Coronary Artery Bypass Graft Surgery — 1994-95 Data

Research Methods and Results

The Pennsylvania Health Care Cost Containment Council
April 1998

TABLE OF CONTENTS

Foreword

The Pennsylvania Health Care Cost Containment Council (PHC4) is issuing a 1994-1995 Coronary Artery Bypass Graft Surgery (CABG surgery) Report. This topic continues to be of great interest to the residents of Pennsylvania because heart disease is the leading cause of death in the Commonwealth. The CABG Report is particularly important because, for the first time, it includes data for specific payor plans, as well hospitals and cardiothoracic surgeons.

The health care industry is experiencing enormous change, and part of this movement involves a shift in traditional roles, especially as it relates to the management of health care. Payors have evolved from the traditional approach of financing the delivery of health care to one of influencing, on an increasing basis, the organization of the delivery system. While it is important to remember that patients are not *treated* by payors, it is increasingly the case that in today's market, payors, directly or indirectly, influence the delivery of care. As emerging and evolving health systems work to achieve positive outcomes for those belonging to their health plans in the most cost-efficient manner, it is important to monitor and report on these issues.

This report is a first step in that direction in that it includes for the first time in a Council report outcome data about health plans who had enrollees undergoing coronary artery bypass graft (CABG) surgery. In doing so, it builds upon previous Council CABG reports that have included data about Pennsylvania hospitals and cardiothoracic surgeons.

It is important to note that this first step is a limited one. Although the Council's ultimate goal is to provide an increasingly comprehensive picture of the system of care, this report focuses on only one procedure. Although a high-volume, high cost procedure, CABG surgery generally represents a small portion of the overall hospital admissions and plan enrollees for health plans. While this report represents a limited view of managed care, it is nevertheless an important step and can serve as a baseline for future reporting. Future reports can better serve the public with the inclusion of additional enrollment information, data which can only be provided by the health plans themselves and which can serve to overcome some of the limitations of this project.

What is included in the 1994-95 CABG Report?

Combining 1994 and 1995 data as a single figure, the report displays:

- risk-adjusted in-hospital mortality outcomes for hospitals, surgeons, and payors.
- risk-adjusted post-operative length of stay for hospitals, surgeons, and payors.
- primary hospital referrals for health plans.
- case-mix adjusted average charge for hospitals.

What is new for the 1994-95 CABG Report?

The 1994-95 CABG Report represents the fifth CABG report published by the Council. Those readers familiar with the previous CABG reports will want to make note of a few important changes:

- For the first time, data for specific payor plans are included.
- Also for the first time in a CABG report, outcomes for *risk-adjusted, post-operative* length of stay are reported for hospitals, surgeons, and payor plans.
- This report includes two calendar years of data with data from both years being reported as a single figure.
- Tracheostomy patients were *not* "automatically" excluded as they had been in previous reports (i.e., they were excluded *only* if they met some other exclusion criteria such as undergoing concurrent valve surgery).
- Several risk factors from previous reports were defined differently for this report. For cardiogenic shock and acute renal failure to be considered, they had to occur pre-operatively. Further, in the case of cardiogenic shock, documentation from the medical record was used to identify those patients with this diagnosis. For *Atlas*™ ASG, there are now *two* disease groups that primarily include CABG cases: myocardial infarction and angina.

What is included in this *Research Methods and Results* document?

This document, *Research Methods and Results*, serves as a technical supplement to the 1994-1995 CABG Report. It represents a "scaled-down" version of the Technical Report that was issued with previous CABG reports. This document describes:

- The process that the Council used in determining significant predictors of in-hospital mortality and length of stay and the results of that analyses.
- The calculations used to determine the expected range and test of significance for in-hospital mortality and length of stay.
- The methodology used in determining hospital average charge.
- A five-year CABG risk factor summary.
- Analysis that quantifies the extent to which hospital and physician characteristics and payor explain in-hospital mortality after accounting for patient risk.

Also included is a "Fact Sheet" (Appendix A), which provides a "quick glance" of some important figures of the 1994-95 CABG Report.

The Council wishes to thank . . .

Throughout this study, the Council made decisions in conjunction with its Technical Advisory Group (a standing committee charged with overseeing all technical and methodological aspects of the Council's research) and its Clinical Advisory Panel (an ad hoc committee charged with assisting the Council in clinical and ICD.9.CM coding matters). The Council's Payor Advisory Group provided special guidance on matters relating to the payor data included in this report. We appreciate the interest that these groups have shown in this study and are grateful for their advice.

The Council would also like to thank the Joint Committee on Health Care Data of the Hospital and Healthsystems Association of Pennsylvania, the Pennsylvania Medical Society, and the Pennsylvania Osteopathic Medical Association, as well as the Pennsylvania Department of Health, the Department of Public Welfare, Insurance Federation of Pennsylvania, the Managed Care Association of Pennsylvania, and MediQual Systems, Inc. for their assistance and support throughout this process.

A special thank you goes to the cardiothoracic surgeons and cardiologists who took the time to personally advise Council staff and helped review the cardiogenic shock cases included in this report: David Campbell, MD, Paul Casale, MD, George Cimochowski, MD, Ancil Jones, MD, Timothy Gardner, MD, and George Magovern, Jr., MD.

Finally, the Council wishes to acknowledge the efforts of the hospitals, surgeons, and payors who checked and rechecked the data included in this study.

As we strive toward the goal of quality health care at lower costs, we truly appreciate the efforts that these individuals and groups committed to this project.

The *1994-1995 CABG Report* and this document, *Research Methods and Results*, are available to the public upon request and can be obtained by contacting the Council.

Pennsylvania Health Care Cost Containment Council
225 Market Street, Suite 400
Harrisburg, PA 17101

Phone: (717) 232-6787
Fax: (717) 232-3821

***Website*: http://www.phc4.org**

Office Hours: 8:30 a.m. - 5:00 p.m.

Advisory Groups

to the Pennsylvania Health Care Cost Containment Council

Technical Advisory Group Members:

David B. Nash, MD, MBA, *Chair*, Associate Dean and Director, Office of Health Policy & Clinical Outcomes, Thomas Jefferson University Hospital, Jefferson Health System, Philadelphia, PA

J. Marvin Bentley, PhD, Associate Professor of Health Economics, School of Public Affairs, Penn State Harrisburg, Middletown, PA

David B. Campbell, MD, Professor of Surgery, Penn State Geisinger Health System, M.S. Hershey Medical Center, Hershey, PA *(cardiothoracic surgeon advisor)*

Paul N. Casale, MD, FACC, The Heart Group, Lancaster, PA *(cardiologist advisor)*

Donald E. Fetterolf, MD, MBA, Senior Medical Officer, Highmark/Alliance Ventures Incorporated, Pittsburgh, PA

George R. Green, MD, Physician-In-Chief, Division of Allergy & Immunology, Department of Medicine, Abington Memorial Hospital, Abington, PA

Sheryl F. Kelsey, PhD, Professor of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA

Judith R. Lave, PhD, Professor of Health Economics, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA

James R. Grana, PhD, Director of Research, USQA/Aetna US Healthcare, Blue Bell, PA

Clinical Advisory Panel Members:

Janet L. Anderson, MPA, RRA, *Co-Chair*, Director of Medical Information Services, Penn State Geisinger Health System, Geisinger Medical Center, Danville, PA

Mary Anne Darragh, RRA, Senior Vice President, Quality and Health Information Management, Allegheny Health Education and Research Foundation, Allegheny University Hospitals, Allegheny General, Pittsburgh, PA

W. Beth Hackman, Chief Operating Officer, Keystone Peer Review Organization, Harrisburg, PA

Ancil A. Jones, MD, FACC, Cardiologist, Crozer-Chester Medical Center, Upland, PA

Barbara Kane, RRA, Independent Coding Consultant, Ardmore, PA

Joseph P. Kosich, RRA, Assistant Vice-President, Health Information Management, Temple University Hospital, Philadelphia, PA

Susan L. Lawrence, RRA, Administrator, Clinical Resource Management, Lehigh Valley Hospital, Allentown, PA

Judy A. Lysiak, RRA, Coding & Registry Supervisor, Penn State Geisinger Health System, M.S. Hershey Medical Center, Hershey, PA

Ellen Myers, RN, Director, Quality Assurance, Community Hospital of Lancaster, Lancaster, PA *(retired)*

Clinical Advisory Panel Members – continued:

Dawn G. Washko, RRA, MedisGroups Program Coordinator, Northeast Regional Council, Hospital Association of Pennsylvania, Blakely, PA *(no longer on staff)*

Nina Zimmer, RRA, Associate Director, Medical Records, Thomas Jefferson University Hospital, Jefferson Health System, Philadelphia, PA

Payor Advisory Group Members:

Leonard A. Boreski, *Chair*, PA Chamber of Business & Industry, Harrisburg, PA

Samuel Capricci, Capital Blue Cross, Harrisburg, PA

Paul N. Casale, MD, The Heart Group, Lancaster, PA

Alanna Clark, HealthAmerica, Harrisburg, PA

Darrell DeMoss, CIGNA Property & Casualty Companies, Philadelphia, PA

Daniel Garofalo, Hospital & Healthsystem Association of PA, Harrisburg, PA

James R. Grana, PhD, USQA/Aetna US Healthcare, Philadelphia, PA

David Gulya, Educators Mutual Life Insurance Co., Lancaster, PA

James A. Heisey, PA Department of Public Welfare, Harrisburg, PA

John Killian, Esq., Killian & Gephart, Harrisburg, PA

Kim Kockler, Managed Care Association of Pennsylvania, Harrisburg, PA

Sam Marshall, Insurance Federation of Pennsylvania, Philadelphia, PA

Mary Ellen McMillen, Independence Blue Cross, Harrisburg, PA

Joseph Reilly, Highmark, Camp Hill, PA

Laura Reimer, Prudential Health Care, Horsham, PA

Lynne M. Rothney-Kozlak, Independence Blue Cross, Philadelphia, PA

David Smith, Oxford Health Plans of Pennsylvania, Philadelphia, PA *(no longer on staff)*

David Wilderman, Pennsylvania AFL-CIO, Harrisburg, PA

William Wolfe, Keystone Health Plan Central, Camp Hill, PA

Data Finalization

Background

The Pennsylvania Health Care Cost Containment Council is mandated by state law to collect and disseminate health care data using guidelines set forth by the Health Care Financing Administration. These data, obtained from the UB-92 (Uniform Billing Form), are submitted quarterly to the Council by Pennsylvania hospitals as directed under Section 912, Data Submission Requirements, of Act 89. The data include demographic information, hospital charges, payor identification, and diagnosis and procedure codes using ICD.9.CM *(International Classification of Diseases, Ninth Revision, Clinical Modification)*.

The data used for this report were submitted originally to the PHC4 by hospitals which perform coronary artery bypass graft surgery (CABG surgery). Cases included in this study are those who were *discharged* in calendar years 1994 and 1995 after undergoing CABG surgery. The Council, in conjunction with hospitals and payor organizations, subsequently performed extensive data verification activities to finalize the data.

Hospital Data Verification

The Council relies on each hospital to carry out data element verification and provides assistance and guidelines for them to do so. As has been our practice in previous CABG reports, hospitals and surgeons were provided an opportunity to review and verify their patient-level data included in this report. Final patient-level data were sent to each hospital for their review prior to the analysis of these data. In particular, surgeons were given an opportunity to confirm that they did, indeed, perform the CABG surgery. Signatures were required to indicate final verification. Surgeons were also asked to provide additional information such as whether they were board certified in thoracic surgery and how many years they had been performing CABG surgery.

As an ongoing activity of the data verification and public report process, the Council identifies data quality concerns related to validity, accuracy, and completeness through computerized logical edits, manual data verification checks, and data auditing. No fewer than three sets of "data error" reports and corrections were exchanged between the hospitals and the Council staff to minimize the number of missing or invalid data entries. Data were also examined for abnormal patterns among hospitals, and, when found, these concerns were shared with hospitals before being resolved. Other specific critical issues, such as peculiar combinations of codes on a patient record, were also brought to hospitals' attention prior to data finalization. Because this is our first attempt at payor-specific reporting, we paid particular attention to the primary payor variable. Several hospitals were asked to re-examine certain payor identifications.

Hospitals were also given an opportunity to submit additional diagnosis and procedure codes beyond the required number of nine and six, respectively, to a maximum of fifteen diagnosis and nine procedure codes. Obtaining these codes added greatly to the clinical information in the data set.

There were a number of other data verification tasks for this report that merit special mention: the collection of additional clinical information and hospitals' verification of primary payor.

Collecting Additional Clinical Information

Cardiogenic shock. In comments that we received about previous CABG reports, hospitals and surgeons have been asking us (1) to use a clinical definition of cardiogenic shock rather than the ICD.9.CM coding guidelines or physician documentation of "cardiogenic shock," and (2) to identify those cases that had cardiogenic shock pre-operatively rather than adjust for cardiogenic shock occurring *anytime* during the hospitalization (thereby giving "credit" when patients develop cardiogenic shock *after* surgery). For this report, hospitals submitted supporting documentation from the patient's medical record indicating that cardiogenic shock was present pre-operatively.

In previous CABG reports cardiogenic shock was defined by an ICD.9.CM code. For this report, the identification of cardiogenic shock involved a number of steps. First, hospitals submitted supporting documentation for cases with one of the following present in the medical record *between admission and surgery (up to the induction of anesthesia)*.

- Hypoperfusion with a systolic blood pressure < 80 mm Hg and central filling pressure > 20 mm Hg without inotropes
- A cardiac index < 1.8 liter/minute/m^2
- Inotropes ± IABP required to maintain cardiac index 1.8 liter/minute/m^2

The second step involved a review of the medical record by Council staff (an RN with medical record expertise) and a six-member panel of cardiothoracic surgeons and cardiologists. This panel assisted staff in making final decisions on whether a case had met the required criteria for cardiogenic shock.

The following figures are provided regarding the cardiogenic shock variable. They reflect cases *before exclusions* were removed.

- If we had used the ICD.9.CM code as in previous years, we would have counted 1,013 cases of cardiogenic shock (2.3% of the cases).

- If we had used only the pre-operative designation submitted by the hospitals without further review of the medical record, we would have counted 580 cases of cardiogenic shock (1.3% of the cases).

- Using the pre-operative designation submitted by the hospitals and with further review of the medical record, we ended up with 397 cases of cardiogenic shock (0.9% of the cases).

By limiting the definition to pre-operative and by reviewing the medical record, we believe we have used the appropriate cardiogenic shock cases in our risk adjustment methodology.

Acute renal failure. Like cardiogenic shock, we have been asked to narrow the time frame for acute renal failure so that we do not give "credit" when patients develop this condition *after* surgery. The data verification software included a "check box" for hospitals to indicate "Yes"

or "No" as to whether a case had acute renal failure *present at any time between admission and surgery up to the induction of anesthesia*. We indicated that supporting documentation would be required only if abnormal patterns were identified. After data were submitted, we conducted a hospital by hospital analysis and found no unusual patterns that required follow up.

