Health Care Quality Assessment

Cardiac Surgery

In New Jersey, 2017-2018

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Table of Contents

Executive summary

This report is for patients and families considering coronary artery bypass graft (CABG) surgery. It summarizes the results of a study of CABG surgery in New Jersey and answers many of the questions you may have about this common procedure.

An important goal of this report is to give you, the patient, and your family information that will help you have more informed discussions with your physicians. Since every patient has different health concerns and risks, we encourage you to discuss the information in this report with your physicians, who can answer your questions and concerns.

Another important goal of this report is to give New Jersey hospitals and surgeons meaningful data they can use in assessing quality of care related to CABG surgery. There is strong evidence, from the handful of states with similar studies, that this kind of information prompts hospitals to examine their process of care in order to improve the overall quality of CABG surgery, prevent infections, and ultimately save lives.

For this study, the Department of Health (Department) collected data on 18,138 patients undergoing open heart surgery at 18 hospitals in the period 2017-2018. Of these patients, 8,006 had CABG surgery with no other major surgery during the same admission, i.e. *isolated CABG surgery* (or simply referred to as *bypass surgery* in this report).

This study was a collaborative effort with a select committee of experts known as the Cardiovascular Health Advisory Panel (CHAP), which includes physicians who specialize in cardiac surgery, cardiologists and other health care professionals.

How to Use This Report

Hospitals and doctors are not the same in their specialties and expertise. Some are better equipped than others to handle patients with different health conditions. These differences will influence the quality of care you receive and the outcomes of your bypass surgery.

Many consumers want a doctor's recommendation on hospitals and surgeons. Frequently, people collect as much information as possible to make informed decisions. This report will provide some of that information.

However, this report is not intended to be used alone. It is designed to provide important information to help you make informed decisions. There are many factors to consider in determining the best hospital for you. Among these are your own personal health risks as well as the experience certain hospitals have treating patients with those risk factors. Before you make your decisions, you should discuss this report with the physician, usually a cardiologist, who refers you for cardiac surgery. The cardiologist's knowledge and expertise will be a valuable guide in making your decision.

Key Findings

The Department analyzed the bypass surgery data using a statistical method to assess hospital and surgeon performance. Before analyzing the data, the Department performed extensive error checks on the entire open heart surgery data, sampled medical records from each hospital for independent medical audit and consulted with the clinical panel of the CHAP. The statistical analysis took into account the patient's health status before surgery as well as demographic factors. This process is commonly known as "risk-adjustment" and allows for fair comparisons among hospitals and surgeons treating diverse patient populations.

Some key findings of the 2017-2018 data analysis are as follows:

Statewide Summary

- 44.1 percent (8,006) of the 18,138 total open heart surgeries performed in New Jersey in the period 2017-2018 were bypass surgeries. 43.2 percent (3,947 of the 9,145) in 2018 and 45.1 percent (4,059 of the 8,993) in 2017 were bypass surgeries.

- 145 of the 8,006 bypass surgery patients died while in the hospital or within 30 days after surgery in the period 2017-2018. The statewide operative mortality rate for bypass surgery patients in the two-year period was 1.81 percent. The statewide operative mortality rate was 1.62 percent (64 deaths of the 3,947 bypass surgeries) in 2018 and 2.00 percent (80 deaths of the 4,059 bypass surgeries) in 2017.

- When comparing 2017 and 2018 on a risk-adjusted basis, the mortality rate decreased 18.0 percent.

- A review of the 25 years of pooled data suggests that the risk-adjusted bypass mortality rate in New Jersey declined 59.8 percent between 1994 (4.36%) and 2018 (1.75%).

Mortality Rate by Hospital and by Surgeon

- Despite the variations in bypass mortality rates among hospitals and surgeons, the quality of care delivered by most hospitals and surgeons were similar to the statewide performance.

- During the period 2017-2018, one hospital, Robert Wood Johnson University Hospital, had a statistically significantly higher risk-adjusted mortality rate than the statewide rate.

- One hospital, Deborah Heart and Lung Center, had statistically significantly lower risk-adjusted mortality rate than the statewide rate during the two-year period.

- Although its rate was not statistically significantly different from the statewide rate, it is nevertheless notable that University Hospital had no bypass surgery deaths in the two-year period.

- During the period 2017-2018, one surgeon, Dr. Anthony Lemaire from Robert Wood Johnson University Hospital, had a statistically significantly higher risk-adjusted mortality rate than the statewide rate.

- During the period 2017-2018, one surgeon, Dr. Roland Ross from Deborah Heart and Lung Center, had a statistically significantly lower risk-adjusted mortality rate than the statewide rate.

- Although their rates were not statistically significantly different from the statewide rate, it is nevertheless notable that a few surgeons, including some who performed less than 100 bypass surgeries in a hospital, had no bypass surgery death in the two-year period. Among surgeons who performed 100 or more bypass surgeries in a hospital in the two-year period, Dr. George Batsides and Dr. Elie Elmann from Hackensack University Medical Center had no bypass surgery death.

Pre-surgery Patient Risk Factors

Key factors that are associated with a patient's chance of surviving the operation include*:

- Patient's age and gender;

- Whether the patient had various preoperative health risk factors, such as cerebrovascular disease, peripheral vascular disease, renal failure requiring dialysis;

- Whether the patient had any previous cardiac surgery;

- Whether the patient had preoperative cardiac risk factors such as low ejection fraction, AMI within one to twenty-one days from the surgery, or was in cardiogenic shock at the time of surgery.

** More information on risk factors and methods used in this report are presented in Appendix D.*

Post-surgery Length of Stay

- The average post-surgery length of hospital stay for a typical bypass surgery patient in the period 2017-2018 was 7.42 days (7.47 days in 2018 and 7.36 days in 2017).

