# Cardiac Surgery in New Jersey
## Technical Report

## 2022-2023 Data

### Health Care Quality Assessment

Health Care Quality and Informatics
Office of Population Health

# Table of Contents


Table of Contents ..... 2

Background ..... 3

Cardiovascular Health Advisory Panel ..... 3

Data ..... 3

Methodology ..... 4

Definition of Operative Mortality for Isolated CABG (Bypass) Surgery ..... 4

Risk-Adjustment ..... 4

Estimation of Risk-Adjusted Mortality Rates ..... 5

Table 1. Risk Factors Identified for Isolated CABG Surgery Operative Mortality*,2022-2023 ..... 7

Risk Factors for Post-Surgery Length of Stay ..... 8

Table 2. Risk Factors Identified for Isolated CABG Surgery Length of Stay, 2022-2023 ..... 9

Results ..... 11

Bypass Surgery Mortality Rate by Hospital Compared with the Statewide Rate in 2022-2023 ..... 11

Table 3. Risk-Adjusted Operative Mortality* and Post-Surgery Length of Stay by Hospital, 2022-2023 ..... 12

Length of Stay by Hospital ..... 13

Figure 1. Risk-Adjusted Operative Mortality* and Length of Stay (LOS)** by Hospital***, 2022-2023 ..... 13

Annual Risk-Adjusted Mortality Rate Compared to the Combined 2014-2023 Mortality Rate 14

Table 4. Annual Risk-Adjusted Operative Mortality* Rate Derived from the Pooled Data, 2014-2023 ..... 15

Statewide Bypass Surgery Related Infections ..... 16

Table 5. Statewide In-hospital Infection Rate, Operative Mortality Rate and Post-Surgery Length of Stay by Infection Type**, 2022-2023 ..... 17

Notes on Data: ..... 18

Appendix A ..... 19

New Jersey's Cardiovascular Health Advisory Panel (CHAP) Members ..... 19

Appendix B ..... 20

Statewide observed in-hospital and operative mortality rates, 1994-2023 ..... 20

Appendix C ..... 21

Cardiac Surgery Volume by Hospital and Type* of Surgery, 2022-2023 ..... 21

References ..... 22

State Reports on CABG Surgery Outcomes ..... 22

## Background

This report assesses the performance records of the 18 hospitals in New Jersey licensed to perform cardiac surgeries (referred to here as open-heart surgeries) in 2022 and 2023. New Jersey is one of five states that has issued reports on outcomes of isolated coronary artery bypass graft (CABG) or bypass surgeries for hospitals and surgeons. The state began reporting on patient mortality related to bypass surgery hospitals and surgeons in 1997, using data from 1994 and 1995.

An important goal of this report is to provide hospitals with information they can use to assess and improve quality of care and patient outcomes related to CABG surgery.

### Cardiovascular Health Advisory Panel

This report was a collaborative effort between the New Jersey Department of Health (NJDOH) and the Cardiovascular Health Advisory Panel (CHAP), a committee of experts including cardiac surgeons, cardiologists, nurses, representatives from professional associations and consumer representatives (Appendix A). The panel was established under the authority of the Commissioner of Health by Executive Order No. 187 (2001) and amended by Executive Order No. 207 and codified under N.J. Admin. Code § 8:33E-1.14 to provide the Commissioner with expert advice on cardiovascular health policy. CHAP advises on cardiovascular health promotion, disease prevention, standards of care, emerging technologies, and their applications to cardiac services across the State. It also reviews the State’s cardiac data for quality assessment, performance evaluation, and research.

## Data

For this report, the Department analyzed data on 18,912 patients who underwent open heart surgery at 18 hospitals during 2022-2023 (Appendix C). Of these patients, 7,524 had CABG surgery without any other major surgery during the same admission (i.e., isolated CABG surgery otherwise referred to as bypass surgery in this report).

Before analysis, the Department performed extensive error checks on the entire cardiac surgery dataset. In addition, sample medical records from each hospital were selected for independent medical audits.

# Methodology

## Definition of Operative Mortality for Isolated CABG (Bypass) Surgery

Isolated CABG surgery (or bypass surgery) refers to heart bypass surgery performed with no other additional major cardiac procedure[1]. Beginning with the 2000 report[2], and upon consultation with the CHAP, the Department included in its definition of "**operative mortality**": 1) all deaths that occurred during the hospitalization after the procedure, regardless of time delay; or 2) all deaths that occurred after discharge and up to 30 days post-surgery. Deaths occurring within 30 days after surgery, but post-discharge, were identified by matching patient records in the Department's cardiac surgery database with the State's official death records.

## Risk-Adjustment

The observed bypass surgery mortality rate for a hospital is estimated as the number of bypass surgery patients who died in the hospital during or after surgery, or patients who died after discharge but within 30 days post-surgery, divided by the total number of patients who underwent bypass surgery.

This observed mortality rate does not account for how sick the patients were before surgery. To make fair comparisons, the Department uses logistical regression to adjust mortality rates for each hospital by pre-surgery risk factors of each patient. Additionally, extremely high-risk patients, where the probability of death is very high, may, with the concurrence of the expert clinical panel, be excluded from the calculation.

A logistic regression model which included all the before-surgery health and demographic factors was fitted to the data for this report period to identify risk factors important in predicting whether a patient would die after bypass surgery (Lash, *et al*., 2020). The general form of a logistic regression model for estimating the "logit" of the probability of dying (p), denoted by $Y_i$, is presented as follows:

$$Y_i = \sum_{k}^{K} \beta_k X_{ki} + \varepsilon_i \text{ , } Where\ X_{0i} = 1;$$

$$Y_i = \log_e\left(\frac{p_i}{1-p_i}\right) = \text{ the "logit" of } p_i$$

$i = 1,2,\ldots,n$; $k = 0,1,2,\ldots,K$,
$\beta_k$ = Logistic regression coefficient for risk factor $X_k$
K = Number of risk factors in the model
n = Number of patients
$\varepsilon_i$ = Random error term i

---

[1] The Department, in consultation with CHAP, reviewed the way operative procedures are coded and issued an operative procedure coding guide to be followed by all hospitals starting with 2005 data.
[2] Prior to 2000, the Department defined patient death for this report as in-hospital death before discharge from the hospital after bypass surgery. As a result, patients who died after being discharged home or to post-acute care facilities were not counted for purposes of calculating bypass surgery mortality rates. This caused concerns about "gaming" of outcomes through discharge practices.