Hospital's Verification of Primary Payor

During the data verification process, hospitals were asked to verify the primary payor for each CABG surgery. The primary payor field as submitted in the original UB-92 format is a 25-character field.

The first two digits contain information about the payor *type*. For the remaining 23 characters (alpha text), hospitals are asked to give us the "payor name." The data verification process became particularly important here because we needed specific information. We were particularly interested in differentiating fee-for-service and licensed HMOs.

We reviewed the plan names found in the alpha text portion (after the original data were submitted) and were able to construct a list of the most frequently reported plan names to use in data verification (Appendix B). Additional information was used in generating this list as well: all licensed HMOs from the Departments of Health, Insurance, and Public Welfare and from HCFA (Medicare) were included on this list. Further, this list included out-of-state designations (e.g., Medicare—out of state). The list was incorporated into the data verification software to allow hospital personnel to simply "point and click" to choose the correct payor, rather than type the entry. The list could be sorted in a number of different ways (e.g., by the first digit, by the second digit, or by the plan name). When hospitals selected plan names from this list, the first two digits (i.e., the payor *type*) were automatically "backfilled" with the appropriate value for the plan that they chose.

Hospitals were asked to pay particular attention to the primary payor field during verification, but we recognized that hospitals might not be able to provide precise payor information on *all* patients. In response, they were able to choose "unknown payor" entries from the list of most frequently reported plan names. In some instances, for example, hospitals were able to identify the primary payor of a case as "Blue Cross" but could give us no more detail. These patients were classified as "Blue Cross unknown." In other instances, no information was provided to us about the primary payor, so these cases were classified simply as "unknown."

Believing that the hospitals had provided as much information as they could for these "unknowns," we went forward with the payor data exchange process, believing that the payors could provide additional information on these cases. The next section describes the *payor* data exchange process.

Payor Data Exchange

Payors have evolved from the traditional approach of financing the delivery of health care to one of influencing, on an increasing basis, the organization of the delivery system. While it is important to remember that patients are not *treated* by payors, it is increasingly the case that in today's market, payors influence, directly or indirectly, the delivery of care.

As part of its strategic planning, the Council identified as its primary future role the development of information about the impact and influence of managed care on health care cost and quality issues. The 1994-95 CABG report is a first step in that direction. Recognizing that a Payor Advisory Group would be helpful in advising us with these issues, one was formed in February 1997. A list of members is included earlier in this document.

Following the hospital data verification process for this report, payors were given the opportunity to examine the information that the hospitals gave us regarding the assignment of the primary payor. This was a *voluntary* process that was coordinated through representatives of the payor community. Some payors took the opportunity to verify the primary payor assignment and others did not. The data from the hospitals indicated that 34 reportable contracts/companies/plans had 30 or more (30 cases is the Council's threshold for public reporting). Of these 34, 19 were examined by the participating payor companies that represented them. In addition, two payors with fewer than 30 cases said they wanted to verify their data but later decided not to.

For those payors participating in the data exchange, a software package was created to display the cases that hospitals attributed to the payors, including hospitalization and patient identification fields (such as admit and discharge dates, patient date of birth and social security numbers). Fields were also provided to differentiate between the payor's individual contracts.

The cases that were identified by the hospitals as "Blue Cross unknown" were divided and distributed to the indemnity Pennsylvania Blue Cross companies according to the patient's home zip code.

Participating payors examined the information in this software, matching the identification information back to their own databases to make certain that the case was indeed paid for by them, and, where necessary, correcting the contract type. Cases that the payor believed to be attributed to them by mistake were marked and returned. After Council staff reviewed these "rejected cases" to make certain that they did not include an abnormally high number of mortalities or high length of stay cases, they were removed from the payor's data.

In addition, payors were offered the opportunity to provide the Council with "added" cases from their own databases that were not attributed to them by the hospitals. Six payors did so. Identification fields for these "added" cases were given to Council staff, who matched them with the CABG data set to find the whole record. After these cases were identified, some turned out to already have been excluded, some were taken from the "unknown" payor category, and some were already attributed to other payors that verified their data.

This last category of cases that were claimed by more than one payor ("conflict" cases) were primarily claimed by Blue Cross companies. Upon investigation, this was found to be caused

by confusion regarding who was responsible for the case; one Blue Cross company may manage the hospitalization and make initial payment but be reimbursed by another Blue Cross company that actually is financially responsible. After a phone conference that included representatives from involved Blue Cross companies, it was decided that these cases would be attributed to the companies that were financially responsible for the hospitalization.

In summary, 89.3% of the cases used in the payor analysis (except for Medicare fee-for-service) were examined to some degree by the participating payors. Of these, 86.1% have the same payor attribution that the hospitals originally provided. The payor data exchange process resulted in the successful identification of the payor in 71.3% of the previously "payor unknown" cases; however, at the same time, payors rejected cases that hospitals had originally indicated "belonged" to them.

In-hospital Mortality Outcomes

"Who" are Reported

- Hospitals
- Surgeons
- Payors

"What" is Reported

- Actual in-hospital mortality
- Expected in-hospital mortality range *(risk-adjusted)*
- Notation if actual is significantly higher or lower than the expected range

Study Population

Inclusion Criteria. The CABG study population includes those patients discharged from Pennsylvania hospitals in calendar years 1994-1995 after undergoing coronary artery bypass graft (CABG) surgery (as identified by one of the following procedure codes in the medical record):

36.10 bypass, aortocoronary, for heart revascularization, unspecified
36.11 bypass, aortocoronary, one coronary artery
36.12 bypass, aortocoronary, two coronary arteries
36.13 bypass, aortocoronary, three coronary arteries
36.14 bypass, aortocoronary, four or more coronary arteries
36.15 bypass, artery, single internal mammary, coronary
36.16 bypass, artery, double internal mammary, coronary
36.19 revascularization, with bypass anastomosis, other specified

Exclusion Criteria. Exclusion criteria were identified two ways. First, with assistance from the Technical Advisory Group, we identified "automatic" exclusion criteria. Cases meeting one of these criteria (based on information contained in the medical record) were automatically excluded from the study. Second, hospitals and physicians were given an opportunity to request that individual cases be excluded. The table below displays the exclusion criteria, number of cases excluded, and percent mortality for each exclusion category.

Table 1. Exclusions from analysis

	Cases		Mortality
	#	%	%
Total cases *before* exclusions	43,729	100.0	3.9
Exclusions:			
Patients designated as "clinically complex"†	5,107	11.7	9.8
Patients who left against medical advice	14	< 0.1	0.0
Patients whose age was < 30 years	23	< 0.1	0.0
Patients in hospitals performing fewer than 30 CABG procedures	8	< 0.1	0.0
Total exclusions	5,152	11.8	9.7
Total cases to be *included* in report	38,577	88.2	3.1

Note: No CABG hospital closed since the reporting period (1994-1995). Such hospitals would have been excluded.

† cases whose principal diagnosis was not cardiac related, cases excluded during individual case review, and cases undergoing certain procedures during the same admission (as defined by one of the following procedures — ICD.9.CM codes are in parentheses):

heart transplant (33.6, 37.5)
lung transplant (33.5) (new for this report)
concurrent valve surgery (35.10 - 35.14, 35.20 - 35.28, 35.99)
operations on structures adjacent to heart valves (35.31 - 35.35, 35.39)
creation of septal defect in heart (35.42)
repair of atrial and ventricular septa (35.50 - 35.54, 35.60 - 35.63, 35.70 - 35.73)
total repair of certain congenital cardiac anomalies (35.81 - 35.84)
other operations on valves and septa of heart (35.91 - 35.95, 35.98)
other heart revascularization (36.3)
repair of aneurysm of coronary vessel (36.91)
other operations on vessels of heart (36.99)
unspecified incision of heart/cardiotomy (37.10, 37.11)
excision of aneurysm of heart or other lesion of heart (37.32, 37.33)
implantation/replacement of automatic cardioverter/defibrillator (37.94 - 37.98) (revised for this report)‡
resection of abdominal aorta, thoracic vessel, abdominal arteries (38.44 - 38.46)
clipping of aneurysm/other aneurysm repair (39.51, 39.52) (new for this report)
diagnosis of constrictive pericarditis & undergoing pericardiectomy (423.2 in combination with 37.31) (new for this report)

‡ AICD: For previous CABG reports, these cases have only been excluded if the total system was implanted/replaced or if leads and pulse generator were implanted/replaced in combination. This year, all AICD cases were excluded.

Logistic Regression -- In-hospital Mortality Risk Adjustment Model

The first step in building the risk adjustment model is to identify *possible* risk-adjustment factors to in-hospital mortality. In doing so, the Council considered both clinical and demographic factors identified in the literature—taking into account the availability and usability of the variables in its data base. The Council also considered risk factors that were tested in previous CABG reports, considered comments received from previous CABG reports, and sought advice from its Technical Advisory Group. These possible risk-adjustment factors are called *candidate variables.*

Candidate Variables

The patient variables listed below were tested as *possible* predictors of in-hospital mortality during the Council's research. Logistic regression analysis was used to determine which ones were *significant* predictors of in-hospital mortality. The significant factors were then used in adjusting in-hospital mortality. In addition to testing MediQual's *Atlas*™ Admission Severity Group as a potential risk-adjustment factor, the Council independently analyzed 18 additional variables separate and apart from MediQual's index. The specific ICD.9.CM codes used to define these conditions are noted in parentheses. All codes are diagnosis codes, unless otherwise stated.

Acute Myocardial Infarction

Acute myocardial infarction as the principal diagnosis (410.x1 – initial episode) was used to identify acute myocardial infarction.

Admission Severity Group

Atlas™ Admission Severity Group (ASG) represents a summarization of patient risk based on clinical data found in the medical record. More detailed information on the *Atlas*™ Admission Severity Score is included in Appendix C.) ASG is defined as:

0 (no risk of clinical instability)
1 (minimal risk of clinical instability)
2 (moderate risk of clinical instability)
3 (severe risk of clinical instability)
4 (maximal risk of clinical instability)

Admission Source

1 = referrals (includes referrals from physicians, clinics, HMOs, court/law enforcement)
2 = transfers (includes transfers from general acute care hospitals, skilled nursing facilities, other health care facilities)
3 = emergency room

Age & Age Squared

Testing for age squared, in addition to age, allows for non-linear relationships. Age and age squared were tested as continuous variables.

Cardiogenic Shock (pre-operative)

0 = no pre-operative cardiogenic shock
1 = pre-operative cardiogenic shock (identified by information in the patient's medical record)

Further information on how cardiogenic shock was defined and identified can be found under the "Data Finalization" section of this document.

Cardiomyopathy

0 = no cardiomyopathy
1 = cardiomyopathy (425.3, 425.4, 425.8, 425.9)

Complicated Hypertension

0 = no complicated hypertension
1 = complicated hypertension:
hypertensive heart disease w/ congestive heart failure (402.x1)
hypertensive renal disease w/ renal failure (403.x1)
hypertensive heart & renal disease w/ congestive heart failure (404.x1)
hypertensive heart & renal disease w/ renal failure (404.x2)
hypertensive heart & renal disease w/ congestive heart failure & renal failure (404.x3)
secondary hypertension (405.xx)

Concurrent PTCA

0 = no concurrent PTCA *(i.e., PTCA was not performed during the same admission as CABG)*
1 = concurrent PTCA (36.01, 36.02, 36.05, 36.09)

Diabetes

0 = no diabetes
1 = diabetes without complications (250.00 - 250.03)
2 = diabetes with complications (250.10 - 250.93)

Dialysis

0 = no dialysis
1 = dialysis (procedure codes 39.95 or 54.98 or diagnosis codes V45.1, V56.0 or V56.8)

Ethnicity

0 = not Hispanic
1 = Hispanic
2 = unknown

Gender

0 = male
1 = female

Heart Failure

0 = no heart failure
1 = left heart failure (428.1)
2 = unspecified heart failure (428.9)
3 = congestive heart failure (398.91, 428.0)

Note: In accordance with coding guidelines, for those cases having one of the above heart failure codes ***and*** a hypertension with congestive heart failure code (402.x1, 404.x1, 404.x3) in the record, only the "hypertension" code was used.

Prior CABG/Valve Surgery

0 = no previous CABG and/or valve surgery
1 = previous CABG and/or valve surgery (V45.81, V42.2, V43.3, 996.03, 414.02, or 414.03)

Race

W = White
B = Black
A = Asian or Pacific Island
I = Native American or Eskimo
N = other
U = unknown

Renal Failure

0 = no renal failure
1 = chronic renal failure (585)
2 = pre-operative acute renal failure (as indicated by hospital during data verification)

Further information on how pre-operative acute renal failure was defined and identified can be found under the "Data Finalization" section of this document. Because we narrowed the definition of acute renal failure to include only pre-operative acute renal failure, we did ***not*** test *unspecified* renal failure as a potential risk factor. Hospitals were asked to pay particular attention to cases with the unspecified renal failure code and to try to determine whether it was chronic renal failure or whether it met the definition of pre-operative acute renal failure.

Urban/Rural Status of the Patient's County of Residence

In an attempt to capture additional demographic information about the patient, we tested the urban/rural status of the patient's county of residence. The classification system below stems from Census Bureau data. Patient zip code was used to assign cases to this system.

AU = *absolutely urban (0% rural)*
DU = *dominantly urban (1-24% rural)*
MU = *mostly urban (25-49% rural)*
MR = *mostly rural (50-74% rural)*
DR = *dominantly rural (75-99% rural)*
AR = *absolutely rural (100% rural)*
OT = *out of state or unknown*

Year

The year the patient was discharged (1994 or 1995) was tested because of the "natural" decline in CABG mortality over time.

Data Preparation

After cases to be excluded from analysis were removed, the cases were randomly split into two equal-size samples. Sample I is the development sample; Sample II is the cross validation sample. The number of cases and number of mortalities are shown below.

Table 2. Case counts and mortality by sample

In-hospital Mortality Model

	Sample I	***Sample II***	***Total***
Number of Cases	19,289	19,288	38,577
Number of Deaths	598	597	1,195
Mortality Rate	3.1%	3.1%	3.1%

Minimum Cell Size Assessment

The volume of cases in each candidate variable category was examined for minimum cell size assessment before the logistic regression analysis could be preformed. (A minimum of five expected cases in each cell—defined by the candidate variable categories crossed with in-hospital mortality—was used as a guide; however, if the variable had a large number of categories or if the number of total cases was small, some flexibility was used in determining a cut-off point.) Variable categories that met minimum cell size were considered to have sufficient volume to be considered in the backwards stepwise logistic regression analysis.

If the volume criteria was not met, mortality was evaluated to determine whether the variable (or variable category) should be considered despite its low volume. If a variable (or variable category) appeared to be highly correlated to mortality, it was retained for analysis. If a category of a categorical variable did not meet the volume or mortality criteria, it was combined with another category of similar mortality or with the next lowest category in the case of an ordered categorical variable.