- The risk-adjusted length of stay by hospital ranged from 5.43 days at Cooper Hospital University Medical Center to 7.25 days at Newark Beth Israel Medical Center in the two-year period.

- There were also differences in length of stay by surgeon. Risk-adjusted average length of stay by individual eligible surgeon in the period 2017-2018 ranged from 5.18 days to 8.49 days.

Post-surgery Infections

- 5.22 percent of patients had some type of infections, including pneumonia, following bypass surgery in 2017-2018 (5.24 percent in 2018 and 5.20 percent in 2017).

- The overall infection rate increased slightly by 0.76 percent from 2017 to 2018 (not risk-adjusted).

- As expected, bypass surgery patients who developed infections after surgery had a much higher mortality rate (12.68 percent vs. 1.21 percent) and a longer hospital stay compared to those who had no infections (20.54 days vs. 6.78 days).

Introduction

This report is for patients and families of patients facing the possibility of coronary artery bypass graft (CABG) surgery. It provides mortality rates for the 18 hospitals that performed cardiac surgery and the physicians performing this procedure in 2017 and 2018. As part of the Department's continued effort to provide information to consumers, this report includes information on hospital length of stay and infections following CABG surgeries. The report provides risk-adjusted length of hospital stay after CABG surgery by hospital and by eligible surgeon (i.e. surgeon who performed at least 100 isolated CABG operations in one hospital in the years 2017 and 2018 combined). The rates of infections are reported for the state as a whole.

An important goal of the report is to give you, the patient, and your family information that will help you have more informed discussions with your physician. Since every patient has different health concerns and risks, we encourage you to discuss the information in this report with your physician, who can best answer your questions and concerns.

Another important goal of this analysis is to give hospitals data they can use in assessing quality of care related to CABG surgery. There is strong evidence, from other states with similar reports, that this information encourages hospitals to examine their processes of care and make changes that can improve quality of care, prevent infections, and ultimately save lives.

For this report, the Department of Health collected data on 8,006 patients who had CABG surgery with no other major surgery during the same admission (simply referred to as isolated CABG surgery or bypass surgery in this report) in 2017 and 2018. These are the most recent years for which death certificate data used to calculate mortality up to 30 days after discharge are available. The data have been "risk-adjusted," which means that they were adjusted to take into account the patient's health conditions before surgery. The risk-adjustment process allows for fair comparisons among hospitals and surgeons treating diverse patient populations.

New Jersey's mortality rate for bypass surgery has shown marked decline since public reporting began with 1994 data. The risk-adjusted mortality rate has declined by 59.8 percent from 4.36 percent to 1.75 percent between 1994 and 2018, which is statistically significant. A difference is called "statistically significant" when it is too large to be due to chance or random variation.

The observed mortality rate in the period 2017-2018 was 1.81 percent. The observed mortality rate was 1.62 percent in 2018, which was lower than the mortality rate of 2.00 percent in 2017. The risk-adjusted mortality rate decreased 18.0 percent between 2017 and 2018, which is not statistically significant (Appendix D).

How to Use This Report

Hospitals and doctors are not the same in their specialties and expertise. Some are better equipped than others to handle patients with different health conditions. These differences will influence the quality of care you receive and the outcomes of your bypass surgery.

Many consumers want a doctor's recommendation on hospitals and surgeons. Frequently, people collect as much information as possible to make informed decisions. This report will provide some of that information.

However, this report is not intended to be used alone. Volume, mortality rate and length of stay in this report are just some of the important factors to consider in deciding where to have cardiac surgery. There are many factors to consider in determining the best hospital for you. Among these are your own personal health risks as well as the experience certain hospitals have treating patients with those risk factors. Before you make your decisions, you should discuss this report with your physician, usually a cardiologist, who refers you for cardiac surgery. You and your physician together can make the best choice after full consideration of your medical needs.

Cardiovascular Health Advisory Panel

A Cardiovascular Health Advisory Panel (CHAP) was established by the Commissioner of Health by Executive Order (No. 187 (2001) and amended by Executive Order 207) to provide the Commissioner with expert advice on sound cardiovascular health policy. CHAP provides advice on cardiovascular health promotion, disease prevention, standards of care, emerging technologies and their applications to cardiac services in the State, and review of the State's cardiac data for quality assessment, performance evaluation and research. CHAP's membership includes surgeons, cardiologists, nurses and professional associations and consumer representatives (See Appendix B).

Heart Disease and Cardiac Surgery in New Jersey

Heart diseases continue to be the leading causes of death of Americans with 655,381 deaths in 2018. Almost every 30 seconds, someone in the United States will suffer a heart attack, and less than once every minute, someone will die from one. In New Jersey, heart diseases are the leading causes of death, accounting for 19,047 deaths in 2018. The age-standardized death rate in 2018 was 163.0 per 100,000, which was slightly lower than the national age-standardized rate of 163.6 per 100,000. (https://www.cdc.gov/nchs/data/nvsr/nvsr69/nvsr69-13-508.pdf, page 58, table 12).

The most common form of heart disease is coronary artery disease. Coronary artery disease occurs when the coronary arteries, which carry blood to the heart muscle, become clogged or partially blocked by fatty deposits on the artery walls. This can lead to chest pain, or angina, which is a warning sign for a heart attack. A heart attack occurs when a coronary artery is totally blocked.

Treatment Options

Treatment for coronary artery disease will vary for different patients. The choice of treatment depends on the nature and severity of the disease and other factors unique to each patient.