The risk factors for this report ($X_k$) identified by using the Bayesian information criterion (BIC) (Lash, *et al*., 2020). BIC balances model fit and complexity by measuring predictive efficiency while penalizing the number of parameters in the model. The finalized model not only includes statistically significant risk factors but also includes risk factors that increase the efficiency of the model. Table 1 includes estimates of coefficients for all risk factors selected using BIC, an indication of the level of statistical significance (p-values), and odds ratios.

The odds ratios are derived from the coefficients and are used to compare the relative importance of the risk factors in predicting mortality from bypass surgery. For each of the risk factors identified in Table 1, the odds ratio represents how much more likely a patient is at risk of mortality when compared to a patient who is in the reference group. For example, Table 1 shows that the odds of mortality for a patient who had renal failure that required dialysis was almost 12 times (odds ratio = 11.81) as high as a patient who did not have renal failure. This assumes that both patients have the same set of other risk factors presented in Table 1.

## Estimation of Risk-Adjusted Mortality Rates

The risk factors presented in Table 1 were used in the fitted logistic regression model to predict the probability of mortality from bypass surgery for each patient. The sum of predicted probabilities of mortality for patients operated on in each hospital divided by the number of patients operated on in that hospital provides the predicted (or expected) mortality rate associated with the hospital (Lash, *et al*., 2020). Terms such as “expected” and “predicted” are used interchangeably in this report to signify that the estimates are derived from predicted probabilities after accounting for risk factors.

The predicted probability of dying for patient i ( $\hat{p}_i$ ) is given as follows:

$$\hat{p}_i = \frac{e^{(\hat{Y}_i)}}{1+e^{(\hat{Y}_i)}}, \text{Where } i = 1,2,3,\ldots,n \text{ ; and}$$

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_{1i} + \hat{\beta}_2 X_{2i} + \hat{\beta}_3 X_{3i} + \ldots + \hat{\beta}_k X_{ki}$$

To assess the performance of each hospital, the observed patient mortality was compared with the expected or predicted patient mortality based on the existing risk factors for the hospital’s patients. The observed patient mortality is divided by the expected mortality. If the resulting ratio is higher than one, the hospital has a higher patient mortality than expected based on their patient mix. If the ratio is lower than one, the hospital has a lower mortality rate than expected, based on their patient mix. The ratio is then multiplied by the statewide mortality rate to produce the risk-adjusted patient mortality rate for the hospital.

The risk-adjusted patient mortality rate represents what a hospital’s patient mortality rate would have been if they had a mix of patients identical to the statewide mix. Thus, the risk-adjusted patient mortality has, to the extent possible, adjusted for differences among hospitals as it applies to variations in the severity of illness of their patients before surgery.

The statistical methods described above were tested to determine if they are sufficiently accurate in predicting the risk of death for all patients – for those who are severely ill prior to undergoing bypass surgery as well as those who are relatively healthy.

In this report's analysis, the tests confirmed that the model is reasonably accurate in predicting how patients of different risk levels will fare when undergoing bypass surgery. The area under the receiver operating characteristic (ROC) curve, denoted by C-statistic in Table 1, was used to evaluate model performance (Lash, *et al*., 2020). The C-statistic may be interpreted as the degree to which the risk factors in the model predicted the probability of death for bypass surgery patients. Specifically, the C-statistic measures whether predicted mortality is higher for patients who died compared to those who were discharged alive and remained alive 30 days after bypass surgery. The 2022-2023 model C-statistic was 79.7 percent, suggesting the model has strong predictive power (Table 1).

## Table 1. Risk Factors Identified for Isolated CABG Surgery Operative Mortality*, 2022-2023

| Patient risk factors identified | Proportion of patients (%) | Logistic regression results | | |
|---|---|---|---|---|
| | | Coefficient | P-value | Odds ratio |
| **Demographic factors** | | | | |
| Age-squared | - | 0.0003 | <.0001 | 1.000 |
| Presented to the hospital | 67.57 | *ref* | | |
| Transferred from another hospital | 32.43 | 0.5273 | 0.0065 | 2.477 |
| **Health factors** | | | | |
| No renal failure | 93.13 | *ref* | | |
| Renal failure without dialysis | 3.39 | 0.1497 | 0.4721 | 6.017 |
| Renal failure with dialysis | 3.48 | 0.8993 | <0.0001 | 11.813 |
| No lung disease | 78.26 | *ref* | | |
| Lung disease – mild | 9.46 | -0.4880 | 0.0881 | 1.978 |
| Lung disease – moderate | 4.04 | 0.6375 | 0.0111 | 5.540 |
| Lung disease – severe | 2.02 | 0.3439 | 0.2927 | 5.081 |
| Lung disease – unknown | 6.22 | -0.0057 | 0.9829 | 3.030 |
| No peripheral vascular disease | 87.00 | *ref* | | |
| Peripheral vascular disease | 13.00 | 0.4875 | 0.0265 | 2.505 |
| **Factors related to functioning of the heart** | | | | |
| No myocardial infarction | 49.99 | *ref* | | |
| Myocardial infarction (MI) | 50.01 | 0.5001 | 0.0195 | 2.508 |
| No cardiogenic shock at surgery | 98.67 | *ref* | | |
| Cardiogenic shock at surgery | 1.33 | 1.0640 | <0.0001 | 15.291 |
| No left main disease | 65.59 | *ref* | | |
| Left main disease | 34.41 | 0.4517 | 0.0170 | 2.277 |
| Intercept | -4.2985 | | | |
| C-statistic | 0.797 | | | |
| Number of CABGs (N) | 7,524 | | | |

SOURCE: 2022 - 2023 New Jersey cardiac surgery data.