Following is a list of the variable categories that were collapsed following minimum cell size assessment:

- **ASG.** There were 16 cases with a blank ASG. These cases were collapsed into the ASG=0 category.
- **Ethnicity.** There were 51 cases designated as unknown ethnicity. These cases were collapsed into the not Hispanic category.

- **Heart failure.** Heart failure was collapsed into a binary variable (yes/no). That is, left heart failure (192 cases) and unspecified heart failure (127 cases) were collapsed with congestive heart failure to form one "heart failure" category.
- **Race.** Several race categories were collapsed: Native America or Eskimo (18 cases), other (605 cases), and unknown (1,023 cases) were collapsed into an "other" race category.
- **Urban/rural status of patient's county of residence.** The absolutely rural category (295 cases) was collapsed into the dominantly rural category.

Appendix D contains frequency of occurrence and percent mortality data for each of the candidate variables after collapsing.

Model Selection – Main Effects Model

Model selection identifies the patient risk factors that are significant predictors of in-hospital mortality. The significant patient factors that contribute to in-hospital mortality were identified using multiple logistic regression. In general, the modeling step is comprised of several sub-processes including model selection (results in Table 3), cross validation (discussed below and results in Table 3), and calculating multiple model adequacy measures (discussed later and results in Table 4). A backwards stepwise logistic regression model was constructed using the cases in Sample I. All tests of significance ($p < 0.10$) were based on the likelihood ratio.

Cross Validation – Main Effects Model

Following construction, the model was cross validated using the cases in Sample II. The first step in the cross validation process was to re-estimate the model built in the initial regression, using only the variables that were significant in Sample I, to determine which factors remain significant in Sample II.

The probability values (p-values) of those variables shown to be significant predictors of in-hospital mortality) are shown in the following table. Note that only one variable (concurrent PTCA) did not cross validate (as indicated by a Sample II p-value that is greater than 0.10).

Table 3. Probability values for each *significant* variable (p < 0.10 — Samples I & II)

Significant Predictors of In-hospital Mortality	Sample I	Sample II
Atlas™ ASG	.0000	.0000
Age (includes age & age squared)	.0000	.0000
Cardiogenic Shock	.0000	.0000
Concurrent PTCA	.0013	.1797
Complicated Hypertension	.0086	.0082
Dialysis	.0000	.0000
Gender	.0001	.0000
Heart Failure	.0000	.0000
Prior CABG and/or Valve Surgery	.0000	.0000

Note: A p-value of 0.10 was used to determine the significant risk factors for this report. In conducting the research for previous CABG reports, three models had been built (p-values were $p<0.01$, $p<0.05$ and $p<0.10$). Because we have traditionally chosen the $p<0.10$ model, we decided to build only the $p<0.10$ model.

Measures of Model Adequacy

For the second step in the cross validation process, the estimated coefficients from Sample I were applied to both Sample I and Sample II. The objective was to evaluate the model's performance in both Sample I and Sample II. The following measures were considered in evaluating the model's performance:

Percentage Explained: This term is used to refer to the percentage of the total (-2 log likelihood) attributable to the estimated model. (The "total" comes from a model containing only a constant and no risk factors.) *Range: 0% to 100%*

R-squared: Coefficient of Determination (R^2) refers to the percentage of the total variability among mortality responses (1 = died, 0 = discharged alive) for the patients in the sample that can be explained by the estimated model involving the specified risk factors. If no risk factors were considered in estimating a patient's probability of death, the overall death rate from the sample would be used to estimate **each** patient's probability of death. (The variability among mortality responses for all patients that remains after adjusting each patient's response by the overall death rate is referred to as the "total variability of mortality responses.") However, if the model including risk factors is used, the estimated probabilities of death for patients would vary according to their risk factors. *Range: 0% to 100%*

ROC Area: The area under the receiver operating characteristic curve measures the tendency of the estimated probabilities of death for patients in the sample that died to be ranked higher than those for patients who were discharged alive. *Range: 50% to 100%*

The values for these measures are displayed in the table below for both Sample I and Sample II. The table also includes the results from fitting the model using all of the data.

Table 4. Model adequacy measures — Main effects model

Measure	Sample I	Sample II	All Cases
Percentage Explained	18.4%	15.2%	17.3%
R^2	9.2%	7.6%	8.6%
ROC Area	82.8%	80.8%	82.0%

Note: The measures of model adequacy were slightly lower than those of previous CABG reports. (For the 1993 CABG report, *all cases*, the Percentage Explained was 20.4%, the R^2 was 13.0%, and the ROC was 82.9%.) Likely reasons for this decrease include the use of *pre-operative* cardiogenic shock and *pre-operative* acute renal failure as variables. In previous years, these two variables were tested as possible risk factors independent of whether they occurred pre- or post-operatively. Of course, the model's predictive power is lessened because those with post-operative cardiogenic shock or post-operative acute renal failure are not being considered. As expected, the measures of model adequacy are slightly less in the cross validation sample than in the development sample.

Interaction Analysis

For this report, the Council performed, on a limited basis, interaction analysis. We limited our interaction analysis primarily because of the relatively large number of candidate variables that were tested in the main effects model. Identifying interaction terms using all of the possible combinations of these variables would have been extremely complex and many terms would not have been clinically meaningful. Instead, we focused on two areas: (1) an examination of year with all candidate variables because—while our previous CABG reports have shown that many of the significant risk factors remain the same—some variables have been significant one year and not the next. Also, for any factor that has been significant in all previous CABG analyses, the values of the estimate and coefficient have not remained the same. (2) An examination of demographic characteristics. All interaction terms were tested using backwards stepwise logistic regression. All tests of significance were based on the likelihood ratio.

Table 5. Interaction analysis results

Interaction Terms Tested	Significant Terms
• year (1994 or 1995) with each candidate variable	year with renal failure and year with heart failure
• gender and race	not significant
• ethnicity and race	not significant
• ethnicity and gender	not significant

Final Model Selection

We chose to go forward with the model containing only main effects (main effects model) for in-hospital mortality rather than incorporate the interaction terms. The interaction analysis added only two significant variables, and neither of the two cross validated. Further, including the interaction terms increased the ROC area to only 82.9% (main effects model was 82.8%). The effort required to incorporate these two terms was not justified.

Calculation of Outcome Measures — In-hospital Mortality

The specific information used for in-hospital mortality (risk factor weights and calculations) is displayed in Tables 6 and 7.

Actual In-hospital Mortality Rate

This rate is determined by dividing the total number of deaths (i.e., cases with a discharge status of "20") by the total number of cases.

Expected In-hospital Mortality

Risk factors. A total of 19 variables, including admission severity (which is derived from a collection of 25 predictor variables for the myocardial infarction disease group and 7 predictor variables for the angina disease group), were tested as possible risk factors during the Council's research. Ten of the 19 were significant and were used as risk-adjustment factors for in-hospital mortality. Table 6 identifies the significant risk factors.

Calculating the expected number of deaths. The first step in calculating the expected number of deaths is to estimate the probability of death for each patient. The number of expected deaths for each hospital, surgeon, and payor is obtained by summing their patients' probabilities of death. Probability of death was estimated by using the statistical technique of logistic regression. In logistic regression, each category for each statistically significant clinical or demographic factor is assigned a coefficient or "weight." A factor category's weight

is higher (lower) if patients with that factor category tend to have a higher (lower) chance of mortality. These weights, determined using the 1994-95 statewide CABG data set, were used to estimate each individual patient's probability of in-hospital death given the risk factors of the patient. The weights used in calculating probability of death are displayed in Table 6. In general the equation to calculate a patient's probability of death is:

$$\text{(constant)} + \text{(age coefficient)(age)} + \text{(age}^2\text{ coefficient)(age}^2\text{)/1,000} + \text{(risk factor category coefficients)}$$

[from Table 6]

The results for all patients are then summed for each hospital, surgeon, and payor to determine the expected number of deaths. The specific calculations performed to estimate a patient's probability of death are summarized in Table 7.

Expected range. The expected *range* reflects upper and lower limits "around" the expected death. The width of the range is determined by both volume and diversity of patient risk. Specific calculations to determine expected range are displayed in Table 7. For those cases for which calculations yield a negative lower bound, zero is reported as the lower bound. The expected range of deaths allows readers of the report to determine:

a. If a hospital (or surgeon or payor) is statistically significant, whether it is barely within the critical level (.05) or well past the .05 level.
b. If a hospital (or surgeon or payor) is <u>not</u> statistically significant, the corresponding mortality rate that would be necessary for significance.

If the number of mortalities is within the expected range but very close to one end of the range, it implies that the p-value was close to .05. If it is closer to the middle of the range, its p-value is much greater than .05. Similarly, mortality far outside the expected range is highly significant, while one with a mortality outside but near the range would have a p-value close to .05.

Statistical Test of Significance

A statistical rating was determined for each reporting level (hospital, surgeon, and payor) based on a comparison of actual to expected in-hospital deaths. The statistical test used was the z-test. A circle ('o') is used in the reports to denote significantly *lower* number of deaths than expected. An asterisk ('*') is used to denote significantly *higher* number of deaths than expected.

The statistical test of significance for in-hospital mortality is based on a comparison of actual to expected deaths *within* an individual hospital, hospital-surgeon combination, or payor.

Coefficients & Odds Ratios

The coefficients associated with the significant risk factors and their p-values are listed below. The entire data set was used in creating the final coefficients (i.e., Sample I and Sample II were "recombined" and the coefficients were re-estimated). Accompanying these coefficients is the odds ratio for each risk factor or risk factor category. For a binary variable, this ratio is the change in the odds (probability of death/probability of survival) for a patient with the risk factor category compared to a patient without it.

Table 6. Coefficients and odds ratios for significant predictors of in-hospital mortality

Variable	Coefficient	p-value	Odds Ratio
Constant	- 2.8800	.0092	
Atlas™ ASG		.0000	
ASG 0 / blank (16 blank ASG cases)	- 1.5361		.22
ASG 1	- 0.8876		.41
ASG 2	- 0.2326		.79
ASG 3	0.4588		1.58
ASG 4	2.1975		9.00
Age	- 0.0599	.0945	*Not applicable*
Age-squared (divided by 1,000)	0.6599	.0147	*Not applicable*
Cardiogenic Shock	1.7563	.0000	5.79
Concurrent PTCA	0.4345	.0011	1.54
Complicated Hypertension	0.5367	.0002	1.71
Dialysis	1.8052	.0000	6.08
Gender *(female)*	0.4462	.0000	1.56
Heart Failure	0.7955	.0000	2.22
Prior CABG and/or Valve Surgery	1.2878	.0000	3.63

The coefficients from the above table suggest an increase in mortality:

- as severity increases *(being an ordered categorical variable, the coefficients are as expected; that is, the higher levels are associated with an increased risk of in-hospital mortality).*
- as age increases (from approximately age 45 and up).
- for patients with pre-operative cardiogenic shock.
- for patients who underwent PTCA during the same admission as CABG.
- for patients with complicated hypertension.
- for patients undergoing dialysis.
- for females.
- for patients with heart failure.
- for patients who had prior CABG and/or valve surgery.

Table 7. Calculations used in in-hospital mortality analysis

Total Cases:	Number of hospitalizations after exclusions.
Actual Deaths:	Total number of deaths (death is a discharge status equal to 20)
Percentage:	Total number of deaths / Total number of cases treated
Expected Deaths:	Sum of each patient's probability of death (PD)
Percentage:	Total number of expected deaths / Total number of cases treated
	To calculate a patient's probability of death:
	Step 1: Calculate BX:
	BX = -2.8800 [constant] + (-0.0599)(patient's age) + (0.6599)((patient's age)^2 /1,000) + (risk factor coefficients) [from Table 6]
	Step 2: Calculate the estimated probability of death (PD) using BX:
	PD = e^{BX} / $(1 + e^{BX})$ where e ≈ 2.7182818285
Test Statistic:	(Actual Deaths - Expected Deaths) / Standard Deviation of Mortality
	To compute Standard Deviation of Mortality:
	Step 1: Compute the estimated variance of each patient's probability of death:
	VARPAT = (PD) (1-PD)
	Step 2: Calculate the Standard Deviation of Mortality
	SUMVAR = sum of VARPAT across all cases Standard Deviation of Mortality = square root of SUMVAR
p-value (two-sided):	Calculated using test statistic as a normal z-score
Statistical Rating:	If .05 > p-value and test statistic > 0, then more deaths than expected (denoted as '*') If .05 > p-value and test statistic < 0, then fewer deaths than expected (denoted as 'o') Otherwise, number of deaths were within the expected range
Expected Range:	Lower limit = Expected Deaths - 1.960(Standard Deviation of Mortality) Upper limit = Expected Deaths + 1.960(Standard Deviation of Mortality)

Post-operative Length of Stay Outcomes

"Who" are Reported

- Hospitals
- Surgeons
- Payors

"What" is Reported

Post-operative length of stay was calculated by subtracting the CABG procedure date from the discharge date. To simplify the reading of this information, references to post-operative length of stay have been shortened to either "length of stay" or LOS.

- Average actual post-op length of stay in days (*geometric* means *not* arithmetic means—geometric means are discussed later in this section)
- Expected post-op length of stay range (*geometric* means *not* arithmetic means) *(risk adjusted)*
- Notation if actual is significantly higher or lower than the expected range

"Why" is Length of Stay Reported

The length of a hospital stay is often used as a measure of resource consumption. The information presented here is a first step at provoking questions about this issue for CABG surgery.

Exclusion Criteria

In addition to the exclusions identified for the in-hospital mortality analysis (discussed earlier) further exclusion criteria have been identified for post-operative length of stay analysis:

- Patients who died
- Atypical lengths of stay:
    - those over 30 days
    - those that were discharged with lengths of stay less than 3 days

Table 8. Exclusions from post-operative length of stay analysis

	Cases #	Cases %	Avg LOS *arithmetic*
Total cases included in the in-hospital mortality analysis	38,577	100.0	8.5
Exclusions:			
patients who died	1,195	3.1	14.0
patients with post-operative lengths of stay greater than 30 days	604	1.6	52.4
patients with post-operative lengths of stay less than 3 days	6	< 0.1	1.8
Total exclusions from post-op length of stay analysis	1,805	4.7	26.8
Total cases *included* in post-op length of stay analysis	36,772	95.3	7.6

When reporting in-hospital mortality outcomes, hospitals, surgeons, and payors with fewer than 30 cases were excluded because mortality is not normally distributed. For length of stay, however, outcomes for any number of cases can be reported because a natural log transformation was done, resulting in a normal distribution. For consistency, however, we did not report length of stay outcomes where the number of cases is less than 30.

