, 35.53, 35.61, 35.62, 35.71, 35.93, 36.03, 36.10, 36.11, 36.12, 36.13, 36.14, 36.15, 36.16, 36.17, 36.19, 36.91, 36.99, 37.32, 37.4x, 37.65, 37.66, 39.61.

Number of Isolated CABG surgeries calculated using the following ICD-9-CM codes: Any record with 36.1x, excluding the following: 32.21, 32.29, 32.4x, 35.1x, 35.2x, 35.3x, 35.4x, 35.5x, 35.6x, 35.7x, 35.8x, 35.9x, 37.32, 37.35, 37.5x, 37.67, 38.10, 38.11, 38.12, 38.14, 38.15, 38.16, 38.17, 38.18, 38.34, 38.41, 38.42, 38.44, 38.45, 38.65, 38.85, 39.21, 39.22, 39.23, 39.24, 39.25, 39.26, 39.28, 39.51, 39.52, 39.53, 39.54, 39.55, 39.57, 39.58, 39.59, 85.22, 85.23, V433, provided the date of the CABG 36.1x procedure and excluded procedure occurred on the same day.

* Name changed to Shasta Regional Medical Center in December 2004.

III. DATA

Staff reviewed the clinical literature on pre-operative risk factors for bypass surgery and examined variables collected by the leading cardiac reporting programs to inform data collection for the program. Details on variable selection can be found in earlier CCMRP reports [***California Report on Coronary Artery Bypass Graft Surgery: 1997-1998 Hospital Data Technical Report*** (July, 2001) and ***California Report on Coronary Artery Bypass Graft Surgery: 1999 Hospital Data Technical Report*** (August 2003)]. These reports are located on OSHPD's Web site at http://www.oshpd.ca.gov/hqad/outcomes/clinical.htm. With some clarifications, CCMRP drew on a subset of data elements collected by the Society of Thoracic Surgeons (STS) for their National Database of Cardiac Surgery. For each public report, the data elements were reviewed and changes in the risk model were made after consultation with the Clinical Advisory Panel. For the 2000-2002 period, the program began collecting additional risk factors that are part of the STS risk model for CABG mortality, most importantly pre-operative *Cardiogenic Shock* and *Body Mass Index* (*BMI*) (See Table 2). In addition, the definitions and response categories for several STS risk factors (e.g., *Arrhythmia Type, Left Main Disease*) have changed substantially since the last report.

Although the STS and CCMRP data definitions are virtually identical, CCMRP provided guidelines on definitions to assist hospitals with coding. To improve the quality and comparability of data submitted across hospitals, staff encouraged each hospital to receive training prior to beginning data submissions.

Table 2: CCMRP Data Elements, 2000-2002

1. Date of Surgery	2. Gender
3. Date of Birth	4. Patient Age
5. Race/Ethnicity (STS: Race)	6. Insurer-payment source (STS: Payor)
7. Height (cm)	8. Weight (kg)
9. Last Creatinine Level (Pre-operative)	10. Hypertension: (Yes, No)
11. Dialysis: (Yes, No)	12. Diabetes: (Yes, No)
13. Peripheral Vascular Disease: (Yes, No)	14. Cerebrovascular Disease: (Yes, No)
15. Arrhythmia: (Yes, No)	16. Arrhythmia Type: (Sustained VT/VF, Heart Block, Afib/Flutter)
17. Myocardial Infarction (MI): (Yes, No)	18. MI-When: (<=6 hrs, >6hrs but <24 hrs, 1-7 days, 8-20 days, >=21 days)
19. Number of Prior Cardiac Operations Requiring Cardiopulmonary Bypass	20. Number of Prior Cardiac Operations without Cardiopulmonary Bypass
21. PTCA/Atherectomy: (Yes, No)	22. PTCA to Surgery Time Interval: (<=6hrs, >6hrs)
23. Chronic Lung Disease: (No, Mild, Moderate, Severe)	24. Cardiogenic Shock: (Yes, No)
25. Angina: (Yes, No)	26. Angina Type: (Stable, Unstable)
27. Canadian Cardiovascular Society (CCS) Angina Class: (No Angina, I, II, III, IV)	28. Congestive Heart Failure: (Yes, No)
29. New York Heart Association (NYHA) Functional Class: (I, II, III, IV)	30. Ejection Fraction (EF): (%)
31. Method of Measuring EF: (LV Gram, Radionuclide, ECHO, Estimate)	32. Left Main Disease >50%: (Yes, No)

Table 2: CCMRP Data Elements, 2000-2002 (Continued)	
33. Acuity (STS: Status): (Elective, Urgent, Emergent, Salvage)	34. Number of Diseased Vessels: (None, One, Two, Three)
35. Mitral Insufficiency: (None, Trivial, Mild, Moderate, Severe)	36. Minimally Invasive Procedure Attempted: (Yes, No)
37. Internal Mammary Artery (IMA) Used: (Left IMA, Right IMA, Both IMAs, No IMA)	38. Date of Discharge
39. Patient Status at Discharge: (Alive, Dead)	40. Date of Death

Data Quality Review and Verification

The data submitted by each hospital was reviewed for completeness and data errors. However, unlike the two prior reports, an independent medical records audit of selected hospitals was not undertaken for data contained in this report. An audit was not possible due to a reduction in staff resources with implementation of the new mandatory CABG reporting program. However, project staff did verify data submissions by comparing them against the OSHPD Patient Discharge Data (PDD) files and requiring hospitals to account for discrepancies. This included a patient-level cross check of *Discharge Status* and a number of clinical risk factors (e.g., presence of *Cardiogenic Shock*, recent *MI*) that otherwise would have been checked through the audit process. Unlike an audit, this process (Step 2 below) allowed us to verify data of all patients at all hospitals. The key steps involved in data cleaning and verification were:

Step 1: Hospital-Specific Data Summaries
This process is very similar to that summarized in the 1999 CCMRP Technical Report, in which hospital-specific rates for each pre-operative risk factor were compared to the state average, highlighting possible coding issues for hospitals to clean-up. Checks for invalid, missing, and abnormally high or low risk factor values are also included in these summaries.

Step 2: Record-Specific Linkage of CCMRP Data with Patient Discharge Data
Data quality review for the 1999 CCMRP report revealed widespread problems with hospitals' coding of patient *Discharge Status* (e.g., dead or alive) and interpretation of the definition of isolated CABG (e.g., submission of appropriate cases). To identify whether these problems also occurred in the 2000-2002 submissions, staff linked the CCMRP dataset with the PDD in order to maximize the validity of the final results. Specifically, CCMRP records were linked, via a probabilistic matching algorithm,[6] to all PDD records classified as Major Diagnostic Category 5 (MDC 5), Diseases and Disorders of the Circulatory System, as well as any records with the ICD-9-CM code 36.1x (bypass anastomosis). Also, an ICD-9-CM code-based definition of isolated CABG was developed to identify those PDD records that were isolated CABG surgeries.

This matched dataset was used to generate hospital reports when any of the two following conditions applied to patients whose *Discharge Status* was "dead" in either dataset:

1. There was a discrepancy in patient *Discharge Status* between PDD and CCMRP (dead vs. alive).
2. An apparent isolated CABG mortality found in the hospital's PDD was not submitted to CCMRP (unreported death).

[6] A description of the methodology and mechanics of the data linkage are available from CCMRP upon request.

For the first condition, 27 cases were found in which patient *Discharge Status* was recorded as "dead" in the PDD but reported as "alive" in the CCMRP submission. Likewise, 36 cases were found in which *Discharge Status* was recorded as "alive" in the PDD but "dead" in the CCMRP submission. The relevant hospitals were contacted and asked to check the cases by reviewing patient medical charts. As a result, 21 of 27 cases reported to CCMRP as "alive" were appropriately re-coded as "dead," and 21 of 36 cases reported to CCMRP as "dead" were re-coded as "alive."

For the second condition, 103 deaths were identified in the PDD as being isolated CABG mortalities that had not been submitted to CCMRP. As a result of hospitals' chart review, 69 of 103 cases were confirmed as isolated CABG surgery deaths and subsequently submitted to CCMRP. These additions resulted in increased mortality rates for several hospitals, and in one instance a hospital was required to add nine additional deaths, which resulted in a doubling of its mortality rate.

The PDD-CCMRP linkage report also listed all cases identified by the PDD as non-isolated CABGs but reported to CCMRP as isolated CABGs if the discrepancy found in CCMRP submissions exceeded 10% of a hospital's total caseload. The 10% threshold was chosen because of the innate problems in precisely identifying isolated CABG cases with ICD-9 codes. There were 452 cases submitted to CCMRP by eleven hospitals that did not appear to be isolated CABG surgeries according to ICD-9 coding in the PDD. The hospitals were asked to review these cases and ultimately, 433 of 452 records were confirmed by the hospitals to be non-isolated CABGs and removed from the database. In one instance, a hospital was required to remove 115 non-isolated CABG cases from their 2002 data submission. This brought the volume and deaths of isolated CABGs in line with other years of data submissions.

The PDD-CCMRP linkage report was also used to verify a number of risk factors, including the prevalence of *Cardiogenic Shock, PTCA, Dialysis,* and *MI*. As a result of this data cross check, the prevalence of *Cardiogenic Shock* fell from 1,304 (2.3%) to 1,099 (1.9%) cases; *PTCA* fell slightly from 10,936 (19.1%) to 10,899 (19.0%); *Dialysis* increased slightly from 1,290 (2.3%) to 1,325 (2.3%); and *MI* increased from 27,463 (47.9%) to 28,551 (49.7%).

The majority of hospitals actively participated in the multiple steps of data validation and submitted data corrections. However, two hospitals failed to correct their data and eventually withdrew from CCMRP participation. Their data were excluded from data analyses and public reporting and are not included in the total of 83 hospitals who submitted useable data.

As with previous reports, CCMRP assigned the lowest risk value to missing data, based on the following rationale: 1) many hospitals may leave data fields blank by design (e.g., blank means a risk factor was not present or the value was normal); 2) to maintain consistency with other major cardiac reporting programs, missing data are replaced with the lowest-risk or normal value; and 3) assigning values for missing data in this way creates an incentive for more complete coding by hospitals.

IV. RISK MODEL FOR ADJUSTING HOSPITAL MORTALITY RATES, 2000-2002

Patients treated at different hospitals often vary in the severity of their pre-operative clinical condition. To fairly compare outcomes at different hospitals, it is necessary to adjust for differences in the case mix of patients across hospitals. CCMRP "levels the playing field" by accounting for the pre-operative condition of each patient. Hospitals that routinely handle complex cases (e.g., sicker prior to surgery) get a larger risk-adjustment weighting in the risk model, while hospitals that handle less complex cases get a smaller weighting.

CCMRP used a multivariable logistic regression model to determine the relationship between each of the demographic and pre-operative risk variables and the likelihood of in-hospital mortality. Multivariable logistic regression models relate the probability of death to the explanatory factor (e.g., *Patient Age, Creatinine Level, Type of Arrhythmia*), while controlling for all other explanatory factors in the model.

In model development, the three-year dataset was divided into two parts: Data for 2000 and 2001 were used as a “training set” to develop the model, and data for 2002 were used as a “test set” to validate the model. After a final model was chosen and tested, the coefficients were re-estimated using the entire three-year dataset.

Table 3 presents the final model based on the 2000-2002 dataset. Although the risk adjustment model is based on data from 83 hospitals, a risk-adjusted mortality rate is reported for only 77 hospitals: Six hospitals provided data but did not want their results published.

The final risk model included all variables used in the 1999 CCMRP risk model with the exception of angina. The 1999 audit and subsequent analyses revealed uneven coding of that risk factor across hospitals, so it was dropped. In addition, *Cardiogenic Shock* (Yes/No), *NYHA* (Class IV), and *BMI* were added to the model.