* = Operative mortality includes: (1) all deaths occurring during the hospitalization in which the operation was performed, even after 30 days; and (2) those deaths occurring after discharge from the hospital, but within 30 days of the procedures.

## Risk Factors for Post-Surgery Length of Stay

To predict a patient's post-operative length of stay, a generalized linear regression model was fit on the log transformation of length of stay. The model was developed using demographic factors, health factors, factors related to functioning of the heart and prior cardiac intervention as predictors. Patients who experienced mortality during the bypass surgery hospitalization were excluded from the analysis, as were patients with hospital stays under two days or over 30 days.

Table 2 presents the final model used to estimate risk-adjusted length of stay by hospital and includes only those predictors found to be statistically significant at five percent or lower levels. Consistent with findings in Pennsylvania, the predictive power of the model is low (20.3%) (Pennsylvania Health Care Cost Containment Council, 2023). Such low predictive power is usually common when one fits a regression model using individual level datasets as large as these.

Please note that the coefficients provided in Table 2 are in log form and interpretation of the values should take that into consideration.

## Table 2. Risk Factors Identified for Isolated CABG Surgery Length of Stay, 2022-2023

| Patient risk factors identified | Proportion of patients (%) | Generalized linear regression results | |
|---|---|---|---|
| | | Coefficient | P-value |
| **Demographic factors** | | | |
| Age | - | -0.01882 | *<.0001* |
| Age-squared | - | 0.00021 | <.0001 |
| Male | 79.02 | *ref* | |
| Female | 20.98 | 0.07806 | <.0001 |
| Non-Hispanic White | 63.77 | *ref* | |
| Non-Hispanic Black | 7.87 | 0.11386 | <.0001 |
| Non-Hispanic other | 16.06 | 0.03364 | 0.0104 |
| Hispanic | 12.30 | 0.04158 | 0.0046 |
| PPO and commercial insurance | 29.18 | *ref* | |
| Medicaid | 7.58 | 0.11615 | <.0001 |
| Medicare | 49.28 | 0.01254 | 0.3231 |
| HMO | 10.60 | 0.00539 | 0.7404 |
| Other (self-pay, uninsured and other) | 3.36 | 0.09474 | 0.0003 |
| **Health factors** | | | |
| No obesity | 61.37 | *ref* | |
| Obesity | 38.63 | 0.03850 | <.0001 |
| No diabetes | 52.93 | *ref* | |
| Diabetes - managed with diet, oral, subcutaneous or other/other | 27.20 | -0.01024 | 0.3419 |
| Diabetes - insulin | 17.70 | 0.04243 | 0.0010 |
| Diabetes - other method | 2.17 | 0.05327 | 0.0870 |
| No renal failure | 93.57 | *ref* | |
| Renal failure without dialysis | 3.21 | 0.25889 | <.0001 |
| Renal failure with dialysis | 3.22 | 0.28560 | <.0001 |
| No cardiovascular disease (CVD) | 83.08 | *ref* | |
| CVD without cerebrovascular accident (CVA) | 9.23 | 0.04191 | 0.0080 |
| CVD and CVA | 7.69 | 0.08997 | <.0001 |
| No lung disease | 78.53 | *ref* | |
| Lung disease - mild | 9.46 | 0.05647 | 0.0003 |
| Lung disease - moderate | 3.91 | 0.13028 | <.0001 |
| Lung disease - severe | 1.94 | 0.12642 | 0.0001 |
| Lung disease - unknown | 6.16 | 0.03666 | 0.0531 |
| No peripheral vascular disease | 87.20 | *ref* | |
| Peripheral vascular disease | 12.80 | 0.08503 | <.0001 |

(table continued)

## Table 2. Risk Factors Identified for Isolated CABG Surgery Length of Stay, 2022-2023 (continued)

| Patient risk factors identified | Proportion of patients (%) | Generalized linear regression results | |
|---|---|---|---|
| | | Coefficient | P-value |
| **Factors related to functioning of the heart** | | | |
| No MI | 50.38 | *ref* | |
| MI – less than 7 days | 28.20 | 0.04047 | 0.0003 |
| MI – 8 to 21 days | 5.74 | 0.08181 | <.0001 |
| MI – more than 21 days | 15.69 | 0.00745 | 0.5712 |
| No congestive heart failure | 78.27 | *ref* | |
| Congestive heart failure | 21.73 | 0.08563 | <.0001 |
| No cardiogenic shock | 98.96 | *ref* | |
| Cardiogenic shock | 1.04 | 0.25514 | <.0001 |
| No resuscitation | 99.77 | *ref* | |
| Resuscitation | 0.23 | 0.23604 | 0.0153 |
| No arrhythmia | 92.91 | *ref* | |
| Arrhythmia – sustained ventricular tachycardia (VT)/ventricular fibrillation (VF) | 1.22 | -0.03523 | 0.4057 |
| Arrhythmia – heart block | 0.49 | 0.13699 | 0.0331 |
| Arrhythmia – atrial fibrillation/Flutter | 5.24 | 0.14113 | <.0001 |
| Arrhythmia – sick sinus syndrome | 0.14 | 0.52814 | <.0001 |
| NYHA^ – I | 37.66 | *ref* | |
| NYHA^ – II | 38.00 | 0.07282 | <.0001 |
| NYHA^ – III | 19.71 | 0.04849 | 0.0002 |
| NYHA^ – IV | 4.63 | 0.08886 | 0.0001 |
| Ejection fraction – 50 to 100% | 72.96 | *ref* | |
| Ejection fraction – 30 to 49% | 21.64 | 0.03745 | 0.0016 |
| Ejection fraction – 1 to 29% | 5.39 | 0.19575 | <.0001 |
| Intercept | 1.8951 | | |
| R-square | 20.32 | | |
| Number of CABGs (N)* | 7,323 | | |

SOURCE: 2022 - 2023 New Jersey cardiac surgery data.