Candidate Variables

The same candidate variables tested as possible risk-adjustment factors to in-hospital mortality were tested for length of stay, with two exceptions: (1) To account for possible length of stay differences between those who were transferred in vs. those who were not transferred in, the variable transfer-in status was also tested. This variable was a binary variable (*yes*, patient was transferred from a general acute care facility or *no*, patient was not transferred from a general acute care facility). (2) Urban/rural status of the patient's county of residence was not tested for length of stay.

The same candidate variable *categories* used for in-hospital mortality were used for length of stay. No further categories were collapsed (see previous discussion on "Results of Minimum Cell Size Assessment" under in-hospital mortality section).

Appendix E contains frequency of occurrence and average length of stay data *(arithmetic means)* for each of the candidate variables. (The variables are displayed after collapsing.)

Construction of the Length of Stay Model

While *logistic* regression was used to construct the models for in-hospital mortality, a general *linear* modeling approach was used for length of stay because it is a continuous variable. The model building steps were similar to those in the in-hospital mortality model development research. That is, the first task in constructing the length of stay model involved randomly splitting the data set into two, equal-size samples (after cases to be

excluded were removed). One set was used as the development sample (Sample I), and the other set was used as the cross-validation sample (Sample II). The model was constructed using Sample I, after a natural log transformation was done to adjust for skewness in the distribution. All tests of significance were based on general linear model F-tests. Only a $p<0.10$ model was built because it allowed the Council to be more liberal in identifying risk factors and that was the p-value used for the in-hospital mortality model.

Table 9. Case counts and average length of stay in days

	Sample I	Sample II	Total
Number of Cases	18,386	18,386	36,772
Average Length of Stay *(arithmetic)*	7.6	7.5	7.6
Average Length of Stay *(geometric)*	6.9	6.9	6.9

Cross Validation of the Length of Stay Model

The steps in the model cross validation were similar to those used for in-hospital mortality. The first step in the cross validation was to re-estimate the model, using only the variables that were significant in Sample I, to determine which factors remain significant in Sample II.

Table 10. Candidate variables tested as possible predictors of post-op length of stay

(Significance was determined at the p < 0.10 level. ~~Strikethrough~~ indicates non significance, with the numbers in parentheses indicating the order in which the variable "fell out" of the model.)

Variables	Sample I	Sample II
AMI principal reason for admission	0.0545	0.9683
Atlas™ ASG	0.0001	0.0001
Admission Source	0.0001	0.0002
Age	0.0001	0.0712
Age-squared	0.0001	0.0001
Cardiogenic Shock	0.0001	0.0001
Cardiomyopathy	0.0004	0.0328
Complicated Hypertension	0.0001	0.0001
Concurrent PTCA	0.0001	0.0001
Diabetes	0.0001	0.0001
Dialysis	0.0001	0.0001
~~Ethnicity~~ (2)	*ns*	——
Gender	0.0001	0.0001
Heart Failure	0.0001	0.0001
Prior CABG and/or Valve Surgery	0.0001	0.0001
Race	0.0001	0.0001
Renal Failure	0.0001	0.0027
~~Transfer in Status~~ (1)	*ns*	——
Year (1994 or 1995)	0.0001	0.0001

Note: ns = not significant at the p < 0.10 level.

Measure of Model Adequacy

For the second step in the cross validation process, the estimated coefficients from Sample I were applied to both Sample I and Sample II. The objective was to evaluate the model's performance in both Sample I and Sample II. R-squared was the measure considered in evaluating the model's performance. (See earlier discussion on R-squared).

Table 11. R-squared values by sample

Development	Cross Validation	All Cases
19.2 %	19.1%	19.2%

Calculation of Outcome Measures — Post-op Length of Stay

The specific information used to determine actual and expected length of stay (risk factor weights and calculations) is displayed in Tables 12 and 13.

Actual Length of Stay

The actual post-operative length of stay can be derived by subtracting the CABG procedure date from the discharge date. (If multiple CABG procedures were performed on different dates, the date of the first surgery was used.) The average length of stay is reported as a *geometric* mean not an arithmetic mean.

Because a natural log transformation of each length of stay value was done to adjust for skewness in the distribution, it was necessary to convert the logarithm values back to days when reporting or displaying length of stay. This process results in **geometric means** for length of stay, *not* arithmetic means. Unlike an arithmetic mean that is derived by summing individual values and dividing by the number of observations, a geometric mean is calculated by multiplying the individual values and taking the *n*th root of the product. Geometric means *are averages* and are the natural result when using the log transformation. A hospital's expected average was determined by averaging the expected lengths of stay for each CABG patient in that hospital. The hospital's expected average was then compared to its actual average (both are geometric averages) to determine whether the actual is significantly higher or lower than expected or within the expected range. Length of stay outcomes for surgeons and payors were evaluated in the same way.

Expected Length of Stay

Risk factors. Seventeen of the nineteen variables tested were significant and were used as risk-adjustment factors for post-operative length of stay. Table 12 identifies the significant risk factors.

Calculating the expected length of stay. Each category for each statistically significant clinical or demographic factor is assigned a weight or coefficient. *(See Table 12).* These coefficients are summed to compute each individual patient's expected length of stay given the risk factors of the patient. The coefficient for a category represents the estimated difference in mean (log) length of stay for this category versus the base category of that factor. Thus, the coefficient for the base category of a factor is always "0" (zero). When dealing with categorical variables in the length of stay model there is no particular importance to the order of these categories. The constant term in the model represents the predicted value for all categorical factors at the base level. The coefficients for the other levels within a factor represent adjustments to that "baseline." No adjustment is required at the base level for any factor because it is already accounted for in the constant. For example, a patient with an ASG of 0 or a blank ASG has a "0" or "baseline" coefficient; while a patient with an ASG of 4 would be adjusted *upward* by 0.279697993. *(See Table 12, below).* The order is not important because each ordering scheme would result in different coefficients, but the estimated *difference* between any pairs of levels would be the same (i.e., the *difference* between ASG 0

and ASG 4 would always be 0.279697993 independent of what the specific coefficients were for each). For quantitative factors (e.g., age and age-squared), there is always an adjustment since the "baseline" age is 0.

Expected range. The expected *range* reflects upper and lower limits "around" the expected length of stay. Specific calculations to determine the expected range are displayed in Table 13.

Statistical Test of Significance

A statistical rating was determined for each hospital, surgeon, and payor based on a comparison of actual to risk-adjusted expected length of stay. The statistical test used was the z-test (see Table 13 for specific calculations). A circle ('o') was used in the reports to denote significantly *shorter* stays than expected. An asterisk ('*') was used to denote significantly *longer* stays than expected.

Coefficients

Each category for each statistically significant clinical or demographic factor is assigned a weight or coefficient. These coefficients are used to compute each individual patient's expected length of stay given the risk factors of the patient.

Table 12. Coefficients (or "weights") for length of stay model

Variable	Natural Log LOS Coefficient	p-value
Constant	1.886192250	0.0001
AMI principal reason for admission		0.1619
yes	-0.007282754	
no	0.000000000	
Atlas™ ASG		0.0001
ASG 0 / blank	0.000000000	
ASG 1	0.017667108	
ASG 2	0.059494677	
ASG 3	0.144354442	
ASG 4	0.279697993	
Admission Source		0.0001
emergency room	0.001955009	
referrals	-0.029131003	
transfers	0.000000000	
Age	-0.008292768	0.0001
Age-squared (divided by 1,000)	0.136740487	0.0001
Cardiogenic Shock		0.0001
yes	0.222024642	
no	0.000000000	
Cardiomyopathy		0.0001
yes	0.064146183	
no	0.000000000	
Complicated Hypertension		0.0001
yes	0.122357896	
no	0.000000000	
Concurrent PTCA		0.0001
yes	0.077353226	
no	0.000000000	
Diabetes		0.0001
with complications	0.128403313	
without complications	0.023343497	
none	0.000000000	
Dialysis		0.0001
yes	0.243205756	
no	0.000000000	
Gender		0.0001
female	0.068032931	
male	0.000000000	
Heart Failure		0.0001
yes	0.173127323	
no	0.000000000	
Prior CABG/Valve Surgery		0.0001
yes	0.074188088	
no	0.000000000	
Race		0.0001
Asian/Pacific Island	0.087943801	
black	0.077645471	
other/unknown	0.010762489	
white	0.000000000	
Renal Failure		0.0001
acute (pre-operative)	0.083237709	
chronic	0.093383496	
none	0.000000000	
Year		0.0001
1994	-0.079326031	
1995	0.000000000	

Table 13. Calculations used in length of stay analysis

Total Cases: Number of hospitalizations *after exclusions*

Actual Mean LOS: Geometric mean of the length of stay across all cases

Calculate geometric mean length of stay (GMLOS):

Step 1: Calculate the natural log ($\ln$) of GMLOS:

$$\ln(\text{GMLOS}) = (1/n)(\ln\text{LOS}_{\text{case 1}} + \ln\text{LOS}_{\text{case 2}} + \cdots + \ln\text{LOS}_{\text{case n}})$$

Step 2: Convert $\ln$(GMLOS) to GMLOS (i.e., convert to days):

$$\text{GMLOS} = e^{\ln(\text{GMLOS})} \quad \text{where } e \approx 2.7182818285$$

Expected Mean LOS: Geometric mean of the *expected* length of stay for all cases

Calculate geometric mean of the *expected* length of stay (GM*E*LOS):

Step 1: Calculate each patient's *E*$\ln$LOS:

$$E\ln\text{LOS} = (\text{constant}) + (-0.008292768)(\text{patient's age}) + (0.136740487)((\text{patient's age})^2/1{,}000) + (\text{risk factor category coefficients})$$ [from Table 12]

Step 2: Calculate the $\ln$GM*E*LOS:

$$\ln(\text{GM}E\text{LOS}) = (1/n)(E\ln\text{LOS}_{\text{case 1}} + E\ln\text{LOS}_{\text{case 2}} + \cdots + E\ln\text{LOS}_{\text{case n}})$$

Step 3: Convert the $\ln$(GM*E*LOS) to GM*E*LOS (i.e., convert to days):

$$\text{GM}E\text{LOS} = e^{\ln(\text{GM}E\text{LOS})} \quad \text{where } e \approx 2.7182818285$$

Note: The following calculation can be used in determining a *patient's* expected length of stay; it is not necessary, however, in determining a hospital's geometric mean of the expected length of stay.

Calculate a patient's *expected* length of stay (*E*LOS):

Convert the *E*$\ln$LOS to *E*LOS (i.e., convert to days):

$$E\text{LOS} = e^{(E\ln\text{LOS})} \quad \text{where } e \approx 2.7182818285$$

$\ln$ = natural logarithm (base e)

Table 13. Calculations used in length of stay analysis - cont.

Test Statistic: [ln(GMLOS) - ln(GM*E*LOS)] / TotStd
where TotStd = Standard Error of ln(GM*E*LOS)

To calculate TotStd or the standard error of ln(GM*E*LOS):

Step 1: Calculate the standard error of the individual *E*lnLOS for each patient (StdI):

StdI = source of variability at the patient level.

Note: The StdI uses calculations from the entire data base, so hospitals, surgeons and payors will be unable to precisely replicate the Council's results. However, we know that the actual measure will never be less than 0.34769806, so this figure can be used as an approximation.

Step 2: Calculate the variance of the individual *E*lnLOS for each patient (VarPat):

VarPat = $(StdI)^2$

Step 3: Calculate the variance of mean ln(GM*E*LOS)

TotVar = (sum of VarPat across all cases) / $(number\ of\ cases)^2$

Step 4: Calculate TotStd:

TotStd = square root of TotVar

p-value (two-sided): Calculated using test statistic as a normal z-score

Statistical Rating: If .05 > p-value and test statistic > 0, then longer LOS than expected (denoted as '*')
If .05 > p-value and test statistic < 0, then shorter LOS than expected (denoted as 'o')
Otherwise, length of stay is within the expected range

Expected Range: ln(Lower Limit) = lnGM*E*LOS - 1.960(TotStd)
ln(Upper Limit) = lnGM*E*LOS + 1.960(TotStd)

To convert to days:

Lower Limit = $e^{\ln(\text{Lower Limit})}$
Upper Limit = $e^{\ln(\text{Upper Limit})}$

Adjustments Applied to Average Charge

"Who" is Reported

- Hospitals

"What" is Reported

- Average charge per stay *(trimmed for outliers and case-mix adjusted)*

Exclusion Criteria

The cases included in the in-hospital mortality analysis were used in determining a hospital's average charge, *with the exception of tracheostomy cases*. Tracheostomy cases (DRG 483) were *excluded* from the average charge analysis.

Determining Average Charge

Trimming of Charge Outliers

Patient total charges that are atypical are excluded from the calculation of a hospital's average charge. The methodology to determine these outlier charges is based on the determination of a high and low trim point that is 2.576 standard deviations from the statewide average for the study population. Before the statewide average was determined, charges over $1 million (N=3) were excluded after determining that they were likely in error (e.g., they did not correspond to the length of stay). Any patient charge that exceeds either trim point is excluded from that hospital's calculation for average charge; however, that patient is still included in the other analyses in the report.

Calculating Cutoffs for Outliers

Find Cutoffs:

Let: X = Total charge for each case
X^2 = Total charge squared for each case

Calculate:

SUM X	= Sum of the X for all cases
SUM X^2	= Sum of the X^2 for all cases
Total	= Number of Cases
AVE X	= SUM X/Total
VAR X	= [(SUM X^2 - ((SUM X) (SUM X)/Total))/(Total - 1)]
Std Dev X	= Square root of VAR X
Low Trim Point	= AVE X - (2.576 times standard deviation)
High Trim Point	= AVE X + (2.576 times standard deviation)

Table 14. Descriptive statistics *(before outliers were excluded)*

Minimum Charge	Maximum Charge	Median Charge	Standard Deviation
$1,441	$638,816	$47,213	$33,884

N = 38,038. Tracheostomy cases (DRG 483) and three cases with invalid charges were excluded from the average charge analysis.

Table 15. Total charge outlier trim points and average charge exclusions *(final data)*

Statewide Average (before $ exclusions)	Lower Limit	Upper Limit	Charge Exclusions	
			Number	%
$55,917	$1.00	$143,196	909	2.4%

N = 38,038. Tracheostomy cases (DRG 483) and three cases with invalid charges were excluded from the average charge analysis.

Case Mix Adjusting Charges

A hospital's case-mix index is used as a means of adjusting its charges according to the number of patients treated in each DRG and the relative costliness associated with treating patients in that DRG. Case-mix adjustment of charges should narrow the range of possible explanations for the variability in charges by accounting for the differences in resource consumption due to the treatment received.

The case-mix adjustment is used as an all payor relative weight for each of the DRGs derived from the CABG cases. The first step is to obtain these relative weights for each DRG.

Case-mix Adjustment Steps:

1. compute all payor relative weights for DRGs 106, 107, and 108
2. calculate each hospital's case-mix index
3. apply that case-mix index to its trimmed average charge

Step 1: Computation of All Payor Relative Weight (RW):

Based on 1994-95 Pennsylvania CABG Data:

- Exclude all outlier patient charges.
- Calculate statewide average charge for DRGs 106, 107, and 108 together (average for all combined).