Table 3: Logistic Regression Risk Model for Inpatient Mortality, 2000-2002

Explanatory Factor		Coefficient	Standard Error	p-value	Significance	OR
Intercept		-9.74 0.	32	0.00	***	
Age (Years)		0.06	0.00	0.00	***	1.06
Gender Male	^			Reference Group		
	Female	0.37 0.	06	0.00	***	1.44
Race	**White ^**			Reference Group		
	Non-White	0.16	0.06	0.01	**	1.18
Body Mass Index	**18.5-39.9 ^**			Reference Group		
<	**18.5**	1.07 0.	16	0.00	***	2.91
	≥ 40.0	0.42 0.	15	0.01	**	1.52
Acuity	**Elective ^**			Reference Group		
	Urgent	0.26	0.07	0.00	***	1.29
	Emergent	1.07	0.11	0.00	***	2.91
	Salvage	2.59	0.22	0.00	***	13.32
Creatinine (mg/dl)		1.15 0.	12	0.00	***	3.16
Hypertension		0.06	0.07	0.37		1.06
Dialysis		0.47 0.	14	0.00	***	1.59
Peripheral Vascular Disease		0.22	0.07	0.00	***	1.25
Cerebrovascular Disease		0.04 0.	07	0.58		1.04
Cardiogenic Shock		0.91	0.11	0.00	***	2.49
Congestive Heart Failure		0.26 0.	07	0.00	***	1.30
Diabetes		0.09	0.06	0.12		1.10
Arrhythmia Type	**None ^**			Reference Group		
Afib/Flutter		0.39 0.	09	0.00	***	1.48
H eart Block		0.38 0.	12	0.00	**	1.47
	Sustained VT/VF	0.50 0.	12	0.00	***	1.65
Chronic Lung Disease	**None ^**			Reference Group		
	Mild	0.28	0.09	0.00	**	1.33
	Moderate	0.34	0.10	0.00	**	1.41
	Severe	0.92	0.12	0.00	***	2.52
Myocardial Infarction	**None ^**			Reference Group		
	21 or more days ago	0.14 0.	08	0.07		1.15
	8 to 20 days ago	-0.14 0.	14	0.31		0.87
	1-7 days ago	0.40 0.	07	0.00	***	1.49
	Within 24 Hours	0.44 0.	12	0.00	***	1.55
NYHA Class IV		0.31	0.07	0.00	***	1.37
Left Main Disease > 50%		0.08 0.	06	0.15		1.09
Prior Operations on Pump	**None ^**			Reference Group		
	1	0.99	0.08	0.00	***	2.69
	2 or more	1.20	0.22	0.00	***	3.32
PTCA N	**one ^**			Reference Group		
	≤ 6 Hours	-0.07 0.	07	0.36		0.94
	> 6 Hours	0.01 0.	21	0.94		1.02
Ejection Fraction (%)		-0.01	0.00	0.00	***	0.99
Number of Diseased Vessels	**One ^**			Reference Group		
	Two	-0.02 0.	16	0.92		0.99
	Three or More	0.09 0.	15	0.54		1.09
Mitral Insufficiency	**None ^**			Reference Group		
	Trivial	0.03	0.10	0.74		1.04
	Mild	0.06	0.09	0.49		1.06
	Moderate	0.08	0.12	0.51		1.08
	Severe	0.29	0.26	0.28		1.33

Note: ^ refers to the category used to replace missing data for a variable.

Guide for Interpreting the Risk Model

Coefficient: The coefficient for each explanatory factor represents the effect that factor has on a patient's likelihood of dying (in the hospital) following bypass surgery. If the value is positive, it means that the characteristic is associated with an increased risk of death compared to not having the characteristic, while controlling for the effect of all other factors. If the coefficient is negative, having that characteristic is associated with a lower risk of death compared to not having it. The larger the value (whether positive or negative), the greater the effect or weight this characteristic has on the risk of dying. For example, the coefficient for *Congestive Heart Failure (CHF)* in the model is 0.26 and statistically significant. This value is positive, so it indicates that CABG patients with congestive heart failure are at an increased risk of dying compared to patients who do not have the condition.

Standard Error: The standard error is the standard deviation of the sampling distribution of an estimate. It measures the statistical reliability of that estimate.

p–value: The p-value is a measure of the statistical significance of the coefficient compared to the reference category. Commonly, p-values of less than 0.05 are considered statistically significant. The smaller the p-value, the more likely the effect of a factor is real, rather than due to chance.

Significance: When the p-value of a coefficient is less than 0.05, it is deemed statistically significant at the 0.05 level and is denoted with one star (*) in the significance column. Two stars (**) indicate statistical significance at the 0.01 level and three stars (***) indicate statistical significance at the 0.001 level. All statistical tests are two-tailed tests.

Odds Ratio: An odds ratio is another way of characterizing the impact of each factor on in-hospital mortality. Mathematically, the odds ratio is the antilogarithm of the coefficient value. The larger the odds ratio, the greater the impact that characteristic has on the risk of dying. An odds ratio close to 1.0 means the effect of the factor is close to neutral. For example, the odds ratio for *CHF* in the model is 1.30. This means that for patients with *CHF*, the odds of dying in-hospital are about 30% higher compared to patients without *CHF*, assuming all other risk factors are the same.

Discrimination

Models that distinguish well between patients who die and those who survive are said to have good discrimination. A commonly used measure of discrimination is the c-index (also known as the c-statistic or the area under the Receiver Operating Curve (ROC)). For all possible pairs of patients, where one dies and the other survives surgery, the c-index describes the proportion of pairs where the patient who died had a higher predicted risk of death than the patient who lived. The c-index ranges from 0 to 1, with higher values indicating better discrimination. For the 2000-2002 data model the c-index is 0.828. In comparison, c-indexes reported in other recently published studies of CABG mortality using logistic regression (including those from New Jersey, New York, Pennsylvania, and the Society of Thoracic Surgeons) range from about 0.78 to 0.82. As such, the CCMRP model appears to discriminate as well as, or better than, models from other programs that produce risk-adjusted outcomes data for isolated CABG surgery.

Calibration

Calibration refers to the ability of a model to match predicted and observed death rates across the entire spread of the data. A model in which the number of observed deaths aligns well with the number of deaths predicted by the model demonstrates good calibration. Good calibration is essential for reliable risk adjustment. A common measure of calibration is the Hosmer and Lemeshow χ^2-statistic, which compares observed and predicted outcomes over deciles of risk. The Hosmer-Lemeshow test statistic is 29.1 (df=8; p-value=0.00) for the 2000-2002 model (i.e., reject the null hypothesis that there is no difference between actual and predicted deaths). This result was not a major cause for concern; with such a large sample it is common to fail the Hosmer-Lemeshow test.

The next step was to inspect the difference between the actual number of deaths and the predicted number of deaths (derived from the risk model) in each of 10 risk groups. The 10 groups are created by sorting all observations by the predicted risk of death and then dividing the sorted observations into deciles of approximately equal size. Table 4 shows the calibration of the 2000-2002 risk-adjustment model.

Table 4: Calibration of 2000-2002 Model (n=57,388)

Group	N	Minimum Predicted Risk	Maximum Predicted Risk	Actual Deaths	Expected Deaths	Difference
1	5,740	0.001	0.004	3	15.2	(12.2)
2	5,739	0.004	0.005	24	26.1	(2.1)
3	5,739	0.005	0.007	35	36.7	(1.7)
4	5,739	0.007	0.010	31	48.8	(17.8)
5	5,741	0.010	0.013	46	63.5	(17.5)
6	5,739	0.013	0.016	77	82.6	(5.6)
7	5,740	0.016	0.022	126	110.3	15.7
8	5,740	0.022	0.033	167	155.4	11.6
9	5,739	0.033	0.057	277	245.8	31.2
10	5,732	0.057	0.962	769	770.6	(1.6)

The first row of Table 4 shows the decile of patients at lowest risk of in-hospital death in the CCMRP model (e.g., the 5,740 patients whose predicted risk of dying ranged from 0.001 to 0.004). Among the first decile, three patients died, but the model predicted death for 15 of the patients. Assuming a Poisson distribution for a binary outcome with mean 0.0026 (15.2 ÷ 5,740), the predicted range of deaths for the first decile is eight to 23. The observed number of three deaths falls below the expected range. However, 49% of actual deaths occurred in the 10^{th} decile, the highest risk decile of patients, where 769 patients died compared to 771 deaths predicted by the model. The predicted range for the tenth decile is 716 to 825 deaths. The number of observed deaths is very nearly the exact number predicted by the model. Overall, in seven of the ten groups, the number of actual deaths is within the range of expected deaths. Although for groups 1, 4, and 5, the number of observed deaths is below the number of expected deaths, the model calibration shows that the risk model has accurately predicted the number of expected deaths, especially for patients with the highest risk of dying.

Key Findings Regarding the Risk Model

- Although some of the risk model variables are not statistically significant (as determined by a p-value of <0.05), all significant coefficients appeared with the expected sign from a clinical standpoint.

- *Age, Acuity* (e.g., urgency of the operation), *Cardiogenic Shock*, *Dialysis, Ejection Fraction, Creatinine,* and the number of *Prior Operations on Pump* were the most important risk model variables.

- Patients who were extremely underweight (*BMI* < 18.5) had a higher risk of dying in-hospital (OR 2.91) than those in the reference group (*BMI* 18.5-39.9). Patients who were extremely overweight (*BMI* > 40.0) were also at increased risk of death (OR 1.52) but not to the extent that the very underweight were. A very low *BMI* may be a proxy for frailty or indicate a wasting comorbid condition not captured by other risk model variables.

- Even after controlling for all other variables, *Gender* had a statistically significant effect, with males having about one-third lower mortality. This gender effect has weakened when compared to the 1997-1999 model, perhaps because of the inclusion of *BMI* in the current model. The literature suggests that *gender* may be a proxy for body size and/or coronary artery size (diameter) and smaller coronary arteries in women may be more prone to thrombosis or restenosis.

- Of the acute comorbidities collected, *Cardiogenic Shock* had the largest effect (OR 2.49). Of the chronic comorbid conditions, severe *Chronic Lung Disease* has the strongest association with inpatient mortality (OR 2.52).

- Patients with *Left Main Disease* > 50% did not appear to be at increased risk (OR 1.09, not significant) of inpatient death. However, when *Left Main Stenosis* was collected as a continuous measure (see 1997-1999 model), patients with Stenoses > 70% were about 50% more likely to die.

- When compared to the 1997-1999 risk model, six variables in the prior model were no longer significant, and two variables not significant in the prior model were significant in the current model. Of most concern from a clinical perspective, there was no increased risk of mortality from *PTCA* <= 6 hours (OR .94, not significant) though a variable definition change might be responsible for this result. Severe *Mitral Insufficiency* was no longer a significant risk factor, which may also go against clinical reasoning. On the other hand, pre-operative *Dialysis* behaved as expected, putting patients at additional risk (OR 1.59); previously, it did not.

- *Creatinine* was entered into the current risk model as a piecewise linear function, so its odds ratio (3.16) is not comparable to prior CCMRP reports where it was entered as a continuous measure.

V. HOSPITAL RISK-ADJUSTED MORTALITY RATES, 2000-2002

The logistic regression model in Table 3 was used to develop risk-adjusted mortality rates for each of the 77 participating hospitals. Among hospitals participating in public reporting, 1,389 patients out of 53,190 died in-hospital reflecting an overall in-hospital death rate of 2.61%. This compares to an overall rate of 2.9% nationally for 2000-2002 as reported by the Society of Thoracic Surgeons for 30-day operative mortality (see www.sts.org). Because some deaths occur after discharge but within 30 days, 30-day operative mortality is slightly higher than in-hospital mortality.

Table 5 and Figure 2 present the risk-adjusted results for each of the hospital participants in 2000-2002. Table 5 displays the results alphabetically and includes the number of isolated CABGs reported to CCMRP, the number of deaths at discharge, the number of expected deaths predicted by the risk model, observed-to-expected death (O/E) ratios, the observed death rate, the expected death rate with 95% confidence interval (CI), and the overall performance rating. Figure 2 shows the results graphically, sorted alphabetically within geographic region. The overall performance rating is based on a comparison of the hospital's observed mortality rate and the 95% CI of that hospital's expected mortality rate predicted by the risk model. If the observed mortality is below the lower limit of the 95% CI of expected mortality, the overall performance rating will be "Better than Expected." If the observed mortality is beyond the upper limit of the 95% CI of expected mortality, the overall performance rating will be "Worse than Expected." For hospitals where the observed mortality is within the 95% CI of the expected mortality rate, the overall performance rating is "As Expected." The 2000-2002 analysis revealed that of the 77 participating hospitals, nine performed "worse than expected" (i.e., their actual death rate was higher than what was expected/predicted), eight performed "better than expected," and 60 performed "as expected."