* N excludes patients who died during hospitalization where CABG was performed; patients with post-surgical LOS > 30 days; and patients with post-surgical LOS < 2 days.

^ New York Heart Association (NYHA) functional classification of heart failure (Criteria Committee of the New York Heart Association, 1994)

## Results

### Bypass Surgery Mortality Rate by Hospital Compared with the Statewide Rate in 2022-2023

Table 3 presents the bypass volume, expected mortality rate, risk-adjusted mortality rate and its confidence interval following bypass surgery for each of the 18 hospitals.

Statewide, the observed operative mortality rate for bypass patients in 2022-2023 was 1.7%, based on 128 deaths out of 7,524 bypass operations performed.

After adjusting for severity of illness of the patients before surgery at each hospital, the estimates of risk-adjusted patient mortality rate for each hospital and related confidence intervals were calculated and presented in columns 4 and 5 of Table 3. Please note that the confidence intervals are narrower for hospitals performing more surgeries, and wider for those with lower volume. This reflects the fact that larger numbers -- in this case, more surgeries -- increase the statistical precision.

If a hospital's 95 percent confidence interval* contains the statewide mortality rate, the difference between the hospital's risk-adjusted mortality rate and the statewide rate was not statistically significant. If a hospital's 95 percent confidence interval falls below the statewide rate, the hospital's risk-adjusted patient mortality rate was statistically significantly lower than the statewide rate. If a hospital's 95 percent confidence interval is above the statewide rate, the hospital's risk-adjusted mortality rate was statistically significantly higher than the statewide rate.

Despite the variations in bypass mortality rates among hospitals, the quality of care delivered by most hospitals were similar across the state in 2022-2023. Only one hospital, Jersey Shore University Medical Center, had a statistically significantly lower risk-adjusted mortality rate than the statewide rate. The risk-adjusted mortality rate for University Hospital and Saint Michael's Medical Center could not be calculated due to their low bypass volume in this two-year period.

95% confidence limits are calculated as follows:

$$LCL = \frac{D\left(1 - \frac{1}{9D} - \frac{1.96}{3\sqrt{D}}\right)^3}{E} S \qquad UCL = \frac{(D+1)\left(1 - \frac{1}{9(D+1)} + \frac{1.96}{3\sqrt{(D+1)}}\right)^3}{E} S$$

Where D = observed mortality, and E = predicted or expected mortality, S = Statewide rate (Liddell, 1984).

# Table 3. Risk-Adjusted Operative Mortality* and Post-Surgery Length of Stay by Hospital, 2022-2023

| Hospital | Number of Isolated CABG Operations | Expected Patient Mortality (%) | Risk-Adjusted Patient Mortality (%) | | 95% Confidence Interval | Risk-Adjusted Patient Post-Surgery LOS (days)** |
|---|---|---|---|---|---|---|
| AtlantiCare Regional Medical Center | 226 | 1.36 | 2.76 | | (0.89, 6.45) | 6.15 |
| Capital Health Regional Medical Center | 122 | 1.57 | 2.66 | | (0.53, 7.76) | 7.83 |
| Cooper University Hospital | 810 | 1.81 | 2.32 | | (1.42, 3.58) | 6.84 |
| Cooperman Barnabas Medical Center | 386 | 1.42 | 2.79 | | (1.27, 5.30) | 7.43 |
| Deborah Heart and Lung Center | 248 | 2.42 | 1.13 | | (0.31, 2.90) | 6.24 |
| Englewood Hospital and Medical Center | 384 | 1.11 | 1.59 | | (0.43, 4.08) | 6.31 |
| Hackensack University Medical Center | 863 | 1.60 | 1.11 | | (0.51, 2.10) | 6.24 |
| Jersey City Medical Center | 210 | 2.24 | 1.81 | | (0.58, 4.23) | 6.63 |
| (-)Jersey Shore University Medical Center | 864 | 1.36 | 0.72 | **LO** | (0.23, 1.69) | 5.26 |
| Morristown Medical Center | 1170 | 1.66 | 1.14 | | (0.61, 1.95) | 6.55 |
| Newark Beth Israel Medical Center | 189 | 2.87 | 2.20 | | (0.88, 4.53) | 7.05 |
| Robert Wood Johnson University Hospital | 1086 | 1.83 | 1.79 | | (1.11, 2.74) | 5.66 |
| Saint Michael's Medical Center*** | 46 | N/A | N/A | | N/A | N/A |
| St. Joseph's University Medical Center | 189 | 1.36 | 3.98 | | (1.45, 8.66) | 5.82 |
| St. Mary’s General Hospital | 98 | 1.55 | 2.24 | | (0.25, 8.09) | 6.02 |
| The Valley Hospital | 165 | 1.21 | 2.55 | | (0.51, 7.45) | 6.24 |
| University Hospital*** | 12 | N/A | N/A | | N/A | N/A |
| Virtua Our Lady of Lourdes Hospital | 456 | 2.37 | 1.89 | | (0.98, 3.30) | 5.80 |
| Statewide | 7,524 | 1.70 | 1.70 | | | 6.90 |

SOURCE: 2022 - 2023 New Jersey cardiac surgery data.

* Operative mortality includes: (1) all deaths occurring during the hospitalization in which the operation was performed, even after 30 days; and (2) those deaths occurring after discharge from the hospital, but within 30 days of the procedures.

** Excluded are patients who died during hospitalization where CABG was performed, patients with post-surgical LOS >30 days; and patients with post-surgical LOS < 2 days.