- Calculate statewide average charge of cases assigned to DRG 106 (average 106).
- Calculate statewide average charge of cases assigned to DRG 107 (average 107).
- Calculate statewide average charge of cases assigned to DRG 108 (average 108).

- Relative Weight DRG 106 = average DRG 106/average all
- Relative Weight DRG 107 = average DRG 107/average all
- Relative Weight DRG 108 = average DRG 108/average all

Table 16. Statewide average charge by DRG and associated relative weights

DRG	Average Statewide Charge	Relative Weight
106	$ 56,520	1.077296
107	$ 44,985	0.857438
108	$ 54,033	1.029889
All Cases	$ 52,465	———

Step 2: Example of Calculation of Case-mix Index:

The first step is to determine a DRG-specific case-mix index for each DRG within each hospital

For example, for "Hospital A" in DRG 106:

DRG-specific Case Mix = R.W. x N

where,

R.W. = **All Payor Relative Weight** associated with DRG 106
N = Number of cases treated for DRG 106 by "Hospital A" (after outliers are deleted)

Based on the information presented in the table below, the DRG-specific case-mix product for DRG 106 for "Hospital A" is: 1.077296 x 120 = 129.27552.

Table 17. Example of case-mix index calculation

"Hospital A"			
DRG	**Relative Weight**	**N**	**DRG Case-Mix**
106	1.077296	120	129.27552
107	0.857438	126	108.03719
108	1.029889	5	5.149445
All Cases	———	251	242.462153

After a DRG-specific case-mix product has been calculated for each DRG, a hospital-specific sum is computed. Each hospital's total patients (N) are also summed across the reported DRGs. These two values (N and DRG case-mix product total) are used to determine each hospital's index or the relative costliness of treating patients for the DRGs at each hospital.

Thus, the case-mix index for "Hospital A" is

$$Hospital\ \ Case\text{-}Mix\ Index \quad = \quad \frac{\sum(DRG\ Case\text{-}Mix)}{N}$$

$$\frac{242.462153}{251} = 0.9659846733$$

After a case-mix index was computed for each hospital, these indices were used to calculate each hospital's adjusted charge. The formula to calculate adjusted charge is as follows:

Step 3: Calculation of Case-mix Adjusted Average Charge:

$$\text{adjusted charge} = \frac{\text{average charge}}{\text{hospital case-mix index}}$$

Assuming "Hospital A" had an average charge of $56,000 across the reported DRGs, the Adjusted Charge for this hospital is:

$$\frac{\$56{,}000}{0.9659846733} = \$57{,}972$$

Since each hospital's case-mix index is derived from the relative weight of each DRG and the number of patients treated within each DRG, the case-mix index is representative of an "average relative weight" of the hospital's intensity of high charge services for the DRGs encompassing cases in the CABG Report. Because heavier DRG weights imply greater resource consumption, it follows that a hospital with a high case-mix index, relative to other hospitals, would have higher average charges. This effect is accounted for in the average charge by dividing out the index, therefore, providing for a more accurate reflection of resource use not related to differences in services received.

Five-Year Risk Factor Summary

The Council has always taken careful steps to identify the appropriate candidate variables to test as possible predictors of in-hospital mortality for its CABG reports. Along the way, we have made incremental improvements to candidate variable definitions and added new variables that better enable us to capture the preoperative status of the patient.

While we continually look for ways to enhance our risk-adjustment model, we also evaluate the data that go into these models. For example, we look for stability in both the frequency of occurrence and the mortality rate for candidate variables across hospitals and across years for possible miscoding or overcoding. We also examine the distribution of patients across risk levels to monitor possible increases in low risk patients and/or possible decreases in high risk patients.

Since this report marks the fifth CABG report released by the Council, we present here a five-year summary of the candidate variables and significant risk factors. While some variables have been significant one year and not the next, many of the significant risk factors remain the same from year to year.

When looking at the summary table below, it is important to consider:

- Significant predictor variables captured in ASG may explain why some of the variables that we tested were not significant. It is likely that some variables that we tested were not significant because they are accounted for in ASG.
- Coexisting conditions might be capturing some of the risk for variables that are not significant.
- Changes to specific variables have been made over the years.

Atlas™ ASG. MediQual's ischemic heart disorder disease group from previous years was split to form two disease groups: myocardial infarction and angina. For this report, 74.8% of the cases were scored using the angina disease group, 23.0% were scored using the myocardial infarction disease group, and 2.2% were scored using some other disease group. A disease group specifically for myocardial infarction patients is likely the reason that our AMI variable did not test as significant this year.

Acute myocardial infarction. This year, AMI was counted only if it was the principal diagnosis and the initial episode of care. Also, as noted above, *Atlas*™ introduced a new disease group specifically for myocardial infarction.

Admission source. In previous years, we tested this variable as a *transfer-in* variable. This year, it was defined as transfer, referral, or emergency room admission.

Admission type. This variable was not tested for 1994-95 because of inconsistency across hospitals in defining emergent, urgent, and elective admissions. Moreover, it has not been significant in previous years.

Angina. Angina was not tested this year because, as noted earlier, MediQual introduced a new disease group specifically for angina.

Artery surgical approach. This variable has not been tested in the past few years because it might be related more to treatment protocol than to risk.

Cardiogenic shock. This year, pre-operative cardiogenic shock was tested and it was defined *clinically*, not using ICD.9.CM codes. We believe this to be a significant improvement and one sought by both hospitals and surgeons.

Concurrent PTCA. In testing concurrent PTCA, we were looking to account for emergent operative status that is not otherwise captured.

Diabetes. Diabetes has not been a significant predictor variable for the last few CABG reports. It is likely that the abnormal blood glucose variable in ASG is accounting for diabetes; however, we recognize that it may not be capturing all CABG patients with diabetes. Conditions that tend to coexist with diabetes also may be capturing some of the risk.

Hypertension. In previous years, hypertension was defined as a categorical variable, including no hypertension, hypertension without complications, and hypertension with complications. This variable has not been significant. This year the definition was changed to include only hypertension with complications (i.e., hypertension with renal and/or heart failure), and it was a significant predictor.

Number of vessels bypassed. We tested this variable for the first CABG report but learned that coding practices limited the capturing of this information with ICD.9.CM codes.

Previous CABG and/or valve surgery. Prior CABG surgery has been a significant predictor of in-hospital mortality for the last few years. This year was the first time we included previous valve surgery as part of the definition for this variable. The variable was significant.

Renal failure. For 1994-95, acute renal failure was captured only if it occurred pre-operatively. As in previous years, we tested chronic renal failure as well but did not test unspecified renal failure. While renal failure has been a significant predictor for the last few years, it was not significant this year (likely because we captured *pre-operative* acute renal failure). ASG includes a number of variables that would capture conditions associated with renal failure: Renal Group (significant for both myocardial infarction and angina disease groups), BUN and fluid imbalance combination (significant for myocardial infarction disease group), and edema (part of the CHF group which is significant for both disease groups). Conditions that coexist with renal failure might also be capturing some of the risk (e.g., dialysis).

Transfer status. This year transfer status was tested as part of the admission source variable. It has not been significant, nor was admission source significant.

New variables for 1994-95. With regard to the new variables tested for 1994-95, this was the first year that race and ethnicity were available to test. Year was tested (1994 or 1995) because of the "natural" decline in mortality following CABG surgery over time. None of the new variables tested this year was significant.

Table 18. Risk factors used for in-hospital mortality — CABG Reports: 1990 – 1995

Candidate Variables	1990	1991	1992	1993	1994-95
Acute Myocardial Infarction	✔	✔	✔	*ns*	*ns* *(tested as principal diagnosis)*
Atlas™ ASG †	✔	✔	✔	✔	✔
Admit Type	*ns*	*ns*	*ns*	*ns*	*not tested*
Age	*ns*	*ns*	*ns*	*ns*	✔
Age Squared	✔	✔	✔	*ns*	✔
Angina	*ns*	*ns*	*ns*	*ns*	*not tested*
Artery Surgical Approach	✔	*not tested*	*not tested*	*not tested*	*not tested*
Cardiogenic Shock	✔	✔	✔	✔	✔
Concurrent PTCA	*ns*	*ns*	*ns*	*ns*	✔
Diabetes	*ns*	✔	*ns*	*ns*	*ns*
Dialysis	*not tested*	✔	✔	✔	✔
Gender – Female	✔	✔	✔	✔	✔
Heart Failure	✔	✔	✔	✔	✔
Hypertension	*ns*	*ns*	*ns*	*ns*	✔ *(complicated hypertension tested)*
Number of Vessels Bypassed	*ns*	*not tested*	*not tested*	*not tested*	*not tested*
Previous CABG	*ns*	✔	✔	✔	✔ *(previous CABG <u>and</u> valve tested)*
Renal Failure	*not tested*	✔	✔	✔	*ns*
Transfer Status	*ns*	*ns*	*ns*	*ns*	*(tested as part of admission source)*
New for 1994-1995:					
year					*ns*
cardiomyopathy					*ns*
admission source					*ns*
ethnicity					*ns*
race					*ns*
urban/rural status of patient's residence					*ns*

✔ = significant predictor of in-hospital mortality for that year
ns = not significant
†*known as MedisGroups 1990 & 1991 (generic scoring in 1990; disease specific scoring in 1991-93—using primarily ischemic heart disorder model; separate angina and myocardial infarction disease models in 1994-95.*

Hospital and Physician Characteristics and Payor Analysis

Background

Analysis conducted for previous CABG reports has shown that patient risk factors are important predictors of in-hospital mortality, and outcomes displayed in the CABG reports were adjusted for these patient risk factors. As part of our analysis for this report, we tested the hypothesis that there are differences among hospitals, physicians, and payors that might further explain differences in mortality *after* adjusting for patient risk.

Determining the Hospital and/or Physician Factors that Contributed to In-hospital Mortality

After completing the *patient* risk model, we tested for hospital and physician effects that explain in-hospital mortality *after* adjusting for patient risk. Taking into consideration the data available to us, we were able to test the following provider characteristics as possible predictors of in-hospital mortality:

Hospital characteristics:

- Region where the hospital is located.
- Number of years the hospital has been included in a PHC4 CABG surgery report. (We do not have easy access to information that tells us the year hospitals actually started performing CABG surgery, so this figure was used as a "proxy" for identifying "new" facilities; 1990 was the first data year that PHC4 began reporting CABG outcomes.)
- Volume of total open heart procedures performed.
- Average CABG volume for the physicians practicing in the hospital.

Surgeon characteristics:

- Number of hospitals in which the physician performed CABG surgery.
- Number of years that the surgeon has been performing CABG surgery.
- Volume of total open heart procedures performed (this figure, rather than total CABG procedures, better captures a physician's total surgical experience).
- Percent of patients undergoing "vein only" surgical approach. (This issue has received some attention in the past with regard to the assumption that a high percentage of patients receiving "vein only" CABG may be an indication of an "outdated" practice style pattern of the surgeon. Of course, some patients, because of their pre-operative risk, may require a "vein only" approach.

Appendix F contains data relevant to these hospital and physician factors.

In an effort to allow for non-linear relationships, several continuous variables were tested as actual numeric values as well as their squared and cubed values (i.e., hospital characteristics: total open heart volume and average CABG volume for physicians practicing in the hospital; surgeon characteristics: number of years performing CABG surgery and total open heart volume). Significant hospital and physician factors were identified by backwards stepwise logistic regression. All tests of significance were based on the likelihood ratio.

Table 19. Probability values for *significant* provider factors – after accounting for patient risk (p < 0.10 — Samples I & II)

Variables	Sample I	Sample II
Surgeon Experience *(in years squared)*	.0131	.1547
Surgeon Volume *(total open heart procedures)*	.0000	.0000
Hospital Volume *(total open heart procedures—cubed)*	.0647	.3515

Note that two variables did not cross validate (as indicated by a Sample II p-value that is greater than 0.10): surgeon experience and hospital total open heart volume.

Table 20. Coefficients and p-values for significant provider factors

Variable	Coefficient	p-value
Surgeon Experience *(in years squared)*	0.0004	.0047
Surgeon Volume *(total open heart procedures)*	- 0.1543	.0000
Hospital Volume *(total open heart procedures—cubed)*	0.00000774	.0547

Note: For scaling purposes, volume and experience values were divided by 100 before being squared and cubed.

Table 21. Adequacy measures for model testing *provider* factors after accounting for patient risk.

Measure	Sample I	Sample II	All Cases
Percentage Explained	19.3	15.5	17.9
R^2	9.5	7.6	8.9
ROC Area	83.6	81.1	82.6

After controlling for patient risk, provider factors added slightly to these model adequacy measures. As noted earlier, model adequacy measures for the model containing patient factors only, *all cases*, were 17.3% (percentage explained), 8.6% (R^2), and 82.0% (ROC).

The following table displays the percentage explained for each significant variable. It shows that, after accounting for patient risk, the provider factors that we tested explained less than one percent (0.60%) of the unexplained mortality.

Table 22. Percent explained by *patient* and *provider* factors

Variable	*Patient Factors* % Exp.	*Patient and Provider Factors* % Exp.	
All Factors	17.3%	17.9%	
Patient Factors:			
Atlas™ ASG	2.98	2.97	
Age *(includes age & age squared)*	0.54	0.54	
Cardiogenic Shock	1.21	1.22	
Concurrent PTCA	0.10	0.09	
Complicated Hypertension	0.13	0.14	
Dialysis	1.28	1.22	
Gender	0.44	0.43	
Heart Failure	1.25	1.26	
Prior CABG and/or Valve Surgery	1.83	1.76	
Provider Factors:			
Surgeon Experience *(squared)*		**0.08**	
Surgeon Volume		**0.52**	**0.60%**
Hospital Volume *(cubed)*		**0.03**	

The provider factors that we tested added only slightly to the percentage explained after controlling for patient risk.

Determining Whether Payor Contributed to In-hospital Mortality

One goal in examining provider (hospital and physician) characteristics was to better understand factors (beyond patient risk) that might explain differences in outcomes. At the same time, we were interested in knowing whether unexplained variance could be explained by payor. After adjusting for the significant *patient* risk factors, we tested payor to see if it added to the predictability of the logistic regression model. A backwards stepwise logistic regression was used, and the test of significance was based on the likelihood ratio.

We tested the following payor categories: Fee-for-Service: Medicare, Medicaid, Blue Cross, and Commercial. HMOs: Medicare, Medicaid, Blue Cross, and Commercial. Payor was not significant.