For some patients, lifestyle changes such as quitting smoking, eating a low-fat diet, and getting more exercise may be enough. Some patients require special medications. Others may need medical procedures such as percutaneous coronary intervention (PCI, commonly known as angioplasty) or CABG surgery. Angioplasty reduces obstructions of fatty deposits in coronary arteries and has become an increasingly common treatment method. CABG surgery uses an artery or vein taken from another part of the body to divert blood around the clogged part of a patient's artery or arteries.

This report is about coronary artery bypass graft (CABG or bypass) surgery outcomes. It describes the performance records of 18 hospitals in New Jersey that offered this type of surgery in 2017 and 2018, as well as the surgeons who performed this operation at least 100 times in a hospital between January 2017 and December 2018.

Definition of Operative Mortality

Beginning with the 2000 report[1], the Department, after consulting with the CHAP, included in its definition of "operative mortality" deaths up to 30 days post-surgery or deaths occurring during the hospital stay in which the surgery was performed, no matter how many days after the procedure. Deaths occurring within 30 days after surgery, but post-discharge, have been identified by matching patient records in the Department's Open Heart Surgery database against the State's official death records.

Further, in an attempt to continuously improve the quality of data used in assessing bypass surgery mortality, the Department, in consultation with CHAP, reviewed the way operative procedures are coded for the purpose of the cardiac surgery report in New Jersey. The Department issued an operative procedure coding guide to be followed by all hospitals starting with 2005 data. This guideline was designed to avoid differential reporting of operative procedures by hospitals.

Applying the revised definitions of mortality, the Department also recalculated the statewide bypass surgery mortality rates for the prior years, in order to analyze the trend over time. Trend in operative mortality rate estimates from 1994 to 2018 are presented in Figure 5. Appendix D, Table D3 also presents the statewide operative mortality rate estimates for the period 1994-2018.

Performance Data

In an isolated CABG (bypass) surgery, no other major heart procedure is performed at the same time. In the period 2017-2018, the number of people who died during the hospitalization in which the operation was performed, or after discharge but within 30 days of the surgery, was 145. This represents 1.81 percent of the 8,006 who had bypass surgery in the two-year period. This rate is referred to as statewide operative mortality rate. This statewide operative mortality rate (1.81 percent) is used as the yard stick in evaluating hospital performance.

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[1] 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.

Risk-adjusted Mortality

In evaluating the performance of hospitals and individual surgeons, it would be unfair to make comparisons only on the basis of how many patients died. The mortality risk for patients undergoing bypass surgery varies significantly with how healthy patients are prior to surgery. For instance, an 85-year-old who had a certain type of cerebrovascular disease and was in cardiogenic shock at the time of surgery would be at higher risk during this surgery than a 50-year-old who had no history of chronic disease.

In order to produce fair comparisons, the Department applied a method that estimates risk-adjusted mortality rates. Each hospital was required to submit data which contain a risk profile for each patient undergoing bypass surgery. The risk-adjusted mortality rate assigns "extra credit" to hospitals and surgeons with sicker patient populations, in order not to disadvantage them in the performance comparisons.

Key factors that are associated with a patient's chance of surviving the bypass operation include:

- Patient's age and gender;
- Whether the patient had various preoperative health risk factors, such as cerebrovascular disease, peripheral vascular disease, renal failure requiring dialysis;
- Whether the patient had any previous cardiac surgery;
- Whether the patient had preoperative cardiac risk factors such as low ejection fraction, AMI within one to twenty-one days from the surgery, or was in cardiogenic shock at the time of surgery.

Weights derived from the statistical model were assigned for each key risk factor and risk-adjusted mortality rate was calculated for each hospital as fair basis for comparison (see Appendix D for more details).

Performance Reports Lead to Improvement

This performance report is for use not only by you and your doctors, but also by hospitals to improve the quality of their care and their patients' outcomes. On a risk-adjusted basis, the New Jersey statewide risk-adjusted mortality rate for bypass surgery declined by 59.8 percent from 4.36 percent in 1994 to 1.75 percent in 2018. Statewide risk-adjusted mortality rate for bypass surgery declined by 67.8 percent from 1994 to 2009 and plateaued after 2009 (see Appendix D, Table D3). Evidence both from New Jersey and other states that have published similar performance reports (i.e. California, Massachusetts, New York and Pennsylvania) suggests that these reports contribute to the decline in mortality rates and improve the overall quality of bypass surgery.

Hospitals

This report provides risk-adjusted mortality rate for each of the 18 hospitals in New Jersey that were licensed to perform coronary artery bypass graft surgery in 2017 and 2018. You will see that there are substantial variations among the 18 cardiac surgery hospitals. Through statistical analysis, the Department is able to determine in which cases the variations reflect real differences in performance after accounting for levels of risk among patients.

Nevertheless, these data should not be used as the sole factor in making choices about hospitals but should be part of the discussion between you and your doctor.

Surgeons

A risk-adjusted mortality rate was also calculated for each of the 32 surgeons who performed at least 100 bypass operations in one hospital in the years 2017 and 2018 combined. Even though two years of data were combined, several surgeons still fell short of the 100 cases the Department considers the minimum needed to calculate reliable risk-adjusted mortality rates. The Department recognizes that the volumes of some surgeons may be low because they had left those facilities during the year. Statistics for these low-volume surgeons are grouped under the hospital where the operations took place, in a category called "All Others." These surgeons are listed by name but with no risk-adjusted mortality rates, since their small numbers do not permit an accurate indication of their performance (Table 2). This report shows the total number of open heart and bypass surgeries these low volume surgeons performed, as well as their number of bypass surgery operative deaths.