*** Risk-adjusted mortality rate and length of stay cannot be reliably calculated for the hospital due to low volume.

LO Risk-adjusted mortality rate significantly lower than the New Jersey statewide mortality rate based on 95 percent confidence interval.

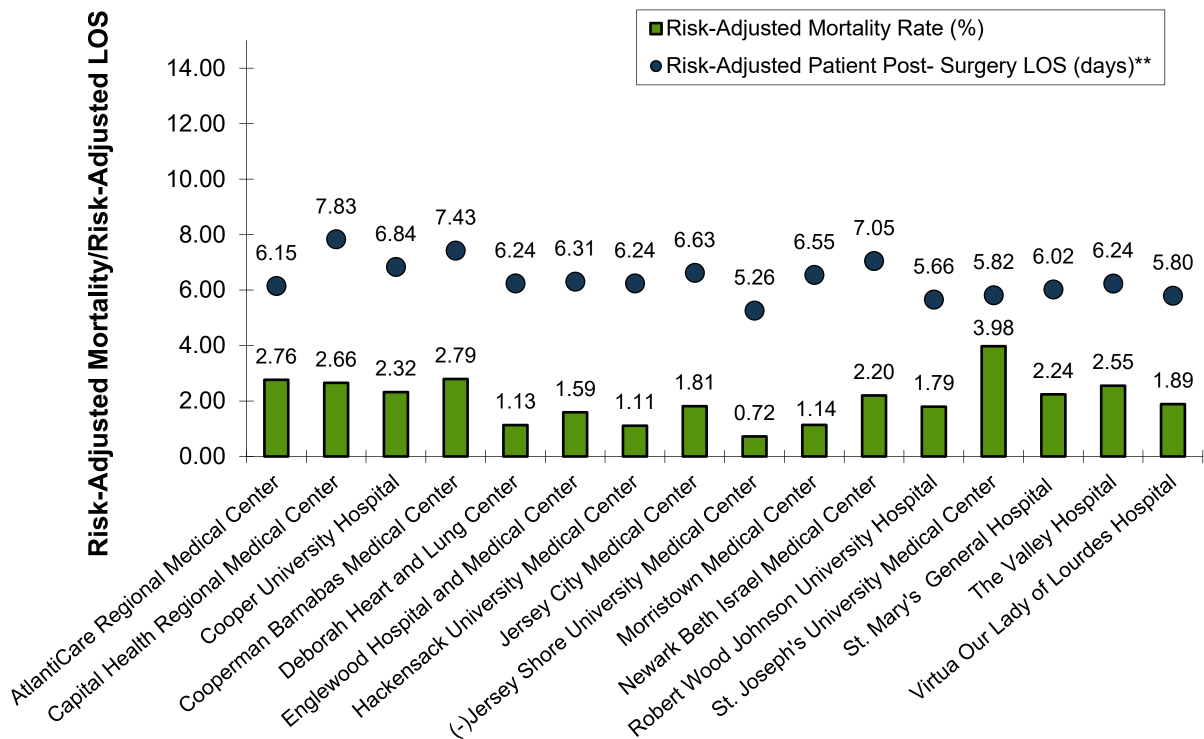
N/A= Cell suppression is applied to observations with counts <6, along with complementary suppression as needed, to maintain confidentiality and prevent disclosure through inference.

## Length of Stay by Hospital

Post-surgery length of stay is an additional tool to measure hospital performance on bypass surgery. The statewide post-surgery length of stay is 7.43 days during 2022-2023 (7.53 days in 2022 and 7.34 days in 2023).

The risk-adjusted length of stay by hospital are displayed in the last column of Table 3 and in Figure 1. There is a marked variation in risk-adjusted length of stay by hospital as shown in Figure 1. The risk-adjusted length of stay by hospital ranged from 5.26 days (Jersey Shore University Medical Center) to 7.83 days (Capital Health System at Fuld) in this two-year period. This report did not find any statistically significant correlation between mortality rate and length of stay.

**Figure 1. Risk-Adjusted Operative Mortality* and Length of Stay (LOS)** by Hospital***, 2022-2023**




SOURCE: 2022 - 2023 New Jersey cardiac surgery data.

* Operative mortality includes: (1) all deaths occurring during the hospitalization in which the operation was performed, even after 30 days; and (2) those deaths occurring after discharge from the hospital, but within 30 days of the procedures.

** Excluded are patients who died during hospitalization where CABG was performed, patients with post-surgical LOS >30 days; and patients with post-surgical LOS < 2 days.

*** Risk-adjusted mortality rate and length of stay cannot be reliably calculated for University Hospital and Saint Michael's Medical Center due to low volume.

(-) Risk-adjusted mortality rate significantly lower than the New Jersey statewide mortality rate based on 95 percent confidence interval.

## Annual Risk-Adjusted Mortality Rate Compared to the Combined 2014-2023 Mortality Rate

Table 4 presents trends in the statewide mortality rate of patients who had bypass surgery using a statistical model based on the pooled data collected over the period 2014-2023. For each year, the table presents statewide observed patient mortality rate, expected patient mortality rate, and risk-adjusted patient mortality rate estimate. Note that the numbers differ from those shown in reports produced in previous years, due to the revised definition of mortality and the use of pooled data for the analysis. The table also indicates whether the annual risk-adjusted mortality rate differ statistically from the pooled 2014-2023 mortality rate.

Table 4 shows that risk-adjusted mortality rate (RAMR) from bypass surgery increased by 28.1% from 1.28% in 2014 to 1.64% in 2023, averaging 0.04% points in absolute terms per year according to a fitted regression line (data not shown).

Between 2022 and 2023, RAMR fell by 17.2%, dropping from 1.98% to 1.64%.