Appendix A

1994-1995 CABG Report - Fact Sheet

CABG Cases (before exclusions):

Number of cases	43,729	3.9% mortality	

CABG Cases (after exclusions):

Number of cases	38,577	3.1% mortality	*(88.2% of all cases)*
Highest number of cases for a hospital	2,331		
Mean number of cases per hospital	897		
Range	242 - 2,331		

Note: the above figures reflect a two-year period (1994-95)

Hospitals:

Total number of hospitals *(before exclusions)*..... 44

Includes 3 new hospitals since 1993 CABG report:
- *Medical Center, Beaver, PA, Inc.*
- *Easton Hospital*
- *Passavant Hospital (has less than 30 cases; excluded from the report)*

From this point on numbers reported are *after exclusions* unless otherwise stated.

Surgeons:

Total number of surgeons 203

131 performed CABG surgery in 1 hospital
53 performed CABG surgery in 2 hospitals
17 performed CABG surgery in 3 hospitals
2 performed CABG surgery in 4 hospitals

Insurance Types:

Total number of payors with 30 or more cases	34	*(including Medicare and Medicaid fee-for service)*
19 licensed HMOs		
15 fee for service *(including Medicare & Medicaid FFS)*		

Percent of cases by payor *type*:

Medicare HMO	2.3%	*(4.3% of all Medicare)*
Medicare Indemnity	51.0%	
Medicaid HMO	0.2%	*(6.1% of all Medicaid)*
Medicaid Indemnity	3.2%	
Blue Cross HMO	2.3%	*(11.6 % of all Blue Cross)*
Blue Cross Indemnity	17.3%	
Commercial HMO	4.6%	*(60.7 % of all Commercial)*
Commercial Indemnity	3.0%	
"Other"	16.1%	

Note: All cases that were not designated as either HMO or indemnity were classified as "Other," including out-of-state cases and cases from the following payor categories: Union Health & Welfare, Workers' Compensation, auto insurance, association. The "Other" category also includes commercial HMO and indemnity entities with fewer than 30 cases, self pay, cases that were rejected by the payors as not belonging to them, one case where two payors claimed the same case, employee direct bill, other government, and unknown. We recognize that there may be some "impurities" in these classifications.

In-hospital Mortality Exclusions:

Number of excluded cases	5,152	9.7% mortality	*(11.8% of all cases)*
Number of included cases	38,577	3.1% mortality	*(88.2% of all cases)*

In-hospital Deaths:

Number of in-hospital deaths	1,195

Total Length of Stay (all cases included in the report):

Mean	11.1 days
Median	9 days

Note: based on the 38,577 cases included in the in-hospital mortality analysis.

Post-operative Length of Stay Exclusions:

Number of excluded cases *(in addition to mortality exclusions)*	1,805	avg LOS *(arithmetic)* = 26.8 days
Number of included cases	36,772	avg LOS *(arithmetic)* = 7.6 days

Post-operative Length of Stay:

Mean (arithmetic).....	7.6 days
Median	6 days

Patient Demographics (in-hospital mortality analysis):

Females	30%	4.5% mortality
Males	70%	2.5% mortality
Average age	65.3	
females	67.7	
males	64.2	
Cases under 65 years old	41.8%	
Race breakdown:		
white	92.2%	3.0% mortality
black	3.3%	4.0% mortality
other/unknown	4.5%	3.8% mortality

Open Heart Surgery & PTCA Case Counts:

Number of open heart surgery cases	51,643	*(85.1% are CABGs)*
Number of PTCA cases.....	52,466	
Hospital range for open heart surgery cases..... *(after excluding one hospital with less than 30 CABG cases)*	315 - 3,079	
Hospital range for PTCA cases ..... *(after excluding one hospital with less than 30 CABG cases)*	361 - 4,715	

Note: all the open heart surgery and PTCA case counts reflect a two-year period.

Total CABG Case Count and Crude Mortality for 1990-1995 — *(before exclusions)*

	1990	1991	1992	1993	1994	1995
Number of Cases	17,209	18,494	19,639	19,483	20,780	22,949
Mortality Rate	5.1%	4.9%	4.6%	4.1%	4.0%	3.8%

Publicly Reported CABG Case Count and Crude Mortality for 1990-1995 — *(after exclusions)*

	1990	1991	1992	1993	1994	1995
Number of Cases	14,895	16,266	17,349	17,413	18,375	20,202
Mortality Rate	3.9%	3.5%	3.4%	2.9%	3.2%†	3.0%†

† Note: Mortality rates after exclusions are higher for 1994 and 1995 because tracheostomy cases are included in this study (they were excluded in previous years). If tracheostomy patients were excluded, the mortality rates for 1994 and 1995 would be 2.77% and 2.55%, respectively.

Appendix B

Table B.1 Payor reference list for hospital verification of primary payor field

UB-92 Digits			Payor Company	
1st Digit	**2nd Digit**	**NAIC Code**	**Insurance Plan**	**Product Line or D/B/A**
Patient Direct Bill (self)				
0	0	SELF	Self pay or Uninsured	
Medicare				
Medicare Indemnity				
1	0	9999999	MEDICARE -INDEMNITY IN STATE	
Medicare HMO				
1	5	96792	Aetna Health Plans of Central & Eastern PA	Senior Choice
1	5	93938	Aetna Health Plans of Western PA, Inc	Aetna Medicare Program
1	5	95923	Geisinger Health Plan - Central	Geisinger Gold
1	5	95102	Greater Atlantic Health Services, Inc	Wise Choice
1	5	95060	HealthAmerica PA, Inc	Advantra
1	5	96601	HMO of Northeastern PA, Inc	First Priority Health 65
1	5	95199	Keystone Health Plan Central, Inc	SeniorBlue
1	5	95056	Keystone Health Plan East, Inc	Keystone 65
1	5	95048	Keystone Health Plan West, Inc	Security Blue
1	5		Phila AFL-CIO Hospital Association	Union Medicare
1	5		Police & Fire Medical Association	
1	5	95109	US Health Care Systems of PA, Inc	US Health Care Medicare
Medicare Out of State *(includes indemnity & HMO)*				
1	0	9999999	MEDICARE -OUT OF STATE	
Medicaid				
Medicaid Indemnity				
2	0	8888888	MEDICAID -INDEMNITY IN STATE	
Medicaid HMO				
2	5	96792	Aetna Health Plans of Central & Eastern PA	Mercy Health Plan
2	5	93938	Aetna Health Plans of Western PA, Inc	
2	5	95102	Greater Atlantic Health Service, Inc	
2	5		Hamilton Health Center	
2	5	95066	Health Partners of Philadelphia, Inc	
2	5	95033	Healthcare Management Alternatives, Inc	
2	5	95056	Keystone Health Plan East, Inc	Keystone First
2	5	95056	Keystone Health Plan East, Inc	Mercy Health Plan
2	5	95048	Keystone Health Plan West, Inc	Gateway Health Plan
2	5	95356	Oxford Health Plans (PA), Inc	Oaktree Health Plan
2	5	95109	US Health Care Systems of PA, Inc	
Medicaid Out of State *(includes indemnity & HMO)*				
2	0	8888888	MEDICAID -OUT OF STATE	

continued

Blue Cross

UB-92 Digits			Payor Company	
1st Digit	**2nd Digit**	**NAIC Code**	**Insurance Plan**	**Product Line or D/B/A**
Blue Cross Indemnity				
3	0	93688	AmeriHealth Insurance Company	
3	0	54747	Blue Cross of Northeast PA	Hospital Serv Assoc NE, PA
3	0	54712	Blue Cross of Western PA	Veritus, Inc *(Actual Company Name)*
3	0	54720	Capital Blue Cross	
3	0	54704	Independence Blue Cross	
Blue Cross HMO				
3	5	95044	AmeriHealth HMO, Inc	Delaware Valley Inc.
3	5	95443	HealthGuard of Lancaster, Inc	
3	5	96601	HMO of Northeastern PA, Inc	First Priority Health
3	5	95199	Keystone Health Plan Central, Inc	
3	5	95056	Keystone Health Plan East, Inc	
3	5	95048	Keystone Health Plan West, Inc	
Blue Cross Administered - Additional or Info Unknown				
3	6		Union Health & Welfare Fund	
3	9		Association	
Blue Cross Out of State & Unknown *(includes indemnity & HMO)*				
3	0		BLUE CROSS -OUT OF STATE	
3	0		BLUE CROSS -UNKNOWN	

Commercial

Commercial Indemnity				
4	0	19038	Aetna Casualty & Surety Company	
4	0	19046	Aetna Casualty & Surety Company of IL	
4	0	31194	Aetna Casualty & Surety of America	
4	0	36137	Aetna Commerical Insurance Company	
4	0	36153	Aetna Casualty Company	
4	0	36170	Aetna Casualty Company of CT	
4	0	60054	Aetna Life Insurance Company	
4	0	78700	Aetna Health & Life Insurance Company	
4	0	86509	Aetna Life Insurance & Annuity Company	
4	0	60232	American Guardian Life Assurance Company	
4	0	10030	CIGNA Indemnity Insurance Company	
4	0	20699	CIGNA Property & Casualty Insurance Co	
4	0	20702	CIGNA Fire Underwriters Insurance Company	
4	0	22667	CIGNA Insurance Company	
4	0	22705	CIGNA Reinsurance Company	
4	0	38741	CIGNA Employers Insurance Company	
4	0	93629	CIGNA Life Insurance Company	
4	0	81426	Commercial Travelers Mutual Insurance Co	
4	0	62804	Educators Mutual Life Insurance Company	
4	0	10244	Geisinger Indemnity Insurance Company	
4	0	64246	Guardian Life Insurance Company of America	
4	0	65099	John Hancock Mutual Life Insurance Co	
4	0	90204	John Hancock Variable Life Insurance Co	
4	0	93610	John Hancock Life Insurance Co of America	
4	0	26298	Metropolitan Property & Casualty Ins Co	
4	0	40169	Metropolitan Casualty Insurance Company	
4	0	65978	Metropolitan Life Insurance Company	
4	0	86428	Metropolitan Insurance & Annuity Company	
4	0	97136	Metropolitan Tower Life Insurance Company	

continued

Commercial (Continued)

Commercial Indemnity (Continued)				
4	0	71412	Mutual of Omaha Insurance Company	

UB-92 Digits			Payor Company	
1st Digit	**2nd Digit**	**NAIC Code**	**Insurance Plan**	**Product Line or D/B/A**
4	0	66583	National Guardian Life Insurance Company	
4	0	66702	National Masonic Provident	
4	0	66826	National Travelers Life Company	
4	0	66974	North American Company for Life & Health Ins	
4	0	68349	North American Insurance Company	
4	0	43702	North American Lumber Insurance Company	
4	0	29874	North American Specialty Insurance Co	
4	0	68187	Provident Indemnity Life Insurance Company	
4	0	68195	Provident Life & Accident Insurance Company	
4	0	68209	Provident Life & Casualty Insurance Company	
4	0	68225	Provident Mutual Life Insurance Company	
4	0	70750	Provident Mutual Life & Annuity Co of America	
4	0	36439	Prudential Commercial Insurance Company	
4	0	36447	Prudential General Insurance Company	
4	0	74020	Prudential Healthcare & Life Ins Co of America	
4	0	68241	Prudential Insurance Company	
4	0	32352	Prudential Property & Casualty Insurance Co	
4	0	66133	Prudential Select Life Insurance Co of America	
4	0	25151	State Farm General Insurance Company	
4	0	25143	State Farm Fire & Casualty Company	
4	0	25178	State Farm Mutual Automobile Insurance Co	
4	0	27998	Travelers Home & Marine Insurance Company	
4	0	25658	Travelers Indemnity Company	
4	0	25666	Travelers Indemnity Company of America	
4	0	25682	Travelers Indemnity Company of CT	
4	0	25674	Travelers Indemnity Company of IL	
4	0	40282	Travelers Indemnity Company of MO	
4	0	39357	Travelers Insurance Company /Casualty	
4	0	87726	Travelers Insurance Company /Life	
Commercial HMO				
4	5	96792	Aetna Health Plans of Central & Eastern PA	Freedom
4	5	93938	Aetna Health Plans of Western PA, Inc	
4	5	96218	Alliance Health Network	
4	5	95010	Central Medical Health Plan, Inc	Advantage Health Plan
4	5	95121	CIGNA Healthcare of PA, Inc	
4	5	95923	Geisinger Health Plan	
4	5	95102	Greater Atlantic Health Service, Inc	
4	5	95052	GroupHealth Partnership, Inc	
4	5	95066	Health Partners of Philadelphia, Inc	
4	5	95060	HealthAmerica PA, Inc	
4	5	95033	Healthcare Management Alternatives, Inc	
4	5	95217	HIP of Pennsylvania, Inc	HIP Health Plan
4	5	98359	Medigroup HMO, Inc	
4	5	95356	Oxford Health Plans (PA), Inc	Oaktree Health Plan
4	5	95040	Prudential Health Care Plan, Inc	Prucare of Philadelphia
4	5	95079	QualMed Plans for Health of PA	
4	5	96873	Riverside Health Plan, Inc	
4	5	95109	US Health Care Systems of PA, Inc	Health Maintenance Org. PA
4	5	96660	Vista Health Plan, Inc	
Commercial Administered				
4	6		Union Health & Welfare Fund	
4	9		Association	

continued

Commercial (Continued)

Commercial Miscellaneous				
4	7		Workers Compensation	
4	8		Auto	

UB-92 Digits		Payor Company		
1st Digit	**2nd Digit**	**NAIC Code**	**Insurance Plan**	**Product Line or D/B/A**
Commercial Out of State & Not Listed *(includes indemnity & HMO)*				
4	0		COMMERCIAL -OUT OF STATE	
4	0		COMMERCIAL -NOT LISTED	

Direct Bill

Employer Direct Bill				
5	0		"INSERT EMPLOYER NAME"	
5	7		Workers Compensation	
Employer PPO				
5	5		"INSERT EMPLOYER NAME"	
Direct Bill				
5	6		Union Health & Welfare Fund	
5	9		Association	

Other Government

Other Government Indemnity				
8	0		GOVERNMENT -NOT LISTED	
8	0	6666666	Champus	
8	0	7777777	Black Lung	
8	0		Alliance	
8	0		APWU	America Postal Workers Union
8	0		BACE	
8	0		Foreign Services	
8	0		GEHA	Govt Employees Hospital Assoc
8	0		Mail Handlers	
8	0		NALC	National Assoc. Letter Carrier
8	0		NAPUS	
8	0		Postmasters	
8	0		Rural Carrier Benefit	
8	0		SAMBA	
8	0		Secret Service	
Other Government Miscellaneous				
8	7	27677	State Workers Insurance Fund	
8	8	34681	Cat Fund	

Unknown Payor

9	0		Unknown	

Appendix C

Atlas™ Admission Severity

In a contractual agreement with MediQual Systems, Inc. in Westborough, Massachusetts, hospitals are required to use MediQual's *Atlas*™ Severity of Illness System to abstract patient severity information. *Atlas*™ is an objective illness severity grouping system that classifies each patient's condition upon admission and at set times during the hospitalization using data known as Key Clinical Findings (KCFs). It represents a summarization of patient risk based on clinical data found in the medical record. Hospital personnel abstract these KCFs during specified timeframes in the hospitalization. The information used in the severity score covers the first two days of the hospital stay. Some pre-admission data are also captured (e.g., cardiac catheterization findings) as are some history findings. The admission severity group (ASG scores) are submitted to the Council for acute care inpatient records.