Among the 77 participating hospitals, 67 hospitals provided more than one year of data (59 hospitals submitted three years of data and eight hospitals submitted two years of data). The overall performance ratings for those 67 hospitals were based on their multiple-year data. The performance ratings for the remaining 10 hospitals were based on one year of data and two of these hospitals had performance ratings based on less than 100 cases (see Appendix B). Rating small volume hospitals on a single year of data is not ideal because statistical methods may not detect quality differences and their results are more likely to vary by chance.

Table 5: Risk-Adjusted Results for CCMRP Hospitals, 2000-2002, Sorted Alphabetically

Hospital Name	CABG Cases Submitted	Number of Observed Deaths	Number of Expected Deaths	O/E Ratio	Observed Death Rate	Lower 95% CL for Expected Death %	Expected Death Rate	Upper 95% CL for Expected Death %	Overall Performance Rating (blank=As Expected)
Alta Bates Medical Center	213	10	5.6	1.8	4.7	0.7	2.6	4.5	Worse Than Expected
Alvarado Hospital Medical Center	228	14	4.1	3.4	6.1	0.1	1.8	3.5	Worse Than Expected
Anaheim Memorial Medical Center	559	19	18.0	1.1	3.4	1.8	3.2	4.6	
Brotman Medical Center	71	3	1.9	1.6	4.2	0.0	2.7	6.4	
CA Pacific Medical Center - Pacific Campus	593	26	14.8	1.8	4.4	1.3	2.5	3.7	Worse Than Expected
Cedars-Sinai Medical Center	985	25	24.1	1.0	2.5	1.5	2.4	3.4	
Centinela Hospital and Medical Center	183	7	6.2	1.1	3.8	0.9	3.4	5.9	
Community Memorial Hosp. of San Buenaventura	551	11	11.6	0.9	2.0	1.0	2.1	3.2	
Dameron Hospital	266	8	8.5	0.9	3.0	1.2	3.2	5.2	
Daniel Freeman Memorial Hospital	249	12	8.6	1.4	4.8	1.3	3.5	5.6	
Desert Regional Medical Center	230	10	5.3	1.9	4.3	0.4	2.3	4.2	Worse Than Expected
Doctor's Medical Center - San Pablo	167	9	5.4	1.7	5.4	0.7	3.2	5.8	
Dominican Hospital	379	8	9.8	0.8	2.1	1.1	2.6	4.0	
El Camino Hospital	285	8	10.5	0.8	2.8	1.7	3.7	5.7	
Encino Tarzana Regional Medical Center	463	13	18.0	0.7	2.8	2.2	3.9	5.5	
Enloe Medical Center	685	30	23.2	1.3	4.4	2.2	3.4	4.6	
Fountain Valley Regional Hospital	170	7	5.7	1.2	4.1	0.9	3.4	5.8	
Glendale Adventist Med Center - Wilson Terrace	636	26	15.6	1.7	4.1	1.3	2.5	3.6	Worse Than Expected
Glendale Memorial Hospital and Health Center	585	30	22.0	1.4	5.1	2.4	3.8	5.2	
Granada Hills Community Hospital	118	3	2.1	1.4	2.5	0.0	1.8	4.2	
Hoag Memorial Hospital Presbyterian	807	14	23.1	0.6	1.7	1.8	2.9	3.9	Better Than Expected
Huntington Memorial Hospital	641	12	20.3	0.6	1.9	1.9	3.2	4.5	

Table 5: Risk-Adjusted Results for CCMRP Hospitals, 2000-2002, Sorted Alphabetically (Continued)

Hospital Name	CABG Cases Submitted	Number of Observed Deaths	Number of Expected Deaths	O/E Ratio	Observed Death Rate	Lower 95% CL for Expected Death %	Expected Death Rate	Upper 95% CL for Expected Death %	Overall Performance Rating (blank=As Expected)
John Muir Medical Center	408	15	15.1	1.0	3.7	2.0	3.7	5.4	
Kaiser Foundation Hospital - Los Angeles	3, 829	79	84.1	0.9	2.1	1.7	2.2	2.6	
Kaiser Foundation Hospital - San Francisco	3, 291	49	60.6	0.8	1.5	1.4	1.8	2.3	
Kaweah Delta Hospital	1, 078	33	41.5	0.8	3.1	2.8	3.8	4.9	
Lakewood Regional Medical Center	134	6	3.2	1.9	4.5	0.0	2.4	4.9	
Loma Linda University Medical Center	1, 006	18	39.6	0.5	1.8	2.8	3.9	5.0	Better Than Expected
Long Beach Memorial Medical Center	1, 159	45	34.8	1.3	3.9	2.1	3.0	3.9	
Marin General Hospital	187	6	4.0	1.5	3.2	0.1	2.1	4.1	
Memorial Medical Center of Modesto	1, 063	30	25.5	1.2	2.8	1.5	2.4	3.3	
Mercy General Hospital	3, 155	27	51.6	0.5	0.9	1.2	1.6	2.1	Better Than Expected
Mercy Medical Center – Redding	253	4	8.6	0.5	1.6	1.4	3.4	5.4	
Mercy San Juan Hospital	448	8	7.0	1.1	1.8	0.4	1.6	2.7	
Methodist Hospital of Southern California	591	9	14.9	0.6	1.5	1.3	2.5	3.7	
Mills-Peninsula Hospital	229	2	6.8	0.3	0.9	1.0	3.0	4.9	Better Than Expected
Mission Hospital and Regional Medical Center	582	14	13.4	1.0	2.4	1.1	2.3	3.5	
Palomar Medical Center	418	13	9.6	1.4	3.1	0.9	2.3	3.7	
Presbyterian Intercommunity Hospital	127	5	3.2	1.5	3.9	0.0	2.6	5.2	
Providence Holy Cross Medical Center	301	18	10.2	1.8	6.0	1.5	3.4	5.3	Worse Than Expected
Providence St. Joseph Medical Center	378	13	8.5	1.5	3.4	0.8	2.2	3.7	
Redding Medical Center	2, 098	33	41.8	0.8	1.6	1.4	2.0	2.6	
Saddleback Memorial Medical Center	394	19	13.4	1.4	4.8	1.7	3.4	5.1	
Salinas Valley Memorial Hospital	902	21	27.0	0.8	2.3	1.9	3.0	4.0	
San Jose Medical Center	165	20	8.8	2.3	12.1	2.3	5.3	8.4	Worse Than Expected

Table 5: Risk-Adjusted Results for CCMRP Hospitals, 2000-2002, Sorted Alphabetically (Continued)

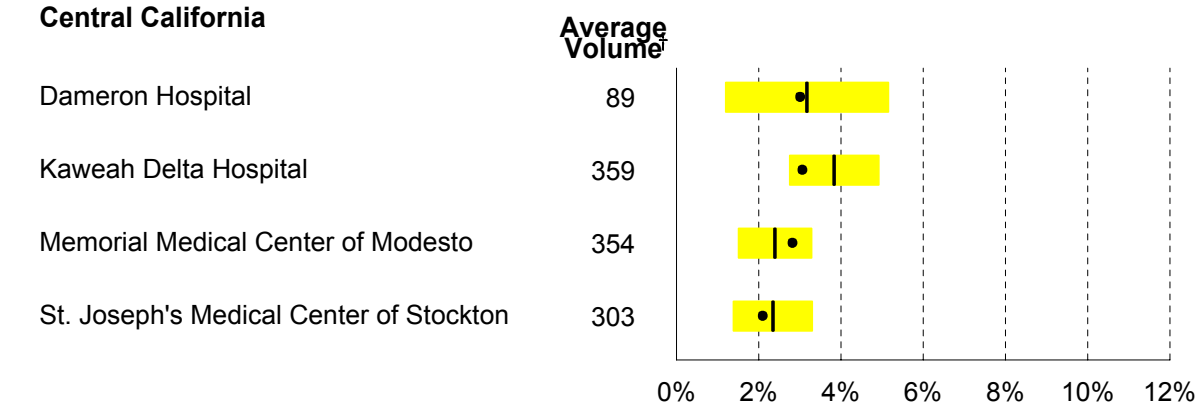
Hospital Name	CABG Cases Submitted	Number of Observed Deaths	Number of Expected Deaths	O/E Ratio	Observed Death Rate	Lower 95% CL for Expected Death %	Expected Death Rate	Upper 95% CL for Expected Death %	Overall Performance Rating (blank=As Expected)
Santa Barbara Cottage Hospital	606	20	21.6	0.9	3.3	2.2	3.6	4.9	
Santa Rosa Memorial Hospital	492	17	20.2	0.8	3.5	2.5	4.1	5.7	
Scripps Green Hospital	577	12	9.4	1.3	2.1	0.6	1.6	2.7	
Scripps Memorial Hospital - La Jolla	1,163	32	32.1	1.0	2.8	1.9	2.8	3.7	
Scripps Mercy	494	22	12.6	1.7	4.5	1.2	2.6	3.9	Worse Than Expected
Sequoia Hospital	566	8	18.5	0.4	1.4	1.9	3.3	4.6	Better Than Expected
Seton Medical Center - Heart Institute	1,010	21	27.0	0.8	2.1	1.7	2.7	3.6	
Sharp Chula Vista Medical Center	984	45	35.1	1.3	4.6	2.5	3.6	4.7	
Sharp Grossmont Hospital	593	20	18.4	1.1	3.4	1.8	3.1	4.4	
Sharp Memorial Hospital	733	13	17.2	0.8	1.8	1.3	2.3	3.4	
St. Bernardine Medical Center	1,589	49	53.1	0.9	3.1	2.5	3.3	4.2	
St. Francis Medical Center	326	18	12.7	1.4	5.5	1.9	3.9	5.9	
St. Helena Hospital	677	23	17.4	1.3	3.4	1.4	2.6	3.7	
St. John's Hospital and Health Center	381	11	8.9	1.2	2.9	0.9	2.3	3.8	
St. Joseph Hospital - Orange	779	21	22.4	0.9	2.7	1.8	2.9	4.0	
St. Joseph's Medical Center of Stockton	908	19	21.4	0.9	2.1	1.4	2.4	3.3	
St. Jude Medical Center	716	18	16.9	1.1	2.5	1.3	2.4	3.4	
St. Mary's Hospital and Medical Center	480	9	13.7	0.7	1.9	1.4	2.9	4.3	
St. Vincent Medical Center	684*	21	26.0	0.8	3.1	2.4	3.8	5.2	
Summit Medical Center	1,896	31	45.6	0.7	1.6	1.8	2.4	3.0	Better Than Expected
Sutter Memorial Hospital	1,876	27	42.9	0.6	1.4	1.6	2.3	2.9	Better Than Expected
The Hospital of the Good Samaritan	1,225	53	45.8	1.2	4.3	2.7	3.7	4.7	
Torrance Memorial Medical Center	607	12	21.3	0.6	2.0	1.2	3.5	4.9	Better Than Expected
Tri-City Medical Center	339	10	8.6	1.2	2.9	0.9	2.5	4.1	

Table 5: Risk-Adjusted Results for CCMRP Hospitals, 2000-2002, Sorted Alphabetically (Continued)

Hospital Name	CABG Cases Submitted	Number of Observed Deaths	Number of Expected Deaths	O/E Ratio	Observed Death Rate	Lower 95% CL for Expected Death %	Expected Death Rate	Upper 95% CL for Expected Death %	Overall Performance Rating (blank=As Expected)
UC Irvine Medical Center	68	3	2.9	1.0	4.4	0.0	4.3	8.7	
UCD Medical Center	553	13	14.7	0.9	2.4	1.4	2.7	3.9	
UCLA Medical Center	379	8	11.2	0.7	2.1 1.	3	2.9 4.	6	
UCSF Medical Center	271	9	6.0	1.5	3.3	0.5	2.2	3.9	
Valley Presbyterian Hospital	119	9	4.4	2.0	7.6	0.5	3.7	6.9	Worse Than Expected
Washington Hospital – Fremont	454	14	21.0	0.7	3.1	2.9	4.6	6.3	
Western Medical Center – Anaheim	250	6	5.7	1.1	2.4 0.	5	2.3 4.	1	
Western Medical Center - Santa Ana	135	3	3.7	0.8	2.2	0.1	2.7	5.4	

* Four non-isolated CABG deaths were removed after the hospital reviewed their risk adjusted results, but the hospital performance rating was unchanged.