## Table 4. Annual Risk-Adjusted Operative Mortality* Rate Derived from the Pooled Data, 2014-2023

| Year | Number of Isolated CABG Operations | Operative Patient Mortality* | Observed Patient Mortality Rate (%) | Predicted Patient Mortality Rate (%) | Risk-Adjusted Patient Mortality Rate (%) | | Yearly Change in Risk-Adjusted Mortality Rate (%) | Percent Change from 2014 Risk-Adjusted Mortality Rate (%) |
|---|---|---|---|---|---|---|---|---|
| 2014 | 3,790 | 51 | 1.35 | 2.00 | 1.28 | **LO** | ---- | ---- |
| 2015 | 3,945 | 79 | 2.00 | 2.14 | 1.78 | **SA** | 0.50 | 39.1 |
| 2016 | 4,121 | 63 | 1.53 | 2.00 | 1.46 | **LO** | -0.32 | 14.1 |
| 2017 | 4,059 | 81 | 2.00 | 1.86 | 2.04 | **SA** | 0.58 | 59.4 |
| 2018 | 3,947 | 64 | 1.62 | 1.84 | 1.68 | **SA** | -0.36 | 31.3 |
| 2019 | 4,094 | 99 | 2.42 | 1.86 | 2.48 | **HI** | 0.80 | 93.8 |
| 2020 | 3,305 | 76 | 2.30 | 1.89 | 2.31 | **SA** | -0.17 | 80.5 |
| 2021 | 3,831 | 94 | 2.45 | 1.87 | 2.50 | **HI** | 0.19 | 95.3 |
| 2022 | 3,796 | 72 | 1.90 | 1.82 | 1.98 | **SA** | -0.52 | 54.7 |
| 2023 | 3,728 | 56 | 1.50 | 1.75 | 1.64 | **SA** | -0.34 | 28.1 |
| **2014-2023** | **38,616** | **735** | **1.90** | **1.90** | **1.90** | | | |

SOURCE: 2014 - 2023 New Jersey cardiac surgery data.

* Operative mortality includes: (1) all deaths occurring during the hospitalization in which the operation was performed, even after 30 days; and (2) those deaths occurring after discharge from the hospital, but within 30 days of the procedures.

**LO** - The risk-adjusted patient mortality is significantly lower than the mortality for the 2014-2023 combined when evaluated with a 95 percent confidence interval.
**SA** - The risk-adjusted patient mortality is same as the mortality for the 2014-2023 combined when evaluated with a 95 percent confidence interval.
**HI** - The risk-adjusted patient mortality is significantly higher than the mortality for the 2014-2023 combined when evaluated with a 95 percent confidence interval.

## Statewide Bypass Surgery Related Infections

Table 5 presents statewide postoperative infection rates for surgical site infections such as leg, thoracotomy, or more severe deep sternal wound infections (an infection extending from the sternum into the surrounding tissue, muscle, and/or mediastinum requiring operative intervention), as well as septicemia (severe complication of infection in the blood stream), urinary tract infection (UTI), and postoperative pneumonia.

Statewide, 4.67% of patients who had bypass surgery developed some type of infection. The highest percentage of infections were due to pneumonia (2.47%), followed by UTI (1.63%), septicemia (0.77%), leg infection (0.33%), and deep sternal wound infection (0.21%).

Observed bypass surgery mortality for patients with infections (13.39%) was almost twelve times as high as those who had no infection (1.13%). In addition, patients who developed post-surgery infections stayed in the hospital almost three times as long (19.44 days) compared to those who had no infection (6.84 days).

Among all infections reported, septicemia had the highest mortality rate of 39.66%, followed by deep sternal wound infection (31.25%), pneumonia (17.20%), UTI (7.32%), and leg infection (4.00%).

Overall infection rate increased by 2.86% from 4.54% in 2019-2020 to 4.67% in 2022-2023. However, the overall infection-related mortality rate remained unchanged at 13.39% in both 2019-2020 and 2022-2023 (data not shown).

## Table 5. Statewide In-hospital Infection Rate, Operative Mortality Rate and Post-Surgery Length of Stay by Infection Type**, 2022-2023

| | Number of cases | Infection rate (%) | Operative mortality* | | Average length of stay (days) |
|---|---|---|---|---|---|
| | | | Number | Rate (%) (observed) | |
| **Cases with infections** | **351** | 4.67 | **47** | **13.39** | **19.44** |
| Deep sternal wound infection** | 16 | 0.21 | N/A | N/A | 25.63 |
| Thoracotomy** | N/A | N/A | 0 | 0.00 | 30.50 |
| Leg** | 25 | 0.33 | N/A | N/A | 17.00 |
| Septicemia** | 58 | 0.77 | 23 | 39.66 | 29.86 |
| Urinary tract infection** | 123 | 1.63 | 9 | 7.32 | 16.04 |
| Pneumonia** | 186 | 2.47 | 32 | 17.20 | 22.68 |
| **Cases without infections** | **7,173** | | **81** | **1.13** | **6.84** |
| **Total CABG cases** | **7,524** | | **128** | **1.70** | **7.43** |

SOURCE: 2022 - 2023 New Jersey cardiac surgery data.

* Operative mortality includes: (1) all deaths occurring during the hospitalization in which the operation was performed, even after 30 days; and (2) those deaths occurring after discharge from the hospital, but within 30 days of the procedures.

** Infection types are not mutually exclusive.

N/A = Cell suppression is applied to observations with counts <6, along with complementary suppression as needed, to maintain confidentiality and prevent disclosure through inference.

## Notes on Data:

The data used in this study were reported by hospitals according to criteria established by the Department in collaboration with clinical experts from CHAP. The Department has made a good faith effort to ensure that the data elements and definitions are consistent with those issued by the Society for Thoracic Surgeons. The data were audited by an independent reviewer under contract with the Department.

Throughout the development of this report, the Department has taken steps to make sure that all hospitals were informed about data reporting and auditing requirements, as well as the statistical methods being used to analyze mortality data.