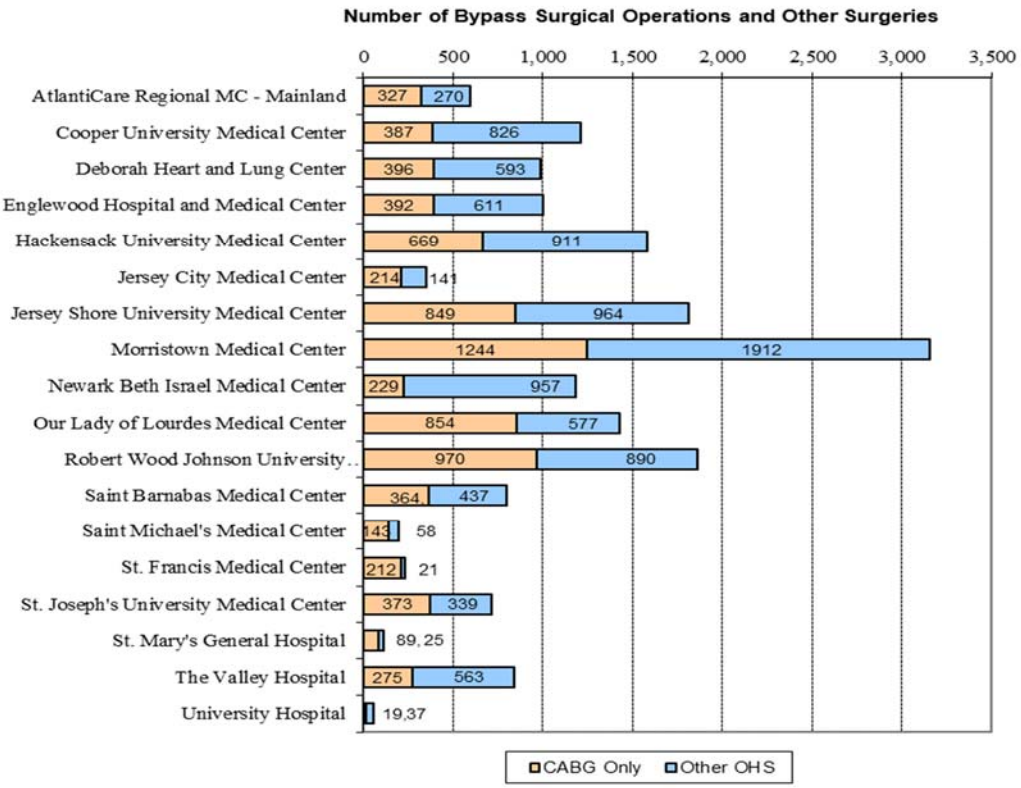
Volume Affects Quality

Many studies nationally and in other states have shown that, in general, hospitals and surgeons that perform bypass surgery more frequently have lower patient mortality rates. New Jersey's data also confirm this general trend. However, there are exceptions, and a number of hospitals with low volumes have results that are in line with the statewide rate.

Bypass Surgery Volume at New Jersey Hospitals in 2017-2018

Bypass surgery is the most common type of cardiac surgery accounting for 44.1 percent in the period 2017-2018. Figure 1 shows the number of bypass operations performed in 2017-2018 in each of the 18 hospitals. You can see that some hospitals do more of these procedures than others, with bypass volumes ranging from a low of 19 at University Hospital to a high of 1,244 at Morristown Medical Center in the two-year period. Bypass surgery volume had been declining in New Jersey starting in 2000 while angioplasty has stabilized at a higher level. Since 2011, bypass surgery volume started to recover. Between 2000 and 2011, the number of bypass surgeries in New Jersey declined by 54.9 percent, although between 2011 and 2016 bypass surgery volume rose by 11.1 percent. However, between 2016 and 2018, bypass surgery volume declined again by 4.22 percent.

Figure 1. Number of Isolated Coronary Bypass Graft Surgeries and Other Open Heart Surgeries, 2017-2018



SOURCE: New Jersey Department of Health.

Hospital Risk-Adjusted Mortality Rate

Figure 2 shows the risk-adjusted mortality rate for each New Jersey hospital performing bypass surgery in 2017-2018[2]. The risk-adjusted mortality rate takes into account the patient's risk factors before surgery as well as the actual mortality rate after the surgery, in order to make a fair assessment of hospital performance.

In trying to determine hospital or surgeon performance, it is important to account for the fact that some differences occur simply due to chance or random variation. Statistical tests are performed on the risk-adjusted bypass mortality estimates so that we can be as certain as possible that the differences are due to actual variations in performance. A difference is called "statistically significant" when it is too large to attribute to chance or random variation.

Each hospital's and each surgeon's mortality rate reflects three components: the quality of their care, the patient's risk factors that affect mortality, and an element of random variation. Readers of this report should be interested only in the first component, the quality of care delivered by hospitals and surgeons. We use a nationally-accepted risk-adjustment method to control for the second component, risk factors of bypass surgery patients seen by hospitals and surgeons. Because the third component, random variation, cannot be observed to be controlled for in the statistical model, we estimate how much higher or lower the risk-adjusted mortality rate could have been given the impact of random variation, using a confidence interval given at the 95% level.

In Figure 2, the dark line in the middle of each hospital's bar represents its estimated risk-adjusted mortality rate. When estimating rates using data, however, we cannot be sure if this number is the actual rate for the facility and not due to chance. We can only be relatively sure that the true rate falls somewhere within the bar. In analyzing data, we use what is called a "95 percent confidence interval," and the bar represents the lower and upper limits of this confidence interval. We are 95 percent confident that the hospital's actual risk-adjusted mortality rate falls within the range shown by the bar. Another way of saying it is that the bar represents the statistical margin of error for the estimation of that rate.