In previous CABG reports, MediQual's Ischemic Heart Disorder disease group was used in determining ASG. With the shift from Atlas Version 1.9 to Atlas Version 2.0, there are now two disease groups that primarily include CABG cases: myocardial infarction and angina. (A small percentage of CABG cases are scored using other disease group models.) While Atlas 2.0 was introduced for data collected for second quarter 1996 data, hospitals rescored ASG for this report to incorporate the enhancements made to the scoring algorithms.

The principal diagnosis determines the scoring algorithm that is used for a particular case. There are a total of 67 different scoring algorithms for admission severity. For this report, 74.8% of the cases were scored using the angina disease group, 23.0% were scored using the myocardial infarction disease group, and 2.2% were scored using some other disease group.

The following pages provide more detail about the myocardial infarction disease group and the angina disease group. Included is a list of the KCFs used to identify variables that predict mortality. Eligibility criteria for a variable to be considered in a model is 3% of the cases or 1% of the cases if there are at least 30 deaths. Only variables found to be significant were included in the final model.

Table C.1 Independent variables considered in MediQual's mortality equations

Code #	Variable Description	Variable Type	Myocardial Infarction		Angina	
			Eligible?	Significant?	Eligible?	Significant?
0	Constant/Intercept			Yes		Yes
277	Age in Years	Continuous		Yes		Yes
278	Gender (F=O; M=1)	Binary				
600	Acute Neuro Combination	Continuous		Yes	Not Eligible	
601	Chronic Neuro Combination	Continuous				
630	Culture Combination	Continuous			Not Eligible	
635	Fluid Imbalance Combination	Continuous		Yes	Not Eligible	
650	Anemia Group	Binary				
651	Non Sinus Rhythm Group	Binary				
654	Coma Group	Binary		Yes	Not Eligible	
655	Cancer Group	Binary				
658	CAD Group	Binary		Yes		
660	History CAD Group	Binary				
664	CHF Group	Binary		Yes		Yes
666	Coagulation Defect Group	Binary		Yes		
670	COPD Group	Binary				
672	Damage Group	Binary		Yes		
673	Diabetes Group	Binary				
676	Hypoxia Group	Binary				
678	Inflammation Group	Binary				
680	Immunocompromised Group	Binary			Not Eligible	
682	Infection Group	Binary			Not Eligible	
684	Liver Group	Binary			Not Eligible	
686	Malnutrition Group	Binary			Not Eligible	
690	MI Group	Binary				
692	Renal Group	Binary		Yes		Yes
694	Seizure Group	Binary		Yes	Not Eligible	
698	Valve Group	Binary				
701	Age Squared	Continuous				
707	Age in Months	Continuous				
720	Circumflex >49%	Binary				
721	LAD >49%	Binary				
722	Left Main >49%	Binary				
723	RCA >49%	Binary				
804	Chronic Anemia	Binary			Not Eligible	
805	Diabetes	Binary				
810	History of Cancer	Binary				
811	Previous Stroke	Binary				
814	Amputation	Binary			Not Eligible	
816	History of Angina	Binary				
820	Previous Seizures	Binary			Not Eligible	
822	Syncope	Binary			Not Eligible	
827	Permanent Pacemaker	Binary			Not Eligible	
831	Previous CABG	Binary		Yes		
832	History of CHF	Binary				
833	Chronic Renal Disease	Binary				
837	Previous PTCA	Binary				
840	Chronic Lung Disease	Binary				
890	Current Med Anticoag	Binary				
892	Current Med Immunosup	Binary			Not Eligible	
894	Current Med Insulin	Binary				
1001	Lesion	Binary				
1030	Cyanosis	Binary			Not Eligible	

Code #	Variable Description	Variable Type	Myocardial Infarction		Angina	
			Eligible?	Significant?	Eligible?	Significant?
1040	Murmur	Binary			Not Eligible	
1301	Circumflex	Continuous				Yes
1305	LAD	Continuous				
1308	Left Main	Continuous		Yes		
1310	RCA	Continuous				
1321	Effusion	Binary			Not Eligible	
1373	Stenosis	Binary				
1399	Edema	Binary			Not Eligible	
1500	CHF	Binary				
1501	MI	Binary		Yes		
1502	Ischemia	Binary				
1700	Enlarged Heart	Binary				
2000	Disoriented	Binary			Not Eligible	
2010	Coma or Stupor	Binary			Not Eligible	
2020	Lethargy	Binary			Not Eligible	
2101	Chronic Paresis	Binary			Not Eligible	
2103	Chronic Cranial Nerve Def	Binary			Not Eligible	
3030	Albumin g/dL	Continuous		Yes	Not Eligible	
3039	AST U/L	Continuous			Not Eligible	
3051	Calcium mg/dL Low	Continuous			Not Eligible	
3052	Calcium mg/dL High	Continuous			Not Eligible	
3060	CPK U/L	Continuous		Yes		
3070	CPK MB %	Continuous				
3073	CPK MB ng/mL	Continuous			Not Eligible	
3080	Creatinine mg/dL	Continuous				
3172	Glucose mg/dL High	Continuous		Yes		
3182	K mEq/L High	Continuous			Not Eligible	
3201	Na Low	Continuous			Not Eligible	
3206	Alk Phos U/L	Continuous			Not Eligible	
3260	BUN mg/dL	Continuous		Yes		
3301	pH Arterial Low	Continuous		Yes	Not Eligible	
3302	pH Arterial High	Continuous			Not Eligible	
3314	pO2 Arterial	Continuous		Yes		Yes
3317	pCO2 Arterial	Continuous		Yes	Not Eligible	
3323	02 Sat Arterial %	Continuous			Not Eligible	
3450	PTT sec	Continuous				
3460	PT sec	Continuous				
3530	Bands %	Continuous			Not Eligible	
3561	Hematocrit % Low	Continuous				
3571	Hemoglobin g/dL Low	Continuous				
3661	WBC Low	Continuous				
3662	WBC High	Continuous		Yes	Not Eligible	
4033	Respiratory Culture	Binary			Not Eligible	
4039	Urinary Culture	Binary			Not Eligible	
4804	E. coli	Binary			Not Eligible	
5001	Oral Temp F Low	Continuous			Not Eligible	
5002	Oral Temp F High	Continuous			Not Eligible	
5011	Pulse Low	Continuous			Not Eligible	
5012	Pulse High	Continuous			Not Eligible	
5021	Systolic BP Low	Continuous		Yes		Yes
5024	Diastolic BP	Continuous		Yes	Not Eligible	
5032	Respirations High	Continuous		Yes		
5043	Coma Score 3-15	Continuous				
5300	F102 > 49%	Binary			Not Eligible	
5330	Wedge Pressure > 14	Continuous			Not Eligible	
5506	Regurgitation	Binary				
5512	AV Conduction Disturbance	Binary			Not Eligible	
5518	Atrial Fibrillation	Binary				

Code #	Variable Description	Variable Type	Myocardial Infarction		Angina	
			Eligible?	Significant?	Eligible?	Significant?
5524	S3 Gallop	Binary			Not Eligible	
5530	Stress Test Positive	Binary	Not Eligible			
5532	Ejection Fraction %	Continuous				
9000	Resuscitation	Binary		Yes	Not Eligible	
9010	Mechanical Vent Days	Continuous				Yes

Table C.2 Variables to compute ASG for myocardial infarction & angina disease groups – Atlas Variable Groups Reference Report

Variables & KCFs	Disease Group	
	Myocardial Infarction	***Angina***
Acute Neuro Combination	✓	
Acute Aphasia		
Acute Apraxia		
Acute Ataxia		
Acute Cranial Nerve Deficit		
Acute Flaccid		
Acute Muscle Weakness		
Acute Paresis		
Acute Sensory Deficit		
Acute Speech Deficit		
Acute Tremors		
Gait Abnormality		
Proprioception		
Age in Years	✓	✓
Albumin g/dL	✓	
BUN mg/dL	✓	
CAD Group	✓	
Circumflex > 49%		
Ischemia		
LAD > 49%		
Left Main > 49%		
RCA > 49%		
Stress Test Positive		
CHF Group	✓	✓
CHF		
Edema		
Effusion Respiratory		
Ejection Fraction < 41%		
History of CHF		
S3 Gallop		
Wedge Pressure > 14		
Circumflex		✓
Coagulation Defect Group	✓	
Platelets < 100 10^9/L		
PT > 15.5 sec		
PTT > 35.9		
Coma Group	✓	
Coma or Stupor		
Coma Score < 8		
CPK U/L	✓	

continued

Variables & KCFs	Disease Group	
	Myocardial Infarction	***Angina***
Damage Group AST > 80 U/L CPK > 150 U/L Damage Tear	✓	
Diastolic BP	✓	
Fluid Imbalance Combination K < 2.5 or > 5.3 Na < 130 or > 150	✓	
Glucose mg/dL High	✓	
Left Main	✓	
Mechanical Vent Days		✓
Myocardial Infarction	✓	
pCO2 Arterial	✓	
pH Arterial Low	✓	
p02 Arterial	✓	✓
Previous CABG	✓	
Renal Group BUN > 30 mg/dL Chronic Renal Disease Creatinine > 1.7 mg/dL Urine Protein mg/24 hr	✓	✓
Respirations High	✓	
Resuscitation	✓	
Seizure Group Previous Seizures Seizure	✓	
Systolic BP Low	✓	✓
WBC High	✓	

Source: MediQual Systems, Inc. Specific information on KCFs is included in the Atlas™ Glossary

Table C.3 Variable definitions for Disease Group 550 — Myocardial infarction

Variable Description	Code #	Definition	Source Documents
Acute Neuro Combination	600	This is an additive group variable based on the presence of any of the individual KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	ED Record, H&P, physician admission note, physician consults, physician progress notes
Age in Years	277	This variable is based on the patient's age in years. For patients under 12 months, 0 is used; patients 12-23 age will be used as 1 and for everyone else the actual age is used.	Facility-defined
Albumin g/dL	3030	This variable uses the value of an abnormal albumin <3.0 g/dL for either a preadmission or admission KCF or imputes a normal of 4.4 for scoring. Records with a laboratory test using another unit of measure will have the result converted for scoring.	Laboratory reports
BUN mg/dL	3260	This variable uses the value of an abnormal BUN of >30 mg/dL for either a preadmission or admission KCF or imputes a normal of 12 for scoring. Records with a laboratory test using another unit of measure will have the result converted for scoring.	Laboratory reports
CAD Group	658	This is a group variable based on the presence of any of the individual KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	Coronary angiography, EKG reports, telemetry strips, exercise/stress tests
CHF Group	664	This is a group variable based on the presence of any of the individual history or KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	ED Record, H&P, physician admission note, physician consults, physician progress notes, chest x-rays, cardiac cath report, echocardiogram, ICU flow sheets
Coagulation Defect Group	666	This is a group variable based on the presence of any of the individual KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	Laboratory reports
Coma Group	654	This is a group variable based on the presence of any of the individual KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	ED Record, H&P, physician admission note, physician consults, physician progress notes, graphic records, ICU flow sheets
CPK U/L	3060	This variable uses the value of CPK > 150 U/L for either a preadmission or admission KCF or imputes a normal of 102 (ages>12y) or >110 (ages <13y) for scoring.	Laboratory reports
Damage Group	672	This is a group variable based on the presence of any of the individual KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	Laboratory reports, x-rays, op-notes, ED Record, H&P, physician admission note, physician consults, physician progress notes

Variable Description	Code #	Definition	Source Documents
Diastolic BP	5024	This variable uses the value of diastolic blood pressure >119 for either a preadmission or admission KCF or imputes a normal of 80 (ages > 12y) or 59 (ages < 13y) for scoring.	ED Record, graphic records, ICU flow sheets
Fluid Imbalance Comb	635	This is an additive group variable based on the presence of any of the individual KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	Laboratory reports
Glucose mg/dL High	3172	This variable uses the value of glucose >249 mg/dL for either a preadmission or admission KCF or imputes a normal of 80 (ages 1 month or more) or 45 (ages 0-30 days) for scoring. Records with a laboratory test using another unit of measure will have the result converted for scoring.	Laboratory reports
Left Main	1308	This variable uses the value of a left main occlusion >49% for either a preadmission or admission KCF or imputes a normal of 0 for scoring.	Coronary angiography
MI	1501	This variable is based on the presence of myocardial infarction as either a preadmission or admission KCF.	EKG reports
pCO2 Arterial	3317	This variable uses the value of arterial pCO2 >45 for either a preadmission or admission KCF or imputes a normal of 40 for scoring.	Laboratory reports
pH Arterial Low	3301	This variable uses the value of arterial pH < 7.35 for either a preadmission or admission KCF or imputes a normal of 7.38 for scoring.	Laboratory reports
pO2 Arterial	3314	This variable uses the value of arterial pO2 <75 for either a preadmission or admission KCF or imputes a normal of 75 for scoring.	Laboratory reports
Previous CABG	831	This variable is based on the presence of the previous CABG history finding.	ED Record, H&P, physician admission note, physician consults, physician progress notes
Renal Group	692	This is a group variable based on the presence of any of the individual history or KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	ED Record, H&P, physician admission note, physician consults, physicians progress notes, laboratory reports
Respirations High	5032	This variable uses the value of respirations >24 for either a preadmission or admission KCF for ages one month or more or imputes a normal of 18 OR > 70 for ages 0-30 days or imputes a normal of 35 for scoring.	ED Record, graphic records, ICU flow sheets
Resuscitation	9000	This variable is based on the presence of the treatment code for resuscitation.	Facility-defined
Seizure Group	694	This is a group variable based on the presence of any of the individual history or KCF variables that are part of the group. Refer to the Variable Groups reference report for a listing of the specific variables.	ED Record, H&P, physician admission note, physician consults, physician progress notes

Variable Description	Code #	Definition	Source Documents
Systolic BP Low	5021	This variable uses the value of systolic blood pressure <90 for either a preadmission or admission KCF for ages >17y or <60 for ages <18y or imputes a normal of 110 for scoring.	ED Record, graphic records, ICU flow sheets
WBC High	3662	This variable uses the value of WBC >17.0 for either a preadmission or admission KCF or imputes a normal of 7.5 (ages one month or more) or 21 (ages 0-30 days) for scoring. Records with another unit of measure will have the result converted for scoring.	Laboratory reports