The Department considers it a vital function of hospitals to be able to collect and report complete, accurate medical information on patients. This function is critical not only to the success of the cardiac surgery report, but to the hospitals' own ongoing efforts to improve the quality of care for all patients. The Department and hospitals will enhance data reporting to ensure public access to accurate information.

# Appendix A

## New Jersey's Cardiovascular Health Advisory Panel (CHAP) Members

**Perry Weinstock, MD - Chairperson of CHAP**
Director, Cooper Heart Institute
Chief of Cardiology
Cooper Hospital University Medical Center, Camden, New Jersey

**Mary T. Abed, MD, FACC**
Chief, Division of Cardiology
Jersey City Medical Center
Jersey City, New Jersey

**Reginald J. Blaber, MD, FACC**
Vice President, Cardiovascular Service Line
Our Lady of Lourdes Medical Center
Camden, New Jersey

**Marc Cohen, MD, FACC**
Chief, Division of Cardiology
Newark Beth Israel Medical Center
Newark, New Jersey

**Raffaele Corbisiero, MD, FACC**
Director of Electrophysiology
Deborah Heart and Lung Center
Browns Mills, New Jersey

**Barry C. Esrig, MD, FACS, FACC, FCCP**
New York Presbyterian Hospital
New York, New York

**Austin Kutscher, Jr., MD, FACC**
Hunterdon Cardiovascular Associates
Flemington, New Jersey

**Glenn Laub, MD**
Chair, Department of Cardiothoracic Surgery
Drexel University College of Medicine
Hahnemann University Hospital
Philadelphia, Pennsylvania

**Leonard Lee, MD**
Chair, Department of Surgery
Robert Wood Johnson Medical School
Chief, Division of Cardiothoracic Surgery
Robert Wood Johnson University Hospital
New Brunswick, New Jersey

**Howard Levite, MD**
Medical Director, Heart Institute
AtlantiCare Regional Medical Center
Pomona, New Jersey

**Richard M. Niebart, MD**
Jersey Shore University Medical Center
Mid-Atlantic Surgical Associates
Neptune, New Jersey

**Joseph E. Parrillo, MD**
Professor of Medicine
Rutgers New Jersey Medical School
Chairman, Heart and Vascular Hospital
Hackensack University Medical Center
Hackensack, New Jersey

**NJDOH Cardiac Surgery Report Team**

**Mehnaz Mustafa**
Executive Director
Health Care Quality and Informatics

**Aras Islam**
Deputy Executive Director
Health Care Quality and Informatics

**Jianping Huang**
Director
Health Care Quality Assessment

**Priya Fox**
Research Scientist

**DaQing Song**
Research Scientist

**Kaiting Lang**
Research Scientist

**Eman Addish**
Research Scientist

**Juana Jackson**
Management Assistant

# Appendix B

**Statewide observed in-hospital and operative mortality rates, 1994-2023**

| Year of operation | Mortality rates | |
|---|---|---|
| | In-hospital | Operative mortality * |
| **1994-1995** | 3.75 | 4.14 |
| **1996-1997** | 3.37 | 3.75 |
| **1998** | 2.60 | 3.01 |
| **1999** | 2.89 | 3.31 |
| **2000** | 2.22 | 2.68 |
| **2001** | 2.01 | 2.51 |
| **2002** | 1.80 | 2.15 |
| **2003** | 1.91 | 2.33 |
| **2004** | 1.54 | 1.98 |
| **2005** | 1.83 | 2.10 |
| **2006** | 1.73 | 2.00 |
| **2007** | 1.66 | 2.00 |
| **2008** | 1.19 | 1.47 |
| **2009** | 1.00 | 1.31 |
| **2010** | 1.58 | 1.95 |
| **2011** | 1.13 | 1.35 |
| **2012** | 1.63 | 2.01 |
| **2013** | 1.13 | 1.57 |
| **2014** | 1.32 | 1.96 |
| **2015-2016** | 1.44 | 1.76 |
| **2017-2018** | 1.40 | 1.80 |
| **2019-2020** | 1.81 | 2.37 |
| **2021-2022** | 1.72 | 2.18 |
| **2022-2023** | 1.42 | 1.70 |

SOURCE: 1994 - 2023 New Jersey cardiac surgery data.

* Operative mortality includes: (1) all deaths occurring during the hospitalization in which the operation was performed, even after 30 days; and (2) those deaths occurring after discharge from the hospital, but within 30 days of the procedures.