The vertical line in Figure 2 represents New Jersey's statewide bypass surgery operative mortality rate per 100 cases for 2017-2018, i.e. 1.81. Each hospital's performance is displayed graphically in relation to this statewide rate.

Figure 2 indicates 16 hospitals have bars that cross the statewide mortality rate line (1.81 percent). That means that their risk-adjusted mortality rates were not statistically different from the statewide rate. Robert Wood Johnson University Hospital has its bar completely to the right of the statewide rate indicating that this hospital has a statistically higher risk-adjusted mortality rate than the statewide rate. Deborah Heart and Lung Center has its bar completely to the left of the statewide rate indicating that this hospital has a statistically lower risk-adjusted mortality rate than the statewide rate.

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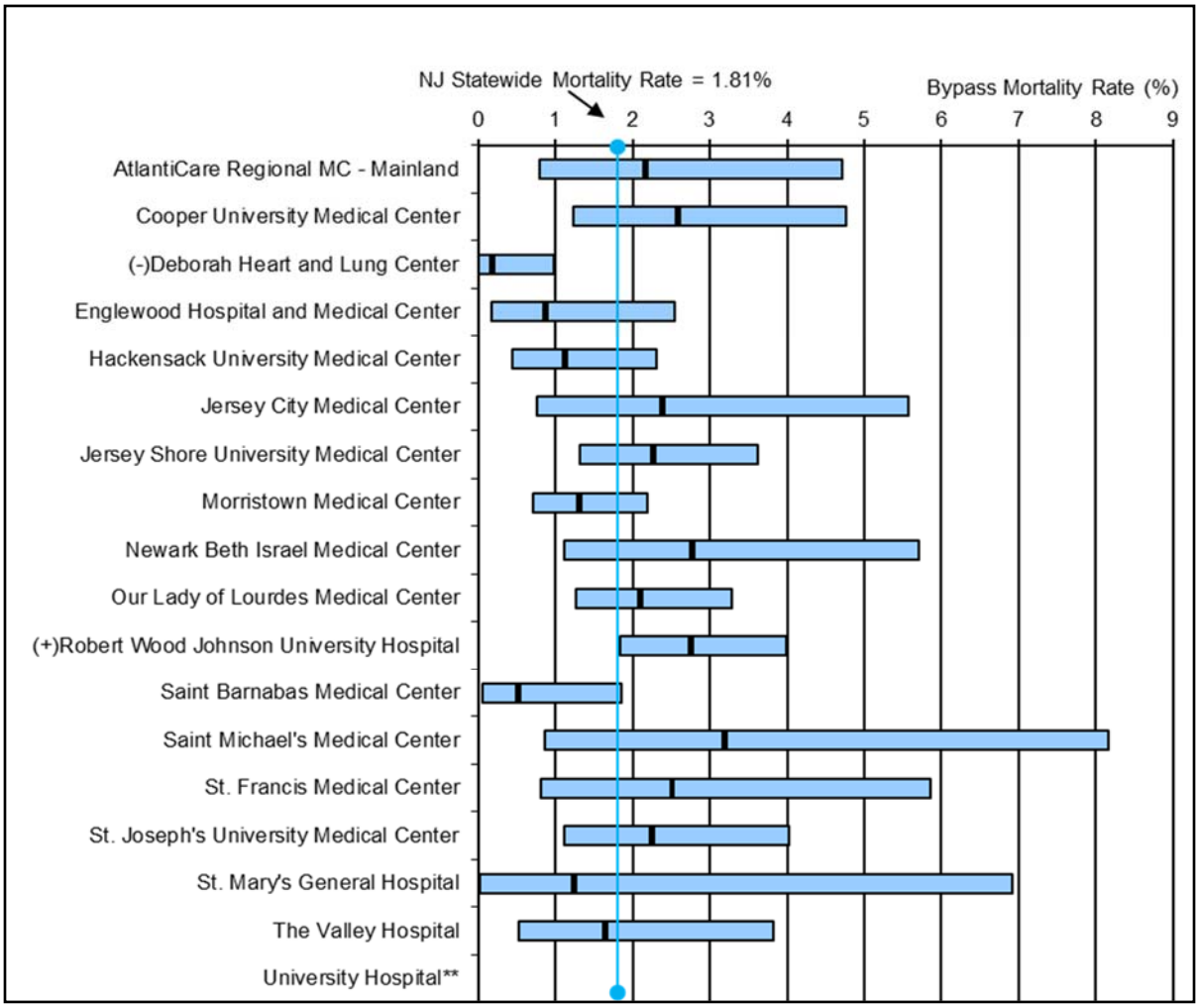
[2] These data may not reflect current performance of a specific hospital, which may have revamped its program since then.

Figure 2. Risk-Adjusted Operative Mortality Rate* by Hospital, 2017-2018



SOURCE: New Jersey Department of Health.

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

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

** = Risk-adjusted mortality rate could not be reliably calculated for the hospital due to small volume.

When using this report, it is important to remember that the charts are designed to show whether a hospital's or surgeon's risk-adjusted mortality rate is significantly above or below the statewide rate, or whether a rate is statistically the same as the statewide rate. Thus, it is more important to view the bars in relation to the statewide mortality rate line than it is to examine the individual calculated rates on the bars. The chart should not be used to make hospital-to-hospital or surgeon-to-surgeon comparisons, only to compare hospitals and surgeons to the statewide rate.

In examining the charts, you will see that some bars are shorter than others. The bar is shorter for hospitals or surgeons performing more surgeries, and longer for those with lower volumes. This reflects the fact that larger numbers -- in this case, more surgeries -- increase the precision of a statistic.