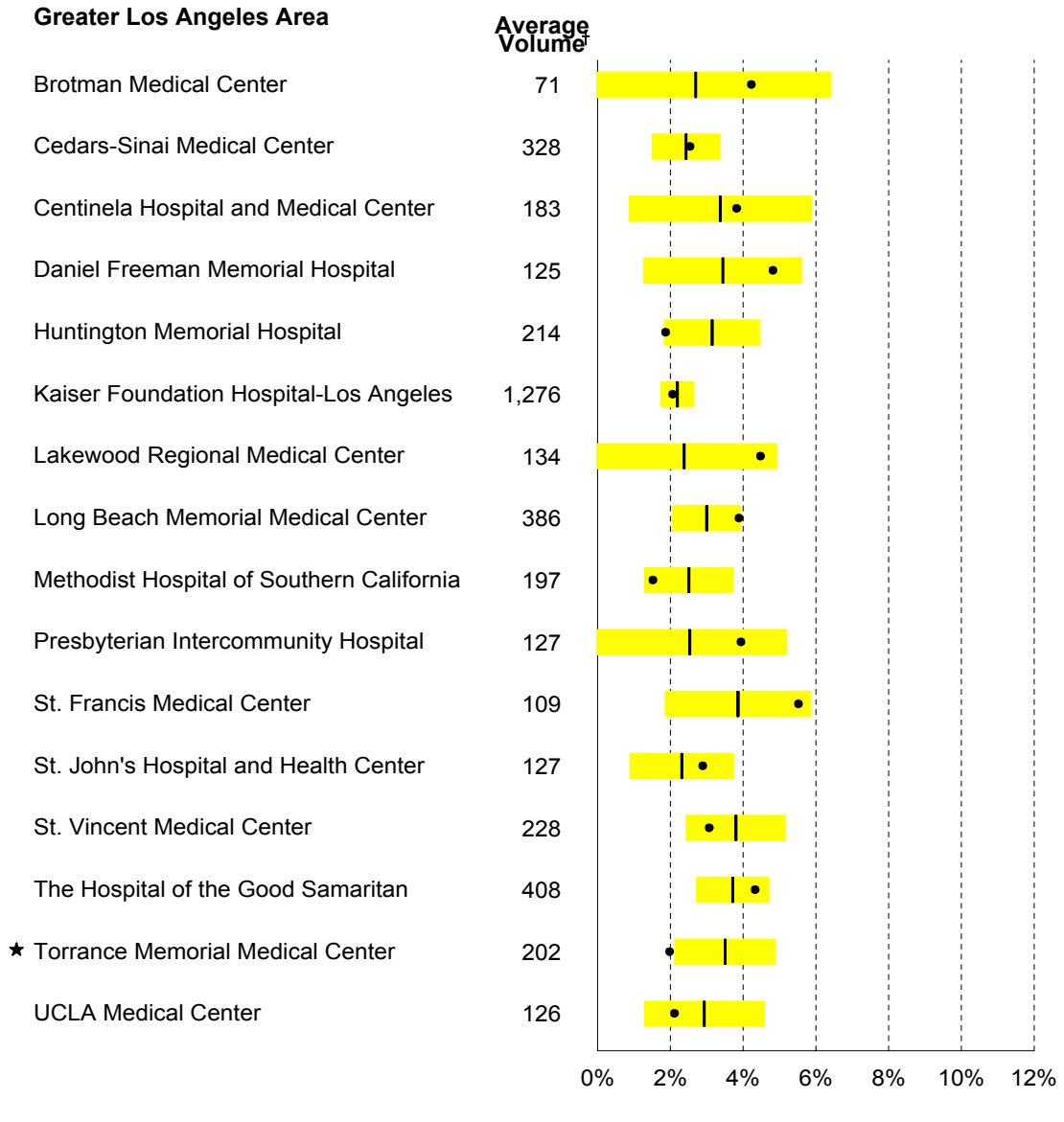
Figure 2: Comparison of Observed to Expected Mortality Rate, 2000-2002
(in Alphabetical Order by Geographical Region)



- Observed Mortality Rate
- Expected Mortality Rate
- Range of Expected Mortality Rate (95% Confidence Level)
- ▼ Observed Mortality Rate Significantly Worse than Expected
- ★ Observed Mortality Rate Significantly Better than Expected
- † Annualized volume of isolated bypass surgery cases.

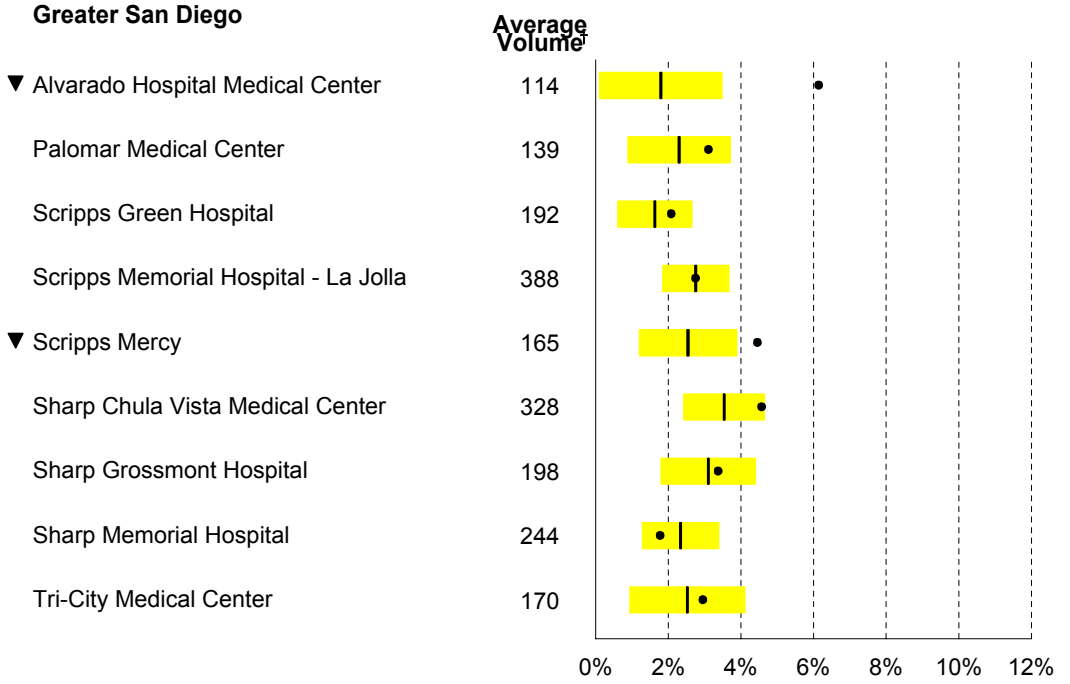
NOTE: The following hospitals in this region declined to participate:
Bakersfield Heart Hospital, Bakersfield Memorial Hospital,
Doctor's Medical Center - Modesto, Fresno Community Hospital and Medical Center,
Marian Medical Center, San Joaquin Community Hospital, St. Agnes Medical Center.

Figure 2: Comparison of Observed to Expected Mortality Rate, 2000-2002
(cont.) (in Alphabetical Order by Geographical Region)



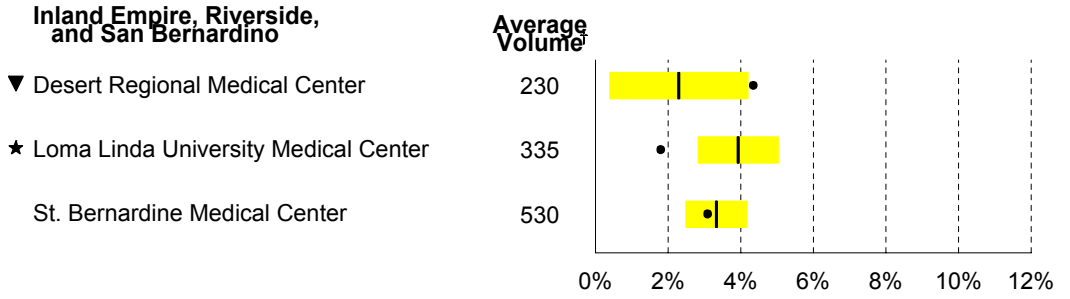
NOTE: The following hospitals in this region declined to participate:
Beverly Hospital, Downey Community Hospital, Garfield Med. Center, Intercommunity/ Citrus Valley Med. Center, LA County Harbor-UCLA Med. Center, LA County/USC Med. Center, Little Company of Mary Hospital, Santa Monica - UCLA Med. Center, St. Mary Med. Center, USC University Hospital, White Memorial Med. Center.

Figure 2: Comparison of Observed to Expected Mortality Rate, 2000-2002
(cont.) (in Alphabetical Order by Geographical Region)



NOTE: The following hospitals in this region declined to participate:
UCSD Medical Center - Hillcrest, UCSD Medical Center - Thornton.

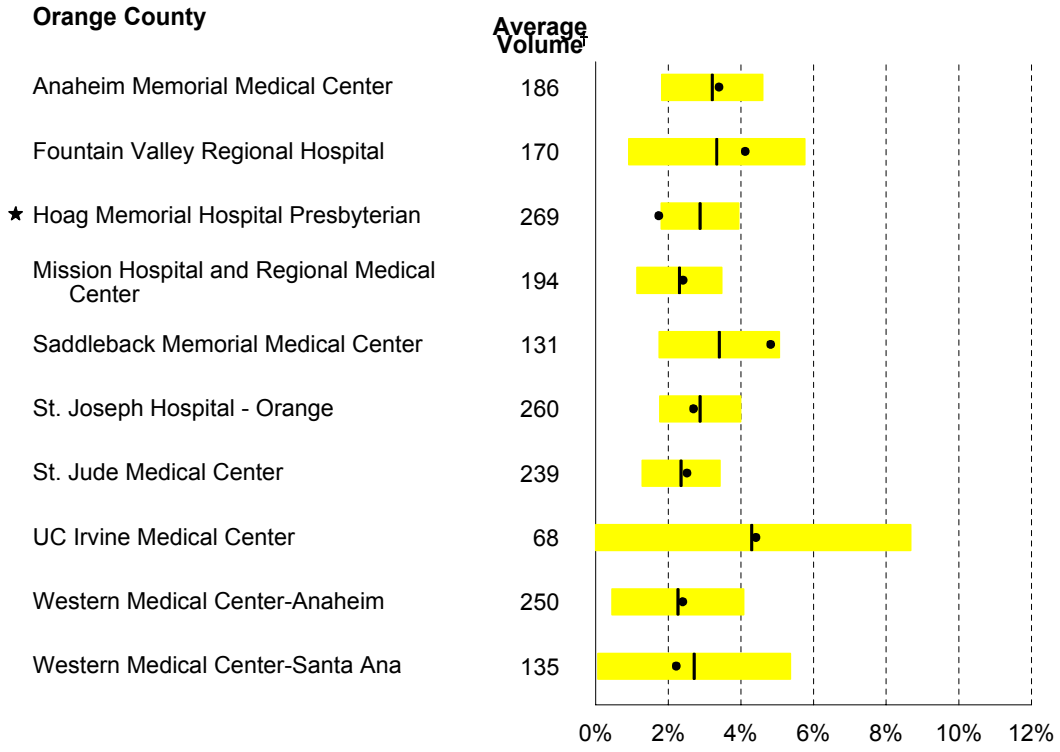
Figure 2: Comparison of Observed to Expected Mortality Rate, 2000-2002
(cont.) (in Alphabetical Order by Geographical Region)



• Observed Mortality Rate	▼ Observed Mortality Rate Significantly Worse than Expected
| Expected Mortality Rate	★ Observed Mortality Rate Significantly Better than Expected
▬ Range of Expected Mortality Rate (95% Confidence Level)	† Annualized volume of isolated bypass surgery cases.