## Appendix C

### Cardiac Surgery Volume by Hospital and Type* of Surgery, 2022-2023

| Hospital | | CABG | Valve | CABG, Valve | Valve, Other | CABG, Valve, Other | CABG, Other | Other | Total |
|---|---|---|---|---|---|---|---|---|---|
| AtlantiCare Regional Medical Center | | 226 | 305 | 36 | 46 | 6 | 9 | 21 | 649 |
| | | 35% | 47% | 6% | 7% | 1% | 1% | 3% | 100% |
| Capital Health Regional Medical Center | | 122 | N/A | N/A | 0 | 0 | 0 | N/A | 132 |
| | | 92% | N/A | N/A | 0% | 0% | 0% | N/A | 100% |
| Cooper University Hospital | | 810 | 616 | 96 | 88 | N/A | N/A | 200 | 1,824 |
| | | 44% | 34% | 5% | 5% | N/A | N/A | 11% | 100% |
| Cooperman Barnabas Medical Center | | 386 | 432 | 88 | 34 | N/A | N/A | 27 | 979 |
| | | 39% | 44% | 9% | 3% | N/A | N/A | 3% | 100% |
| Deborah Heart and Lung Center | | 248 | 449 | 93 | 50 | N/A | N/A | 79 | 935 |
| | | 27% | 48% | 10% | 5% | N/A | N/A | 8% | 100% |
| Englewood Hospital and Medical Center | | 384 | 50 | 57 | 0 | N/A | N/A | 445 | 937 |
| | | 41% | 5% | 6% | 0% | N/A | N/A | 47% | 100% |
| Hackensack University Medical Center | | 863 | 648 | 76 | 94 | 18 | 26 | 197 | 1,922 |
| | | 45% | 34% | 4% | 5% | 1% | 1% | 10% | 100% |
| Jersey City Medical Center | | 210 | 136 | 24 | 12 | N/A | N/A | 17 | 405 |
| | | 52% | 34% | 6% | 3% | N/A | N/A | 4% | 100% |
| Jersey Shore University Medical Center | | 864 | 960 | 102 | 61 | 20 | 11 | 99 | 2,117 |
| | | 41% | 45% | 5% | 3% | 1% | 1% | 5% | 100% |
| Morristown Medical Center | | 1,170 | 1,796 | 204 | 225 | 34 | 30 | 175 | 3,634 |
| | | 32% | 49% | 6% | 6% | 1% | 1% | 5% | 100% |
| Newark Beth Israel Medical Center | | 189 | 294 | 48 | 57 | N/A | N/A | 85 | 691 |
| | | 27% | 43% | 7% | 8% | N/A | N/A | 12% | 100% |
| Robert Wood Johnson University Hospital | | 1,086 | 282 | 66 | 148 | 53 | 11 | 229 | 1,875 |
| | | 58% | 15% | 4% | 8% | 3% | 1% | 12% | 100% |
| Saint Michael's Medical Center | | 46 | 40 | N/A | N/A | 0 | 0 | 0 | 88 |
| | | 52% | 45% | N/A | N/A | 0% | 0% | 0% | 100% |
| St. Joseph's University Medical Center | | 189 | 215 | 43 | 41 | 7 | 11 | 36 | 542 |
| | | 35% | 40% | 8% | 8% | 1% | 2% | 7% | 100% |
| St. Mary's General Hospital | | 98 | N/A | 17 | 0 | 0 | 0 | N/A | 138 |
| | | 71% | N/A | 12% | 0% | 0% | 1% | N/A | 100% |
| The Valley Hospital | | 165 | 433 | 23 | 89 | 30 | 13 | 51 | 804 |
| | | 21% | 54% | 3% | 11% | 4% | 2% | 6% | 100% |
| University Hospital | | 12 | 69 | N/A | N/A | N/A | 0 | 7 | 95 |
| | | 13% | 73% | N/A | N/A | N/A | 0% | 7% | 100% |
| Virtua Our Lady of Lourdes Hospital | | 456 | 562 | 36 | 35 | 7 | 6 | 43 | 1,145 |
| | | 40% | 49% | 3% | 3% | 1% | 1% | 4% | 100% |
| Statewide | | 7,524 | 7,313 | 1,019 | 983 | 222 | 138 | 1,713 | 18,912 |
| | | 40% | 39% | 5% | 5% | 1% | 1% | 9% | 100% |

SOURCE: 2022 - 2023 New Jersey cardiac surgery data.

* CABG = Coronary artery bypass graft surgery without any other major cardiac surgery performed at the same time.
Valve = Valve surgery without any other major cardiac surgery performed at the same time.
Other = Including left ventricular aneurysm repair, ventricular septal defect repair, surgical ventricular restoration, cardiac trauma repair, cardiac transplant, aortic aneurysm repair, carotid endarterectomy, and others.
N/A = *Cell suppression is applied to observations with counts <6, along with complementary suppression as needed, to maintain confidentiality and prevent disclosure through inference.*

## References

Criteria Committee of the New York Heart Association. (1994). *Nomenclature and criteria for diagnosis of diseases of the heart and great vessels* (9th ed., M. Dolgin, Ed.). Little, Brown and Company.

Lash, T.L., VanderWeele, T. J., Haneuse, S., & Rothman, K.J. (2020). *Modern epidemiology* (4th ed.) Wolters Klouwer.

Liddell F. D. (1984). Simple exact analysis of the standardised mortality ratio. *Journal of epidemiology and community health*, *38*(1), 85–88. https://doi.org/10.1136/jech.38.1.85

New Jersey Department of Health, Cardiac Surgery in New Jersey, 2019-2020, Health Care Quality Assessment, Office of Population Health, August 2022. https://www.nj.gov/health/healthcarequality/documents/Cardiac%20Surgery%20Report%202019t2020_08162022%20(1).pdf

New Jersey Department of Health, Cardiac Surgery in New Jersey, 2021-2022, Technical Report, Health Care Quality Assessment, Office of Population Health, August 2022. https://www.nj.gov/health/healthcarequality/documents/CABG-Technical-Report-2021-2022.pdf

NJ Admin Code 8:33E-1.14

Pennsylvania Health Care Cost Containment Council. (2023). Cardiac procedures report 2020-2021. https://www.phc4.org/reports/cardiac-procedures-report-2020-2021/

## State Reports on CABG Surgery Outcomes

California Office of Statewide Health Planning and Development. (2024). 2022 California Hospital Performance Ratings for Coronary Artery Bypass Graft (CABG) Surgery. https://data.chhs.ca.gov/dataset/california-hospital-performance-ratings-for-coronary-artery-bypass-graft-cabg-surgery/resource/86773748-705f-4d8c-b862-4d7b76a8f8e7

New York State Department of Health. (2023). Adult Cardiac Surgery in New York State: 2017-2019. https://www.health.ny.gov/statistics/diseases/cardiovascular/heart_disease/docs/2017-2019_adult_cardiac_surgery.pdf

Pennsylvania Health Care Cost Containment Council. (2023). Cardiac procedures report 2020-2021.https://www.phc4.org/reports/cardiac-procedures-report-2020-2021/

The Massachusetts Department of Public Health. (2016). Adult Coronary Artery Bypass Graft Surgery FY14 Annual Report. Massachusetts Data Analysis Center, Department of Health Care Policy, Harvard Medical School. https://www.mass.gov/doc/cardiac-surgery-hospital-report-2014/download