Statewide Bypass Surgery Related Infections

The Department has included information on bypass surgery in-hospital infections as an additional tool to monitor hospital performance. The statewide infection rates are provided as one more factor to be considered by policy makers and others involved in quality of care monitoring.

Infections reported in the Open Heart Surgery database included sternal-deep infection (involving muscle, bone and/or mediastinum requiring operative intervention), thoracotomy, leg infections, septicemia (presence of bacteria in the blood stream) and urinary tract infections (UTI). The table also includes post-operative pneumonia. For comparison purposes, statewide infection rates, the corresponding mortality rates and the average post-surgery length of stay are presented in Table 1 to provide perspective to the statewide rates.

Table 1 shows that, statewide, 5.22 percent of patients who underwent bypass surgery had some type of infection (including pneumonia). 3.17 percent of bypass patients had pneumonia, 1.60 percent of patients had UTI, 0.76 percent had septicemia, 0.30 percent had leg infections, 0.31 percent had sternal-deep infections and 0.04 percent had thoracotomy.

Observed bypass surgery mortality for those who had infections (12.68%) was almost ten times as high as those who did not (1.21%). In addition, patients who developed post-surgery infections stayed in the hospital more than three times as long (20.54 days) as those who had no infection (6.78 days).

Septicemia had the highest mortality rate of 37.70 percent among all infections reported, followed by sternal-deep (28.00%), and pneumonia (13.78%).

Statewide, overall infection rate increased slightly by 0.76 percent from 2017 to 2018 (not risk-adjusted) from 5.20 percent in 2017 to 5.24 percent in 2018 (not risk-adjusted). Mortality rate for overall infections decreased by 51.9 percent from 17.06% in 2017 to 8.21% in 2018.

Table 1. Statewide In-hospital Infection Rate, Operative Mortality Rate and Post-Surgery Length of Stay by Infection Type, 2017 - 2018

	Number of Cases	Infection Rate	Operative Mortality*		Average Length of Stay (in Days)
		(%)	Number	Rate (%) (Observed)	
Cases with Infections	**418**	5.22	**53**	**12.68**	**20.54**
Sternal-Deep	25	0.31	7	28.00	62.44
Thoracotomy	3	0.04	0	0.00	19.33
Leg	24	0.30	0	0.00	21.63
Septicemia	61	0.76	23	37.70	24.33
UTI	128	1.60	11	8.59	23.88
Pneumonia	254	3.17	35	13.78	19.29
Cases without Infections	**7,588**		**92**	**1.21**	**6.78**
Total CABG cases	**8,006**		**145**	**1.81**	**7.42**

SOURCE: NJ Department of Health.

*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.

Length of Stay by Hospital

The Department has included information on post-surgery length of stay as an additional tool to monitor hospital and surgeon performance on bypass surgery. The statewide post-surgery length of stay is 7.42 days in the period 2017-2018.

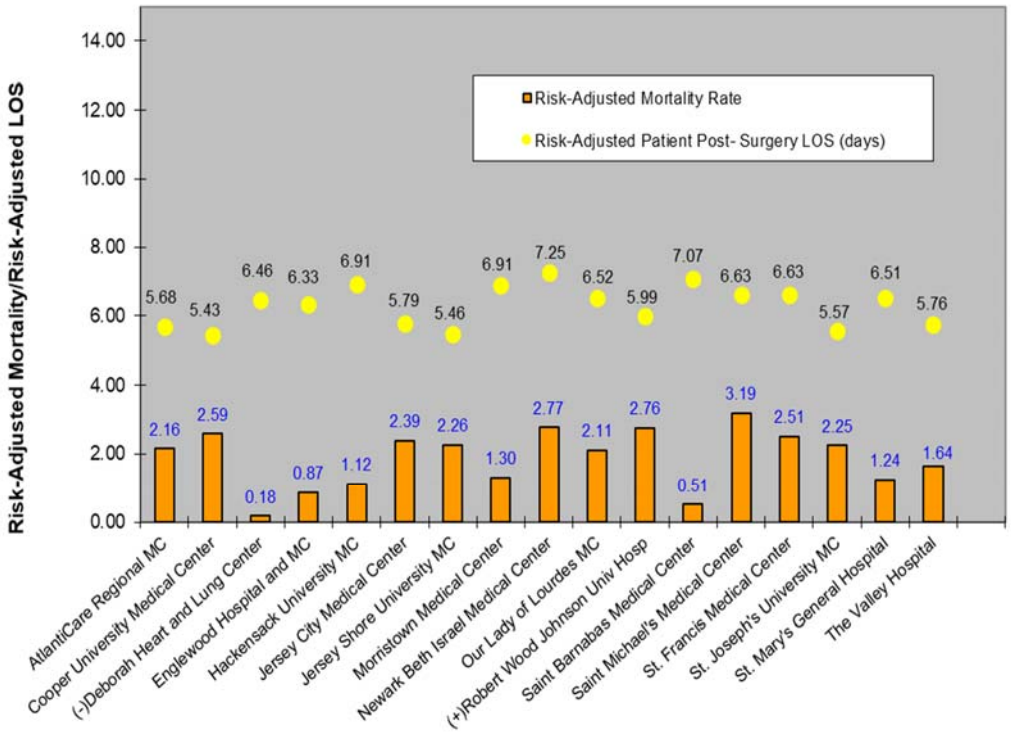
The risk-adjustment length of stay model excludes in-hospital deaths, very low lengths of stay (low outliers) and very long lengths of stay (high outliers) while fitting the regression model to reduce outlier effects on the model.

The risk-adjusted length of stay by hospital are displayed in Figure 3 and compared against their respective risk-adjusted mortality rates.