Table C.4 Definitions for Disease Group 555 — Angina

Variable Description	Code #	Definition	Source Documents
Age in Years	277	This variable is based on the patient's age in years. For patients under 12 months, 0 is used; patients 12-23 age will be used as 1 and for everyone else the actual age is used.	Facility-defined
CHF Group	664	This is a group variable based on the presence of any of the individual history or KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	ED Record, H&P, physician admission note, physician consults, physician progress notes, chest x-rays, cardiac cath report, echocardiogram
Circumflex	1301	This variable uses the value of a circumflex occlusion of >49% for either a preadmission or admission KCF or imputes a normal of 0 for scoring.	Coronary angiography
Mechanical Vent Days	9010	This variable is based on the presence of the treatment code for mechanical ventilation. The actual number of days on the ventilator will be used for scoring. Note: for patients on a ventilator <1 day a value of .5 will be used. Patients not on a ventilator will have a normal of 0 imputed.	Facility-defined (example - mechanical vent flow sheets)
pO2 Arterial	3314	This variable uses the value of arterial pO2 <75 for either a preadmission or admission KCF or imputes a normal of 75 for scoring.	Laboratory reports
Renal Group	692	This is a group variable based on the presence of any of the individual history or KCF variables that are part of the group. Refer to the Atlas Variable Groups reference report for a listing of the specific variables.	ED Record, H&P, physician admission note, physician consults, physician progress notes, laboratory reports
Systolic BP Low	5021	This variable uses the value of systolic blood pressure <90 for either a preadmission or admission KCF for ages >17y, or <60 for ages <18y, or imputes a normal of 110 for scoring.	ED Record, graphic records, ICU flow sheets

Appendix D

Table D. 1 In-hospital mortality — Candidate variable frequency and percent mortality

(after collapsing cells)

Variable and ICD.9.CM Codes	Number of Cases			Percent Mortality		
	sample I	*sample II*	*total*	*sample I*	*sample II*	*total*
	19,289	19,288	38,577	3.1	3.1	3.1
Acute Myocardial Infarction (AMI)						
no	14,968	14,827	29,795	2.6	2.7	2.6
yes (initial episode as principal diagnosis).....410.x1	4,321	4,461	8,782	4.8	4.5	4.6
***Atlas*™ Admission Severity Group (ASG)**						
0 / blank (16 cases with blank ASG)	107	107	214	0.0	0.9	0.5
1	10,203	10,248	20,451	1.2	1.3	1.2
2	7,366	7,273	14,639	3.6	3.5	3.6
3	1,512	1571	3,083	11.4	10.7	11.1
4	101	89	190	39.6	47.2	43.2
Admission Source						
referrals	9,741	9,737	19,478	2.2	2.3	2.2
transfers	6600	6,628	13,228	4.2	4.0	4.1
emergency room	2,948	2,923	5,871	3.7	3.9	3.8
Age & Age-Squared *(tested as continuous variables)*						
30-39 years	175	164	339	0.6	0.6	0.6
40-49 years	1,398	1,441	2,839	1.4	1.3	1.3
50-59 years	3,597	3,619	7,216	1.5	1.6	1.6
60-69 years	6,713	6,795	13,508	2.6	2.4	2.5
70-79 years	6,412	6,270	12,682	4.2	4.6	4.4
80-89 years	983	992	1,975	7.8	7.1	7.4
90-99 years	11	7	18	0.0	0.0	0.0
Average age: 65.3 (males 64.2; females 67.7)						
Cardiogenic Shock						
no	19,107	19,113	38,220	2.8	2.9	2.8
yes (before surgery)..... *(using clinical information from the medical record)*	182	175	357	35.2	28.0	31.7
Cardiomyopathy						
no	18,983	19,013	37,996	3.0	3.1	3.0
yes 425.3, 425.4, 425.8, 425.9	306	275	581	8.2	6.6	7.4
Complicated Hypertension						
no	18,881	18,897	37,778	2.9	2.9	2.9
yes 402.x1, 403.x1, 404.x1, 404.x2, 404.x3, 405.xx	408	391	799	11.3	12.8	12.0
Concurrent PTCA						
no	18,465	18,456	36,921	2.9	3.0	3.0
yes 36.01, 36.02, 36.05, 36.09	824	832	1,656	6.9	4.7	5.8
Diabetes						
none	13,755	13,823	27,578	2.8	2.8	2.8
diabetes without complication 250.0x	4,744	4,727	9,471	3.5	3.5	3.5
diabetes with complication ..... 250.1x - 250.9x	790	738	1,528	5.4	5.7	5.6

Variable and ICD.9.CM Codes	Number of Cases			Percent Mortality		
	sample I	*sample II*	*total*	*sample I*	*sample II*	*total*
	19,289	19,288	38,577	3.1	3.1	3.1
Dialysis						
no	19,080	19,100	38,180	2.9	2.8	2.9
yes 39.95, 54.98, V56.0, V56.8, V45.1	209	188	397	25.4	28.7	27.0
Ethnicity						
not Hispanic / unknown	19,124	19,118	38,242	3.1	3.1	3.1
Hispanic	165	170	335	3.0	3.5	3.3
Gender						
male	13,487	13,614	27,101	2.6	2.4	2.5
female	5,802	5,674	11,476	4.3	4.8	4.5
Heart Failure						
no	15,848	15,873	31,721	2.0	2.0	2.0
yes 398.91, 428.0, 428.1, 428.9	3,441	3,415	6,856	8.3	8.0	8.2
Note: For those cases having one of the above heart failure codes and a hypertension with congestive heart failure code (402.x1, 404.x1, 404.x3) in the same record, only the hypertension code was used.						
Prior CABG and/or Valve Surgery						
no	17,936	17,865	35,801	2.7	2.8	2.7
yes V45.81, 996.03, 414.02, 414.03, V42.2, V43.3	1,353	1,423	2,776	8.8	7.0	7.9
Race						
White	17,741	17,809	35,550	3.0	3.0	3.0
Black	675	611	1,286	4.4	3.6	4.0
Asian or Pacific Island	40	55	95	5.0	1.8	3.2
other/unknown	833	813	1,646	3.8	3.9	3.9
Renal Failure						
none	18,945	18,932	37,877	2.9	2.9	2.9
chronic renal failure 585	173	169	342	13.3	6.5	9.9
acute renal failure (before surgery)... (as indicated by hospital)	171	187	358	16.4	21.4	19.0
Urban/Rural Status of Patient's County of Residence						
absolutely urban	1,824	1,795	3,619	4.7	4.6	4.6
dominantly urban	5,710	5,725	11,435	2.9	3.1	3.0
mostly urban	5,917	5,911	11,828	2.7	2.7	2.7
mostly rural	1,762	1,776	3,538	3.2	3.2	3.2
dominantly/absolutely rural	1,796	1,763	3,559	3.1	2.8	2.9
out of state/other	2,280	2,318	4,598	3.5	2.9	3.2
Year of Discharge						
1994	9,210	9,165	18,375	3.2	3.3	3.2
1995	10,079	10,123	20,202	3.0	2.9	3.0

Appendix E

Table E. 1 Post-operative length of stay — Candidate variable frequency and arithmetic average length of stay *(after collapsing cells)*

Variable and ICD.9.CM Codes	Number of Cases			Avg. Post-op LOS (arithmetic)		
	sample I	*sample II*	*total*	*sample I*	*sample II*	*total*
	18,386	18,386	36,772	7.6	7.5	7.6
Acute Myocardial Infarction (AMI)						
no	14,339	14,259	28,598	7.4	7.4	7.4
yes (initial episode as principal diagnosis).....410.x1	4,047	4,127	8,174	8.0	8.0	8.0
***Atlas*™ Admission Severity Group (ASG)**						
0 / blank (16 cases with blank ASG)	97	115	212	5.7	6.1	5.9
1	10,036	10,044	20,080	6.8	6.8	6.8
2	6,948	6,901	13,849	8.1	8.2	8.2
3	1,279	1,297	2,576	10.3	10.0	10.1
4	26	29	55	10.8	14.4	12.7
Admission Source						
referrals	9,402	9,399	18,801	7.2	7.2	7.2
transfers	6,195	6,244	12,439	7.9	7.9	7.9
emergency room	2,789	2,743	5,532	8.0	7.9	7.9
Age & Age-Squared *(tested as continuous variables)*						
30-39 years	161	173	334	6.3	6.4	6.3
40-49 years	1,382	1,408	2,790	6.1	6.0	6.0
50-59 years	3,585	3,485	7,070	6.6	6.5	6.6
60-69 years	6,432	6,540	12,972	7.3	7.4	7.3
70-79 years	5,920	5,899	11,819	8.4	8.4	8.4
80-89 years	896	875	1,771	9.7	9.5	9.6
90-99 years	10	6	16	10.4	10.7	10.5
Average age: 65.3 (males 64.2; females 67.7)						
Cardiogenic Shock						
no	18,264	18,293	36,557	7.5	7.5	7.5
yes (before surgery)..... *(using clinical information from the medical record)*	122	93	215	10.8	11.8	11.2
Cardiomyopathy						
no	18,114	18,145	36,259	7.5	7.5	7.5
yes 425.3, 425.4, 425.8, 425.9	272	241	513	9.3	8.8	9.0
Complicated Hypertension						
no	18,064	18,047	36,111	7.5	7.5	7.5
yes 402.x1, 403.x1, 404.x1, 404.x2, 404.x3, 405.xx	322	339	661	10.3	10.2	10.3
Concurrent PTCA						
no	17,608	17,639	35,247	7.5	7.5	7.5
yes 36.01, 36.02, 36.05, 36.09	778	747	1,525	8.1	7.9	8.0

Variable and ICD.9.CM Codes	Number of Cases			Avg. Post-op LOS (arithmetic)		
	sample I	*sample II*	*total*	*sample I*	*sample II*	*total*
	18,386	18,386	36,772	7.6	7.5	7.6
Diabetes						
none	13,291	13,128	26,419	7.4	7.3	7.4
diabetes without complication 250.0x	4,419	4,561	8,980	7.7	7.9	7.8
diabetes with complication 250.1x - 250.9x	676	697	1,373	9.1	9.2	9.2
Dialysis						
no	18,265	18,251	36,516	7.5	7.5	7.5
yes 39.95, 54.98, V56.0, V56.8, V45.1	121	135	256	12.2	12.1	12.1
Ethnicity						
not Hispanic / unknown	18,232	18,226	36,458	7.6	7.5	7.6
Hispanic	154	160	314	7.7	7.6	7.7
Gender						
male	13,066	13,000	26,066	7.3	7.2	7.2
female	5,320	5,386	10,706	8.3	8.3	8.3
Heart Failure						
no	15,362	15,430	30,792	7.2	7.1	7.1
yes 398.91, 428.0, 428.1, 428.9	3,024	2,956	5,980	9.7	9.7	9.7
Note: For those cases having one of the above heart failure codes and a hypertension with congestive heart failure code (402.x1, 404.x1, 404.x3) in the same record, only the hypertension code was used.						
Prior CABG and/or Valve Surgery						
no	17,116	17,149	34,265	7.5	7.5	7.5
yes V45.81, 996.03, 414.02, 414.03, V42.2, V43.3	1,270	1,237	2,507	8.2	8.1	8.2
Race						
White	16,938	16,982	33,920	7.5	7.5	7.5
Black	610	604	1,214	8.4	8.4	8.4
Asian or Pacific Island	53	39	92	8.5	7.8	8.2
other/unknown	785	761	1,546	7.8	7.7	7.7
Renal Failure						
none	18,111	18,115	36,226	7.5	7.5	7.5
chronic renal failure 585	140	147	287	10.1	9.9	10.0
acute renal failure (before surgery) (as indicated by hospital)	135	124	259	11.0	11.1	11.1
Transfer-in Status						
no, not transferred in from a general acute care hospital	12,586	12,504	25,090	7.4	7.4	7.4
yes, transferred in from a general acute care hospital	5,800	5,882	11,682	7.9	7.9	7.9
Year of Discharge						
1994	8,631	8,829	17,460	7.8	7.8	7.8
1995	9,755	9,557	19,312	7.3	7.3	7.3

Appendix F

Table F.1 *Hospital Factors* — Frequency of occurrence, percent mortality, statewide ranges

Variable		Number of Cases			Percent Mortality		
		sample I	*sample II*	*total*	*sample I*	*sample II*	*total*
		19,289	19,288	38,577	3.1	3.1	3.1
Region where Hospital is Located							
Region 1	*10 hospitals*	5,465	5,586	11,051	3.0	3.0	3.0
Region 2	*2 hospitals*	978	959	1,937	3.3	4.3	3.8
Region 3	*2 hospitals*	833	851	1,684	1.8	1.4	1.6
Region 4	*2 hospitals*	578	569	1,147	2.6	1.6	2.1
Region 5	*6 hospitals*	2,587	2,661	5,248	2.7	3.0	2.9
Region 6	*3 hospitals*	1,220	1,216	2,436	2.7	2.5	2.6
Region 7	*5 hospitals*	2,167	2,025	4,192	2.6	3.0	2.8
Region 8	*3 hospitals*	1,278	1,300	2,578	2.4	2.7	2.6
Region 9	*10 hospitals*	4,183	4,121	8,304	4.5	4.0	4.2
Number of Years Hospital was Included in a PHC4 CABG Report *(a proxy for evaluating "new" facilities)*							
2 years	*2 hospitals*	321	286	607	2.2	1.8	2.0
3 years	*5 hospitals*	895	863	1,758	2.9	3.4	3.1
4 years	*1 hospital*	186	200	386	1.6	3.0	2.3
5 years	*2 hospitals*	733	722	1,455	2.3	1.7	2.0
6 years	*33 hospitals*	17,154	17,217	34,371	3.2	3.2	3.2
Volume of Total Open Heart Procedures Performed		*range is 315 to 3,079 — statewide average is 1,200 (over a two-year period)*					
Average CABG Volume for Physicians Practicing in the Hospital		*range is 35.8 to 426.5 — statewide average is 190 (over a two-year period)*					

Table F.2 *Physician Factors* — Frequency of occurrence, percent mortality, statewide ranges

Variable		Number of Cases			Percent Mortality		
		sample I	*sample II*	*total*	*sample I*	*sample II*	*total*
		19,289	19,288	38,577	3.1	3.1	3.1
Number of Hospitals in which Physician Performed CABG							
1 hospital	*131 physicians*	10,936	10,817	21,753	3.0	2.9	3.0
2 hospitals	*53 physicians*	5,385	5,385	10,770	3.6	3.8	3.7
3 hospitals	*17 physicians*	2,620	2,718	5,338	2.4	2.6	2.5
4 hospitals	*2 physicians*	348	368	716	3.4	1.4	2.4
Number of Years of Experience Performing CABG Surgery		*25% of the surgeons had 5 or fewer years experience* *50% had 10 or more years experience*					
Volume of Total Open Heart Procedures Performed		*range is 1 to 771— statewide average is 249 (over a two-year period)*					
Percent of Patients Undergoing "Vein Only" Approach		*25% of the surgeons performed "vein only" CABG on less than 12.6% of their patients* *25% of the surgeons performed "vein only" CABG on more than 28.5% of their patients* *10% of the surgeons performed "vein only" CABG on more than 42% of their patients*					