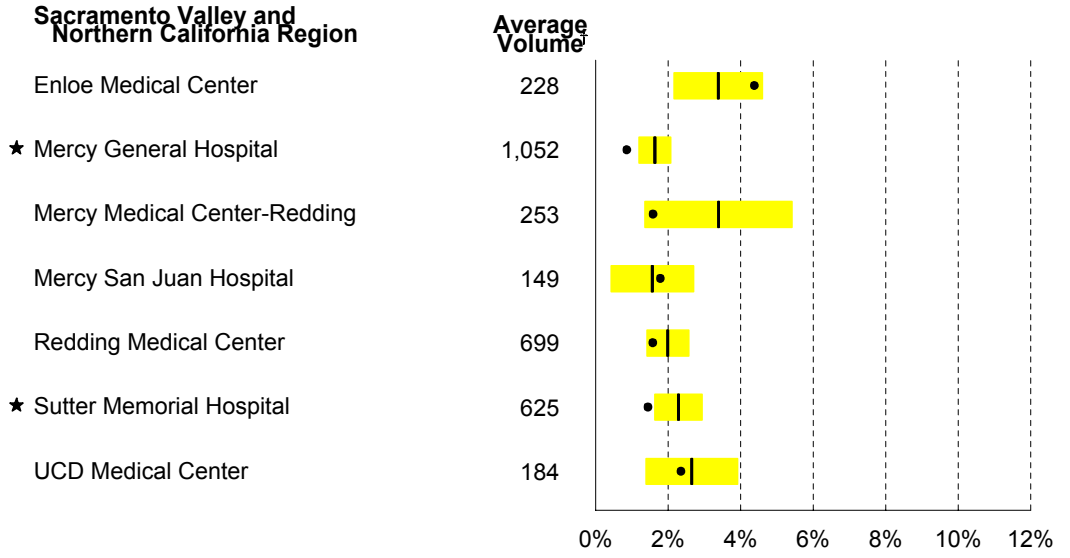
NOTE: The following hospitals in this region declined to participate:
Eisenhower Memorial Hospital, Pomona Valley Hospital and Medical Center, Riverside Community Hospital Medical Center, San Antonio Community Hospital St. Mary's Regional Medical Center.

Figure 2: Comparison of Observed to Expected Mortality Rate, 2000-2002
(cont.) (in Alphabetical Order by Geographical Region)



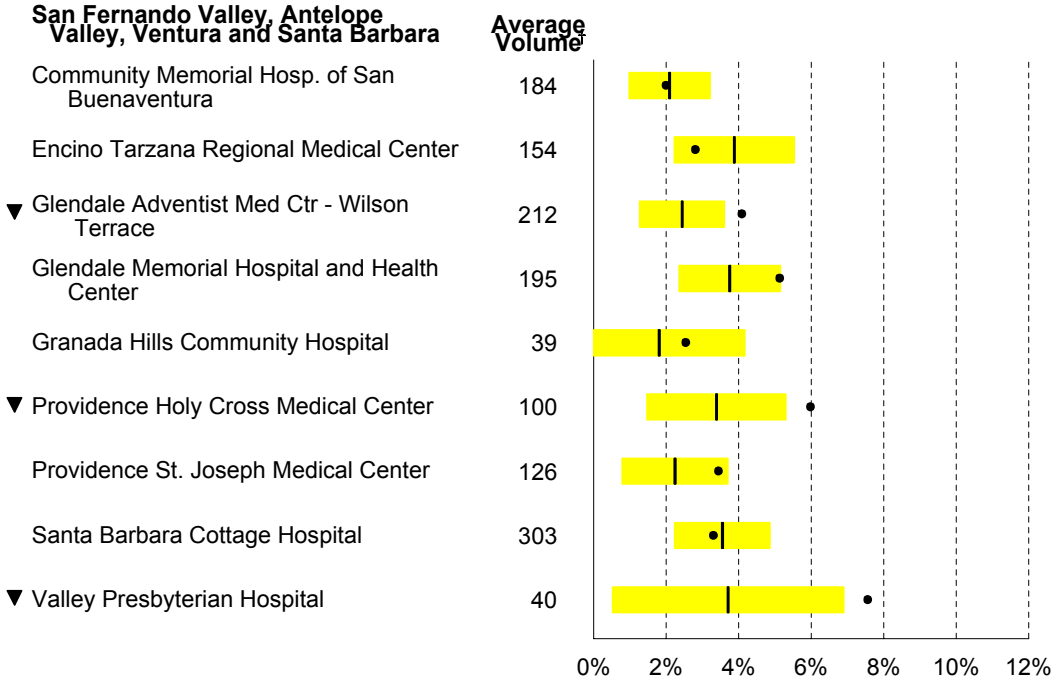
NOTE: The following hospitals in this region declined to participate:
West Anaheim Medical Center

Figure 2: Comparison of Observed to Expected Mortality Rate, 2000-2002
(cont.) (in Alphabetical Order by Geographical Region)



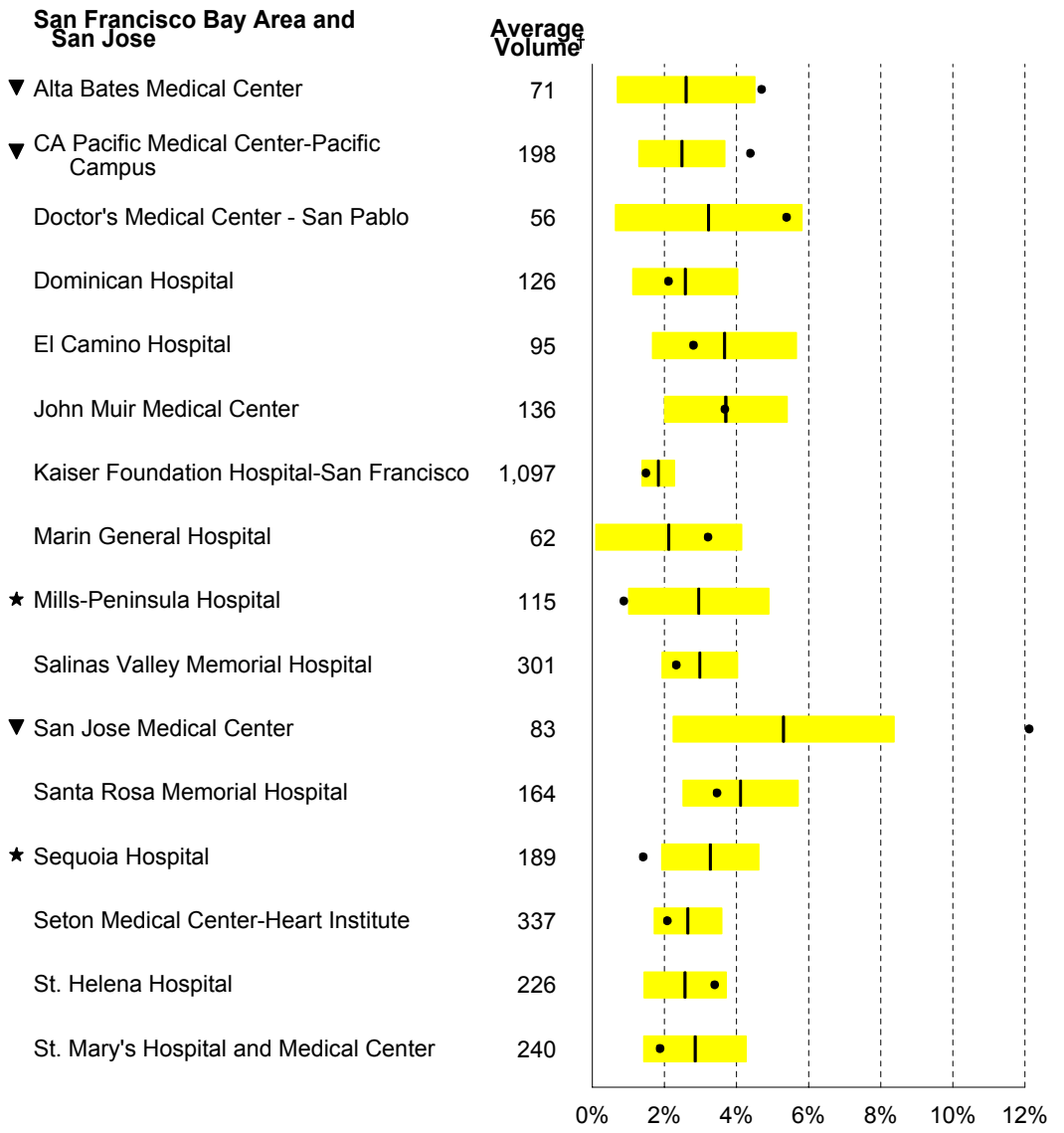
NOTE: The following hospitals in this region declined to participate:
St. Joseph Hospital - Eureka, Rideout Memorial Hospital.

Figure 2: Comparison of Observed to Expected Mortality Rate, 2000-2002
(cont.) (in Alphabetical Order by Geographical Region)



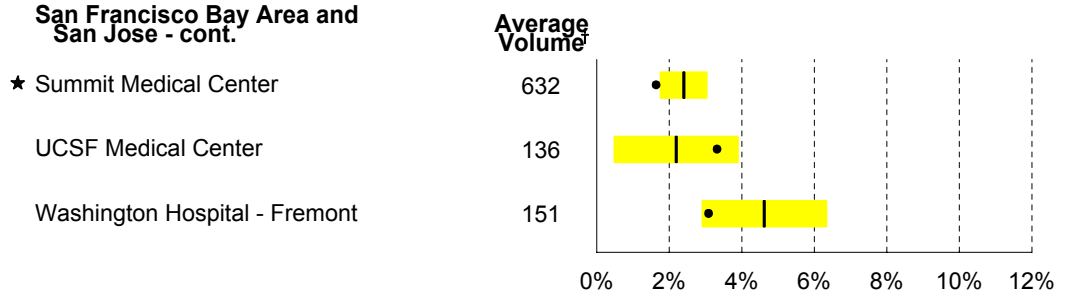
NOTE: The following hospitals in this region declined to participate:
Antelope Valley Hospital and Medical Center, French Hospital - San Luis Obispo, Granada Hills Community Hospital, Lancaster Community Hospital, Los Robles Regional Medical Center, Northridge Hospital Medical Center, Sierra Vista Regional Medical Center, St. John's Regional Medical Center, West Hills Regional Medical Center.

Figure 2: Comparison of Observed to Expected Mortality Rate, 2000-2002
(cont.) (in Alphabetical Order by Geographical Region)



NOTE: The following hospitals in this region declined to participate:
Good Samaritan Hospital, Mt. Diablo Medical Center, O'Connor Hospital
Queen of the Valley Hospital, San Ramon Regional Medical Center,
Santa Clara Valley Medical Center, Stanford University Hospital,
Sutter Medical Center of Santa Rosa.

Figure 2: Comparison of Observed to Expected Mortality Rate, 2000-2002
(cont.) (in Alphabetical Order by Geographical Region)



- • Observed Mortality Rate
- | Expected Mortality Rate
- ▬ Range of Expected Mortality Rate (95% Confidence Level)
- ▼ Observed Mortality Rate Significantly Worse than Expected
- ★ Observed Mortality Rate Significantly Better than Expected
- † Annualized volume of isolated bypass surgery cases.

NOTE: The following hospitals in this region declined to participate:
Good Samaritan Hospital, Mt. Diablo Medical Center, O'Connor Hospital
Queen of the Valley Hospital, San Ramon Regional Medical Center,
Santa Clara Valley Medical Center, Stanford University Hospital,
Sutter Medical Center of Santa Rosa.

VI. HOSPITAL PERFORMANCE OVER TIME, 1997-2002

One way to examine trends in hospital performance is to look at changes in the observed to expected mortality (O/E) ratio over time. Hospitals with O/E ratios less than 1.0 have fewer deaths than expected following CABG surgery, while hospitals with O/E ratios above 1.0 have more deaths than expected, given their patient case mix. The expected hospital mortality rate for 2000-2002 is predicted by the risk adjustment model as presented in Section IV of this report, and the expected mortality for 1997-1999 is obtained from the risk adjustment model published in the 1999 CCMRP Technical Report.

Of the 77 CCMRP 2000-2002 participating hospitals, 67 hospitals participated in this program for more than one year between 2000 and 2002 and, among them, 25 hospitals have participated in the program every year since 1997. Figure 3 presents the O/E ratios over time for the 67 participating hospitals that have at least two years of data available for 2000-2002.