Figure 3 shows that there is a marked variation in risk-adjusted length of stay by hospital. The risk-adjusted length of stay by hospital ranges from a low of 5.43 days at Cooper Hospital University Medical Center to 7.25 days at Newark Beth Israel Medical Center in the two-year period. The correlation between hospital mortality rate and length of stay is not statistically significant.

Length of stay data for individual surgeons are presented later in this report.

.Figure 3. Risk-Adjusted Operative Mortality and Length of Stay (LOS) by Hospital, 2017-2018



SOURCE: New Jersey Department of Health.

Note: Risk-Adjusted Operative Mortality Rate and Length of Stay could not be reliably calculated for University Hospital due to small volume.

*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.

Individual Surgeon Performance

Figure 4 and Table 2 show the risk-adjusted mortality rate for each of the 32 surgeons who performed at least 100 bypass surgery operations in one hospital in New Jersey in the years 2017 and 2018 combined[3]. In addition, Table 2 shows the post-surgery risk-adjusted length of stay for each surgeon.

Figure 4 and Table 2 list surgeons by name under the hospital in which they practiced. At the end of each list of named surgeons, some hospitals have an "All Others" category. "All Others" includes all surgeons who performed too few procedures in that hospital for an individual risk-adjusted mortality rate to be reliably calculated.

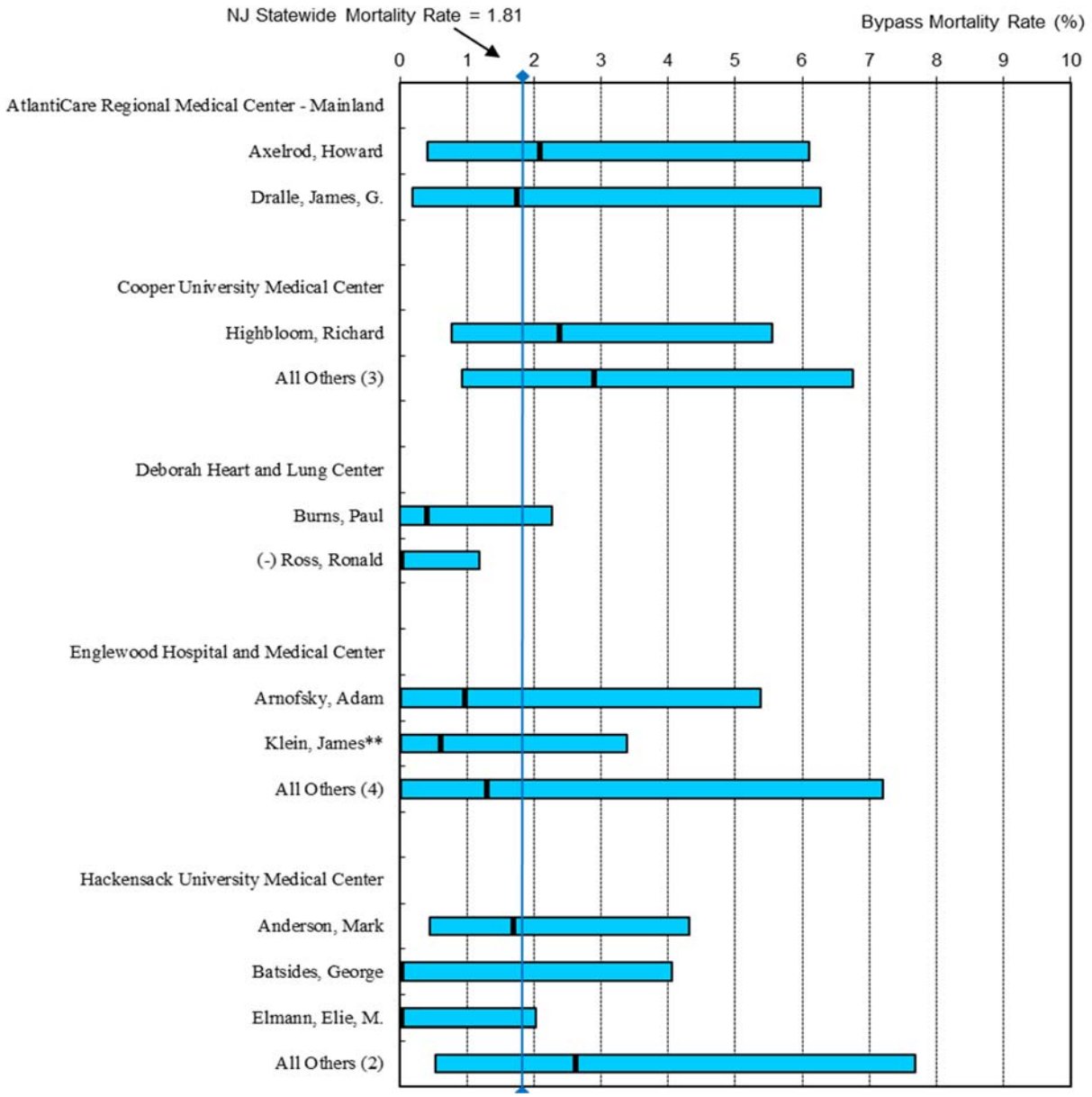
Figure 4 displays a bar for a surgeon only if 100 or more bypass surgeries were performed by the surgeon in one hospital in the years 2017 and 2018 combined. For a group of surgeons (i.e. All Others) a bar is shown when the group includes at least two or more surgeons and 25 or more total patients. Similarly, mortality rate for the "All Others" category is displayed in Table 2 only when it includes at least two or more surgeons and 25 or more bypass patients. It is important to note that some surgeons may no longer be practicing cardiac surgery in the facilities where they are listed.