For the majority of hospitals presented in Figure 3, the O/E ratios did not demonstrate a consistent direction from year to year. For those 25 hospitals that have participated every year since 1997, four had O/E ratios below 1.0 throughout the six-year period, meaning their observed death rates have been consistently below the expected death rates. They are: Hoag Memorial, Mercy General, Sutter Memorial and Redding Medical Center, and the first three are also identified as “better then expected” performers for 2000-2002. Only one hospital (Alta Bates Medical Center) had an O/E ratio above 1.0 for the entire six-year period, meaning this hospital’s observed death rate has been consistently above the expected death rate. This medical center is one of the “worse than expected” hospitals for 2000-2002. This subset of 25 hospitals may not be representative of all hospitals that perform CABG surgery in California and may include a disproportionate share of hospitals with better performance over the six-year time period.

Figure 3: O/E Ratios Over Time for 67 CCMRP Participating Hospitals that Have at Least Two Years of Continuous O/E Ratios Available Between 2000 and 2002

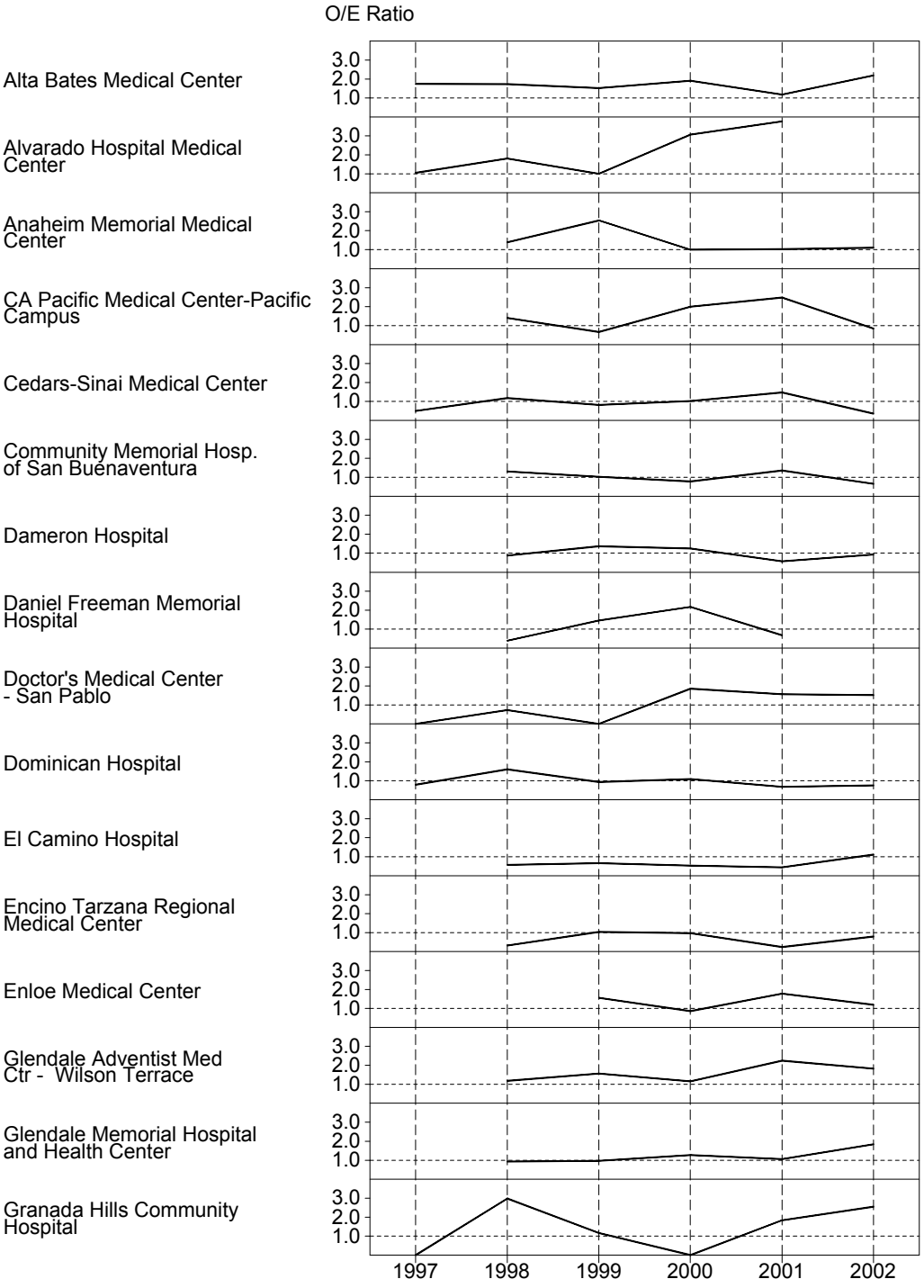


Figure 3: O/E Ratios Over Time for 67 CCMRP Participating Hospitals that Have at Least Two Years of Continuous O/E Ratios Available Between 2000 and 2002 (Continued)

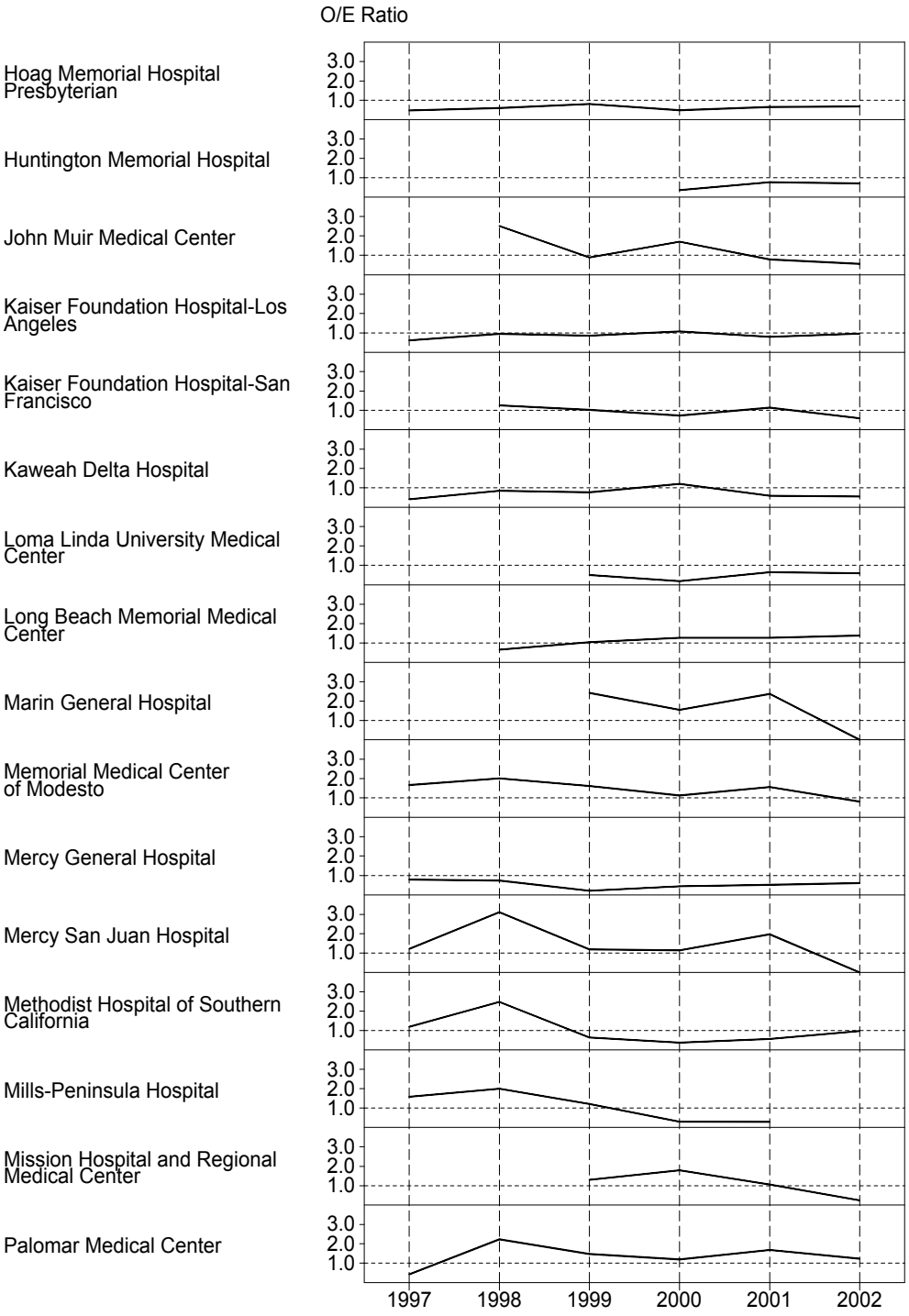


Figure 3: O/E Ratios Over Time for 67 CCMRP Participating Hospitals that Have at Least Two Years of Continuous O/E Ratios Available Between 2000 and 2002 (Continued)

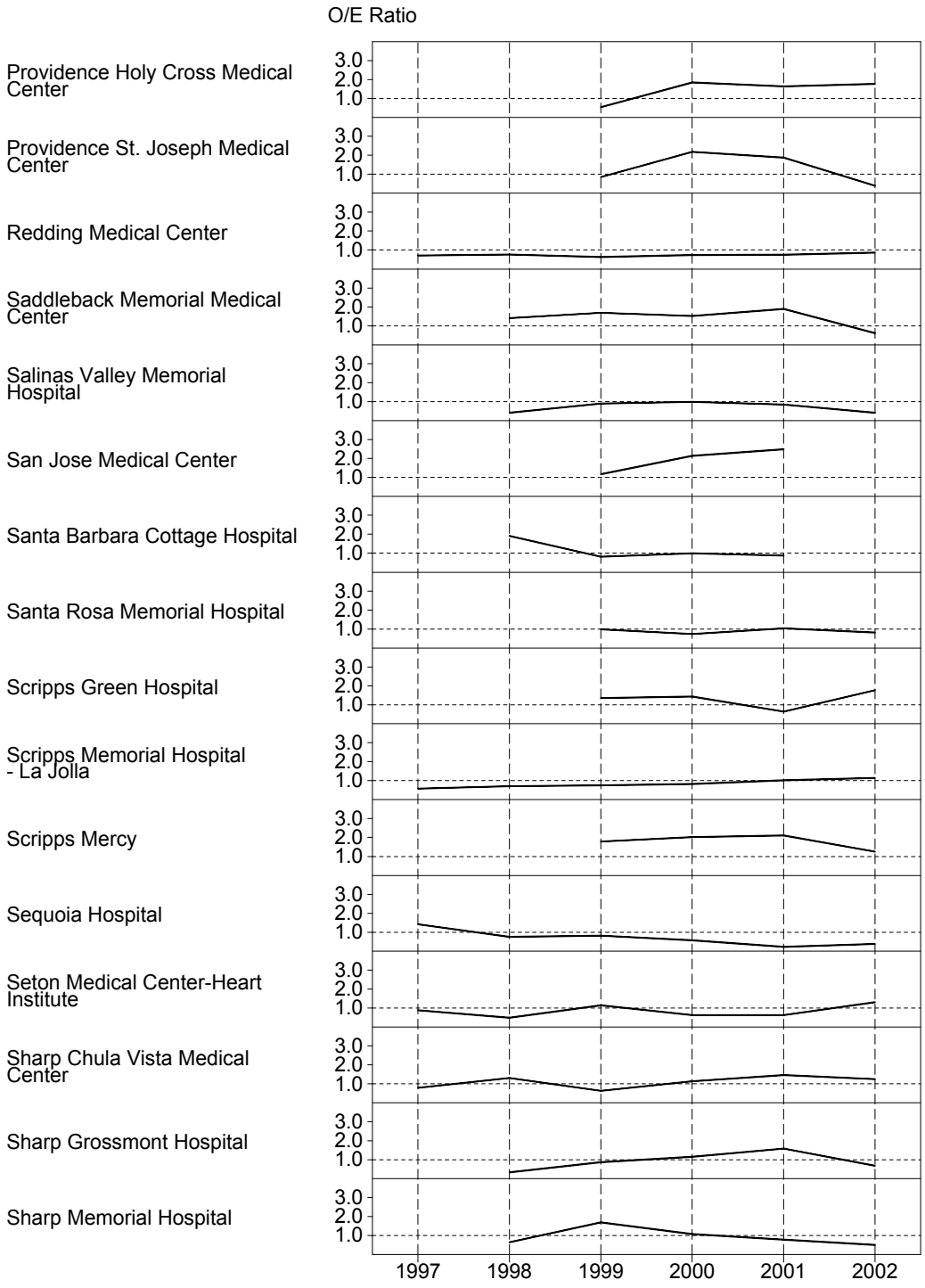


Figure 3: O/E Ratios Over Time for 67 CCMRP Participating Hospitals that Have at Least Two Years of Continuous O/E Ratios Available Between 2000 and 2002 (Continued)

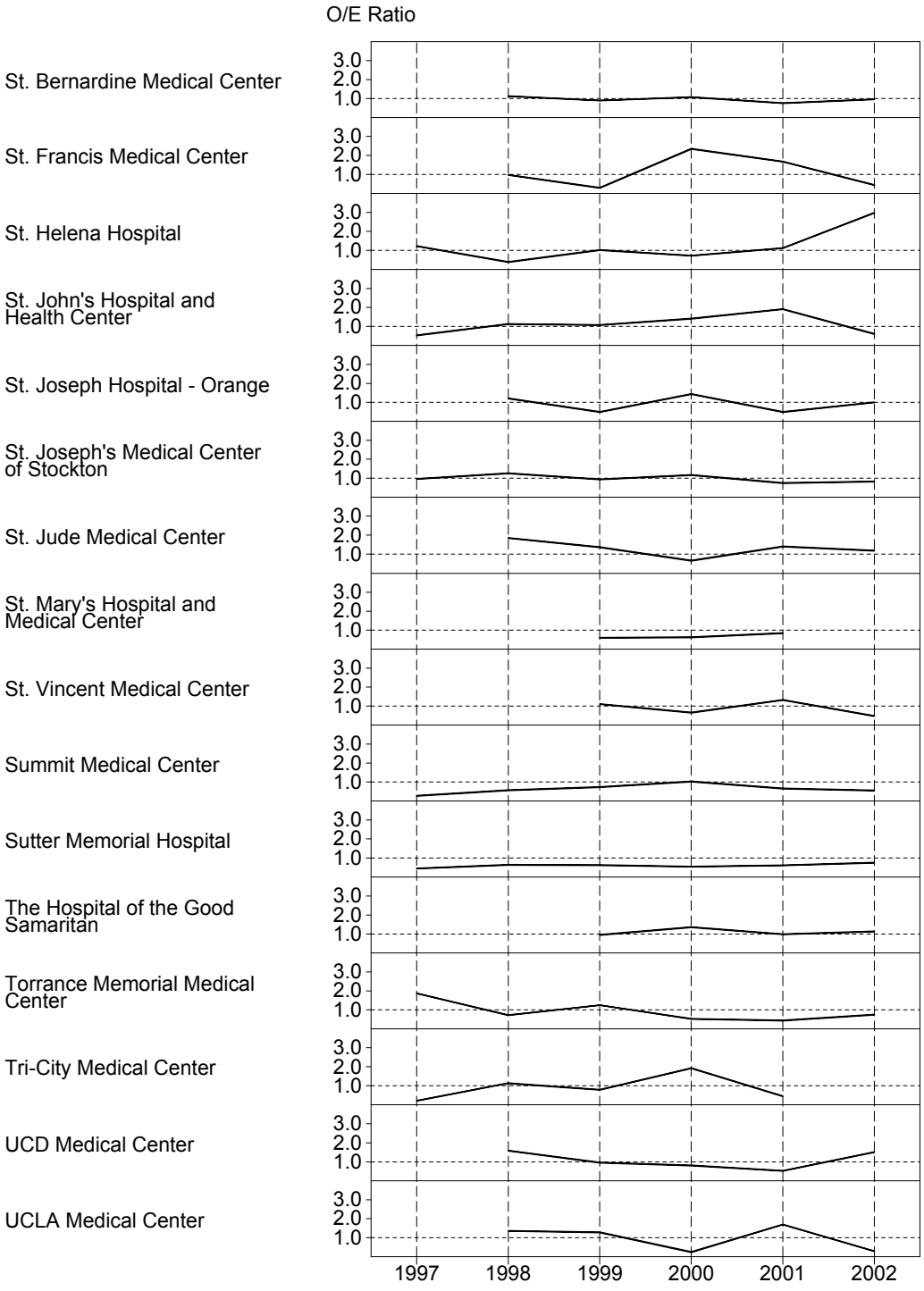
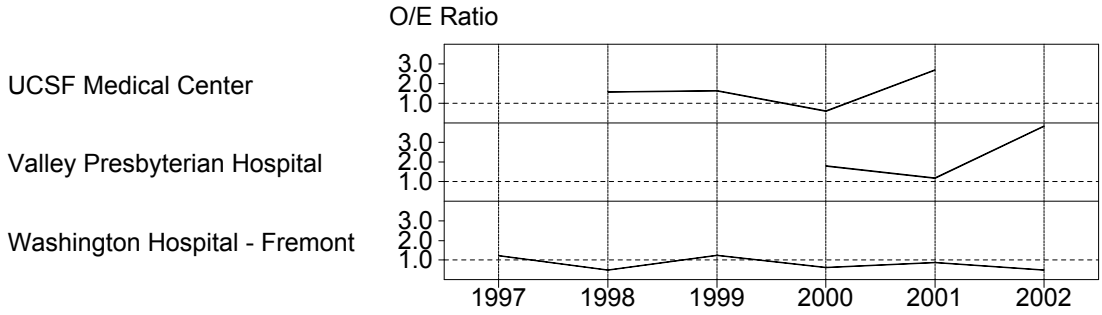


Figure 3: O/E Ratios Over Time for 67 CCMRP Participating Hospitals that Have at Least Two Years of Continuous O/E Ratios Available Between 2000 and 2002 (Continued)



VII. HOSPITAL VOLUME AND CORONARY ARTERY BYPASS GRAFT SURGERY OUTCOMES

The association between the quantity of care that a physician or hospital provides and the quality of care that patients receive has been intensely investigated by clinicians and health services researchers. In the majority of the published data investigating this relationship, researchers have generally found that the higher the number of patients a physician or hospital treats with a specific condition, the better, on average, the patients' health outcomes. This "volume-outcome" relationship has been documented for a wide variety of medical conditions and surgical procedures at several levels of care, including the physician, clinical team, and hospital level. In a report reviewing the volume-outcome relationship, published by the Institute of Medicine (Hewitt, 2000), the author noted that 77% of the published volume-outcome studies demonstrate a significant relationship between higher physician and hospital volumes and better health outcomes. In fact, in this Institute of Medicine review, no studies were found to demonstrate a significant negative relationship between higher volumes and outcomes (i.e., resulted in worse health outcomes).

The volume-outcome relationship has been most extensively studied for patients receiving coronary artery bypass graft (CABG) surgery. This observed relationship could imply that regionalizing services, thereby increasing average physician and hospital volumes, would improve the quality of healthcare. Whereas most of these studies found that hospitals performing more CABG surgeries had better outcomes, the policy significance of this relationship remains controversial. Many question the magnitude of the CABG volume-outcome association since several recent studies using more robust statistical methods have failed to find a clinically significant relationship (Peterson, 2004; Shahian, 2001; Christiansen, 1997; Kalant, 2004; Panageas, 2003).

CCMRP 2000-2002 Analyses

The following analyses and report examine the volume-outcome relationship in CABG surgery using the California CABG Mortality Reporting Program (CCMRP) data from 2000 to 2002. The primary goal of these analyses is to use the most current methodological techniques to determine whether hospitals performing more CABG surgeries have lower risk-adjusted mortality than hospitals performing fewer CABG surgeries in California.

First, a patient-level risk-adjusted mortality prediction model was developed using a hierarchical or multi-level technique. Hierarchical models (also referred to as multi-level models, random or mixed-effect models, and random coefficient/intercept regression models) are increasingly used in health services research to analyze multi-level data, particularly when analyses are done on patient data from many hospitals. These models are more appropriate than traditional patient-level models for making inferences at the hospital level because they adjust for the "clustering" of patients (Shahian, 2001; Christiansen, 1997; Leyland, 2003; Burgess, 2000). Specifically, it is known that patients are not randomly distributed among all hospitals and that similar patients are cared for at similar hospitals. These techniques adjust for non-randomly distributed, unmeasured characteristics that contribute to a patient's CABG mortality rate. All of these characteristics could contribute to a hospital's observed CABG mortality rate that may not be accounted for in a traditional patient-level logistic regression model. Not accounting for some of these factors, particularly patient-level factors, may cause a hospital's CABG mortality rate to appear better or worse than it should be. For example, if one hospital treats more patients from lower socioeconomic neighborhoods (a factor not accounted for in the mortality risk model but

known to be associated with CABG mortality), this so called "clustering" of such patients may increase the observed mortality rate of this hospital, thereby resulting in a higher than expected "observed-to-expected" (O/E) mortality ratio.

To demonstrate the validity and reliability of the hierarchical model, it was compared to the mortality prediction model developed using traditional logistic regression. Then, to assess the relationship between hospital CABG volume and mortality, annual hospital volume was first included as a continuous independent variable in both the traditional logistic regression and the hierarchical logistic regression models (using a random intercepts model). Second, to visualize the hospital volume-outcome relationship, the hierarchical model was used to plot the O/E ratio for each hospital against its annualized volume over the three years. Third, hospitals were grouped into volume categories depending upon the number of CABG procedures performed on average over the three years. Then, these categories were included as indicator variables in the hierarchical logistic regression to determine whether the different volume categories were significantly associated with higher or lower mortality.

Results

The CCMRP CABG database contains detailed patient-level clinical data on 57,388 isolated CABG surgery procedures in 83 hospitals in California from 2000 to 2002.[7] The average annual hospital CABG volume was 251 cases, with a range among individual hospitals of 39 to 1,277. The overall inpatient mortality rate was 2.71%, and the average hospital mortality rate was 3.30%, with a range among individual hospitals of 0.86% to 12.12%. On average, mean predicted mortality rates were higher among low-volume hospitals than among high-volume hospitals, which is consistent with previous data.

The hierarchical model resulted in very little change of the patient-level coefficients from the standard logistic regression model. None of the independent variables changed with respect to the direction of their association with mortality. In the hierarchical model, when annualized hospital volume was entered into the analysis as a continuous variable, it was significantly associated with risk-adjusted mortality (coefficient of -0.0007, odds ratio of 0.9994, and p-value of 0.0026 for every additional patient). For example, for a hospital with state average volume per year (n=251), adding 100 more CABG procedures would reduce the in-hospital mortality rate by 0.08%.

The expected number of deaths at each hospital was calculated by summing the probabilities of death for all patients at each hospital, using the hierarchical model. The observed-to-expected (O/E) ratios were then plotted against annualized volume for the three years of data. These plots are shown in Figure 4. Each dot in the figure identifies a single hospital. The mean O/E ratio computed using the hierarchical logistic regression model was 1.021, with a range of 0.426 to 1.512. Figure 4 reveals that higher volume CABG hospitals tend to cluster around an O/E of 1.0, with less variation in performance as compared to hospitals with annual volumes below 200, where there is significant variation in performance results. Further, Figure 4 demonstrates that not all low volume hospitals have higher severity-adjusted mortality rates, and in fact, some low volume hospitals have very low severity-adjusted mortality rates.

[7] Six hospitals submitted data for at least one complete year but did not want their results published.

Figure 4: Plot of Observed to Expected (O/E) Ratio Versus Annualized Hospital Volume Using Results from the Hierarchical Logistic Regression Model

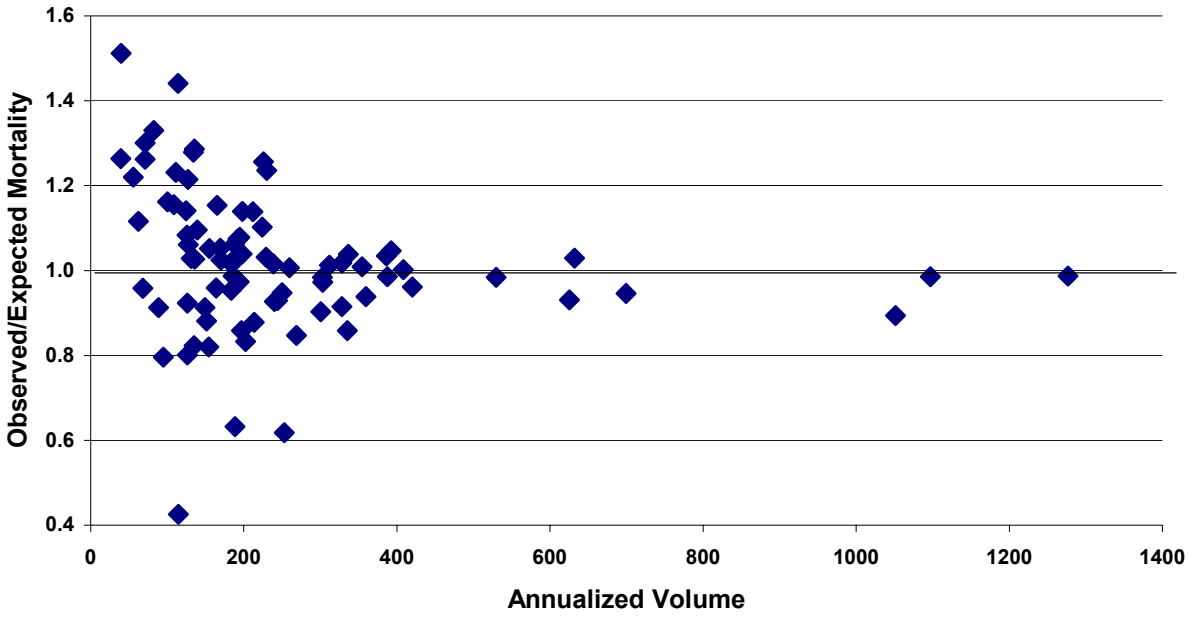


Table 6 presents the summary statistics when hospital volume was categorized into quartiles (<200, 200-299, 300-599, >=600) and dichotomized (>=450 and <450; and >=250 and <250). The quartiles were chosen because these volumes were used in the previous CCMRP report and because these cut-points split the data into four groups with a similar numbers of cases in each group. The split point of 450 procedures per year was chosen because of current recommendations by The Leapfrog Group (www.leapfroggroup.org). Again, the data show that patients face a reduced risk of dying from a CABG procedure in hospitals with higher annual volumes of CABG surgeries.

Table 6: Hospital Volume Groups and Predicted Mortality Outcomes

Volume Group	Hospitals (n=83) N (%)	Patients (n=57,387) N (%)	OR (95% CI)
>=600	6 (7)	16,145 (28)	0.56 (0.40, 0.79)
300-599	16 (19)	17,052 (30)	0.80 (0.63, 1.02)
200-299	14 (17)	8,168 (14)	0.74 (0.57, 0.97)
<200	47 (57)	16,022 (28)	Reference
>=450	7 (8)	17,734 (31)	0.65 (0.47, 0.89)
<450	76 (92)	39,653 (69)	Reference
>=250	26 (31)	35,286 (61)	0.73 (0.59, 0.89)
<250	57 (69)	22,101 (39)	Reference

What are the policy implications of these results? If, for example, all CABG patients went to hospitals with an annual volume of >=250 cases, an overall reduction in predicted mortality of 0.51% would result. In other words, assuming 25,000 CABG procedures are conducted each year, 50 lives would be saved annually. If all CABG patients went to hospitals in the >=450 volume group, a reduction in predicted mortality of 0.64% would result, or 110 lives saved annually. These projections assume that the higher-volume hospitals would continue to perform at their current standard of quality given increased volume.

APPENDICES

APPENDIX A: CLINICAL DEFINITION OF ISOLATED CABG FOR DATA YEARS 2000-2002

Definition/Description:
When any of the procedures listed in section A is performed concurrently with the coronary artery bypass surgery, the surgery will be considered non-isolated and the data element coded 'No.' It is not possible to list all procedures because cases can be complex and clinical definitions imprecise. When in doubt, the data abstractor should first seek an opinion from the responsible surgeon and then consult CCMRP.

Section A (Excluded):

- Any aortic aneurysm repair (abdominal or thoracic)
- Aorta-iliac-femoral bypass
- Aorta-renal bypass
- Aorta-subclavian-carotid bypass
- Caval-pulmonary artery anastomosis
- Coronary artery fistula
- Endarterectomy of aorta
- Excision of aneurysm of heart
- Extracranial-intracranial (EC-IC) vascular bypass
- Head and neck, intracranial endarterectomy
- Heart transplantation
- Implantation of cardiomyostimulation system (Note: Refers to cardiomyoplasty systems only, not other heart-assist systems such as pacemakers or internal cardiac defibrillators (ICDs))
- Mastectomy for breast cancer (not simple breast biopsy)
- Maze procedures, surgical or catheter
- Operations on structures adjacent to heart valves (papillary muscle, chordae tendineae, traebeculae carneae cordis, annuloplasty, infundibulectomy)
- Other open heart surgeries, such as aortic arch repair, pulmonary endarterectomy
- Repair of atrial and ventricular septa, excluding closure of patent foramen ovale
- Repair of certain congenital cardiac anomalies, excluding closure of patent foramen ovale (e.g., tetralology of fallot, atrial septal defect (ASD), ventricular septal defect (VSD), valvular abnormality)
- Resection of a portion of the lung (e.g., excision of an emphysematous bleb, lobectomy or segmental resection of lung). Does not include simple biopsy of lung nodule in which surrounding lung is not resected or biopsy of a thoracic lymph node
- Thoracic endarterectomy (endarterectomy on an artery outside the heart)
- Valve repairs or replacements
- Ventriculectomy

If a procedure listed in section B is performed concurrently with the coronary artery bypass surgery, the surgery will be considered an isolated CABG and the data element coded 'Yes,' unless a procedure listed in section A is performed during the same surgery. These particular procedures are listed because the Office has received frequent questions regarding their coding.

Section B

- Coronary endarterectomy
- Internal cardiac defibrillators (ICDs)
- Fem-fem cardiopulmonary bypass (a form of cardiopulmonary bypass that should not be confused with aortofemoral bypass surgery listed in Section A)
- Pacemakers
- Pericardiectomy and excision of lesions of heart
- Repair/restoration of the heart or pericardium
- Transmyocardial laser revascularization (TMR)

APPENDIX B: CCMRP 2000-2002 PARTICIPATING HOSPITALS DATA SUBMISSIONS BY YEAR, 1997-2002

Hospital Name	1997	1998	1999	2000	2001	2002
Alta Bates Medical Center	152	124	96	81	80	52
Alvarado Hospital Medical Center	144	153	148	115	113	-
Anaheim Memorial Medical Center	-	130	137	141	198	220
Brotman Medical Center	-	-	-	-	-	71
CA Pacific Medical Center-Pacific Campus	-	176	172	212	197	184
Cedars-Sinai Medical Center	447	421	352	395	308	282
Centinela Hospital and Medical Center	-	-	-	-	-	183
Community Memorial Hosp. of San Buenaventura	-	202	188	182	184	185
Dameron Hospital	-	107	109	88	78	100
Daniel Freeman Memorial Hospital	-	173	156	145	104	-
Desert Regional Medical Center	-	122	133	-	-	230
Doctor's Medical Center - San Pablo	73	96	81	64	54	49
Dominican Hospital	136	136	160	143	127	109
El Camino Hospital	-	49	108	91	92	102
Encino Tarzana Regional Medical Center	-	145	172	158	147	158
Enloe Medical Center	-	-	210	221	244	220
Fountain Valley Regional Hospital	-	-	-	-	-	170
Glendale Adventist Med Ctr - Wilson Terrace	-	57	267	239	204	193
Glendale Memorial Hospital and Health Center	-	223	178	178	204	203
Granada Hills Community Hospital	67	74	72	50	39	29
Hoag Memorial Hospital Presbyterian	249	247	255	309	253	245
Huntington Memorial Hospital	-	-	-	248	222	171
John Muir Medical Center	-	128	126	133	140	135
Kaiser Foundation Hospital-Los Angeles	1,013	1,289	1,597	1,531	1,236	1,062
Kaiser Foundation Hospital-San Francisco	-	992	1,282	1,176	1,101	1,014
Kaweah Delta Hospital	263	299	402	390	347	341
Lakewood Regional Medical Center	-	-	-	-	-	134
Loma Linda University Medical Center	-	-	402	389	308	309
Long Beach Memorial Medical Center	-	378	363	399	397	363
Marin General Hospital	-	-	67	82	65	40
Memorial Medical Center of Modesto	274	276	299	309	372	382

APPENDIX B: CCMRP 2000-2002 PARTICIPATING HOSPITALS DATA SUBMISSIONS BY YEAR, 1997-2002 (CONTINUED)

Hospital Name	1997	1998	1999	2000	2001	2002
Mercy General Hospital	1,327	1,238	1,040	1,113	1,075	967
Mercy Medical Center-Redding	-	112	216	253	-	-
Mercy San Juan Hospital	222	186	184	168	164	116
Methodist Hospital of Southern California	215	213	282	248	197	146
Mills-Peninsula Hospital	156	167	136	133	96	-
Mission Hospital and Regional Medical Center	-	-	237	214	170	198
Palomar Medical Center	170	179	115	127	130	161
Presbyterian Intercommunity Hospital	-	117	73	127	-	-
Providence Holy Cross Medical Center	-	-	106	104	76	121
Providence St. Joseph Medical Center	-	-	192	157	123	98
Redding Medical Center	539	498	518	654	721	723
Saddleback Memorial Medical Center	-	175	132	141	136	117
Salinas Valley Memorial Hospital	-	135	323	344	285	273
San Jose Medical Center	-	-	66	105	60	-
Santa Barbara Cottage Hospital	-	261	272	309	297	-
Santa Rosa Memorial Hospital	-	-	187	188	168	136
Scripps Green Hospital	-	-	229	235	197	145
Scripps Memorial Hospital - La Jolla	327	347	424	420	368	375
Scripps Mercy	-	-	256	166	170	158
Sequoia Hospital	240	243	234	228	166	172
Seton Medical Center-Heart Institute	694	555	481	505	277	228
Sharp Chula Vista Medical Center	269	262	290	330	325	329
Sharp Grossmont Hospital	-	133	148	199	185	209
Sharp Memorial Hospital	-	304	251	234	243	256
St. Bernardine Medical Center	-	405	557	535	492	562
St. Francis Medical Center	-	62	96	94	110	122
St. Helena Hospital	171	248	261	276	230	171
St. John's Hospital and Health Center	129	126	148	144	126	111
St. Joseph Hospital - Orange	-	293	313	271	260	248
St. Joseph's Medical Center of Stockton	317	293	269	277	352	279
St. Jude Medical Center	-	204	293	261	239	216
St. Mary's Hospital and Medical Center	-	-	553	414	66	-
St. Vincent Medical Center	-	-	282	290	195	199
Summit Medical Center	168	157	197	337	774	785
Sutter Memorial Hospital	840	694	623	615	659	602

APPENDIX B: C CMRP 2000-2002 PA RTICIPATING HOSPITALS DATA SUBMISSIONS BY YEAR, 1997-2002 (CONTINUED)

Hospital Name	1997	1998	1999	2000	2001	2002
The Hospital of the Good Samaritan	-	-	649	526	351	348
Torrance Memorial Medical Center	198	203	202	240	196	171
Tri-City Medical Center	209	222	196	172	167	-
UC Irvine Medical Center	-	94	70	68	-	-
UCD Medical Center	-	59	169	164	218	171
UCLA Medical Center	-	190	177	161	113	105
UCSF Medical Center	-	141	134	152	119	-
Valley Presbyterian Hospital	-	-	-	52	38	29
Washington Hospital - Fremont	166	168	168	164	162	128
Western Medical Center-Anaheim	-	-	-	-	-	250
Western Medical Center-Santa Ana	-	-	-	-	-	135
All Hospitals	**9,175**	**14,681**	**19,281**	**19,384**	**17,310**	**16,496**

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