Once again, the vertical line in Figure 4 represents the statewide operative mortality rate for 2017 and 2018 combined. The statewide operative mortality rate was 1.81 percent. If a surgeon has a bar completely to the left of the statewide line, i.e. 1.81, it means that the surgeon's mortality rate was statistically significantly lower than the statewide rate. One surgeon, Roland Ross from Deborah Heart and Lung Center, had a statistically significantly lower risk-adjusted mortality rate than the statewide rate.

If a surgeon has a bar completely to the right of the statewide mortality rate line, it means that the surgeon's mortality rate was statistically significantly higher than the statewide rate for this two-year period. During 2017-2018, one surgeon, Dr. Anthony Lemaire from Robert Wood Johnson University Hospital, had a statistically significantly higher risk-adjusted mortality rate than the statewide rate.

[3] These data may not reflect the current performance of a specific surgeon, who may have improved his/her performance since then. Also, some surgeons listed in the cardiac surgery centers may have already left the facility since the data were reported.

Figure 4. Surgeon Risk-Adjusted Operative Mortality* Rate, 2017 - 2018



SOURCE: New Jersey Department of Health.

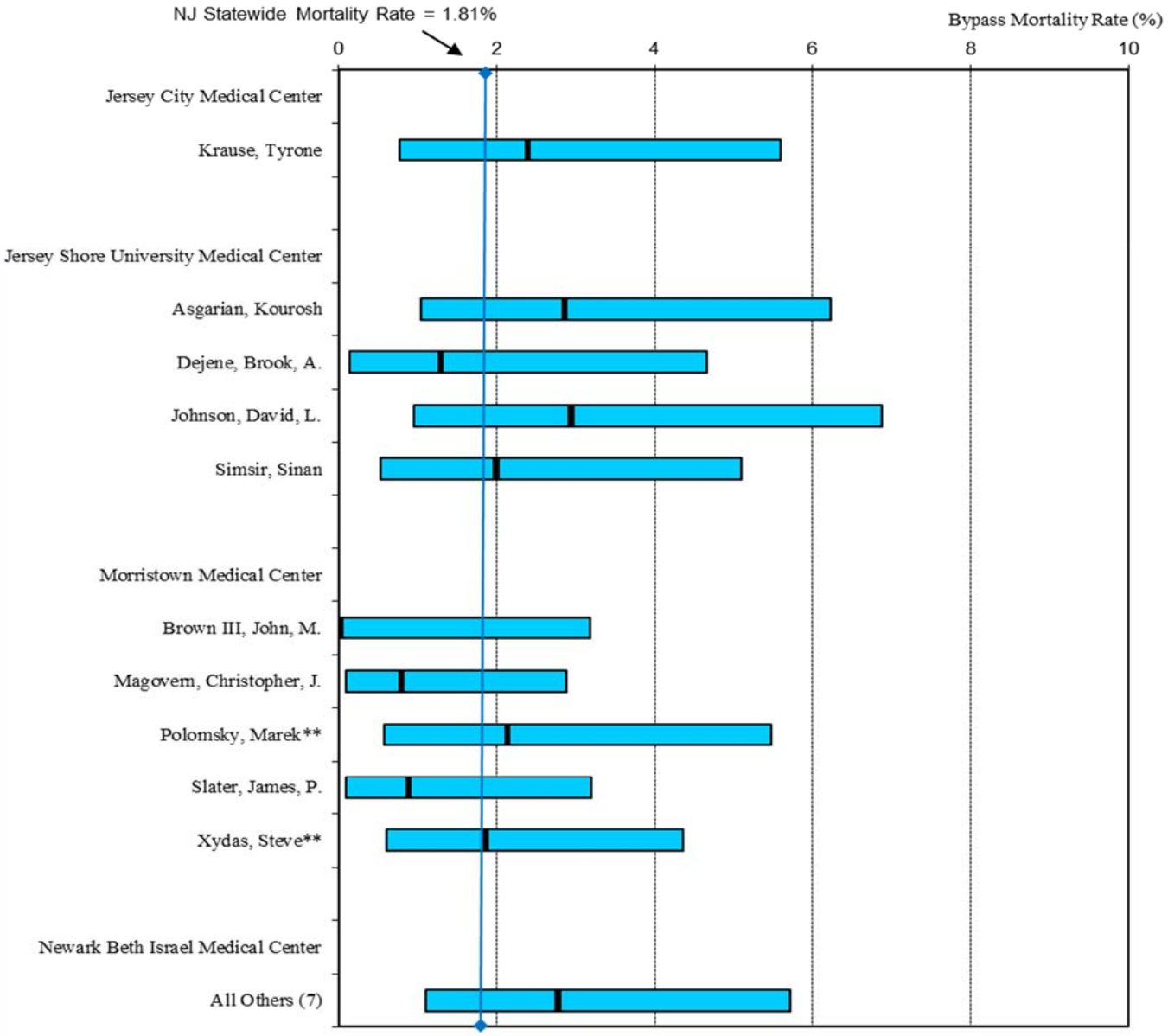
* = Operative Mortality includes: (1) all deaths occurring during the hospitalization in which the operation was performed, even after 30 days; and (2) those deaths occurring after discharge from the hospital, but within 30 days of the procedures.

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

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

** = Surgeon not currently performing CABG surgery in this hospital.

Figure 4. Surgeon Risk-Adjusted Operative Mortality* Rate, 2017 - 2018 (continued)



SOURCE: New Jersey Department of Health.

* = 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-adjusted mortality rate significantly lower than the New Jersey statewide mortality rate based on 95 percent confidence interval.
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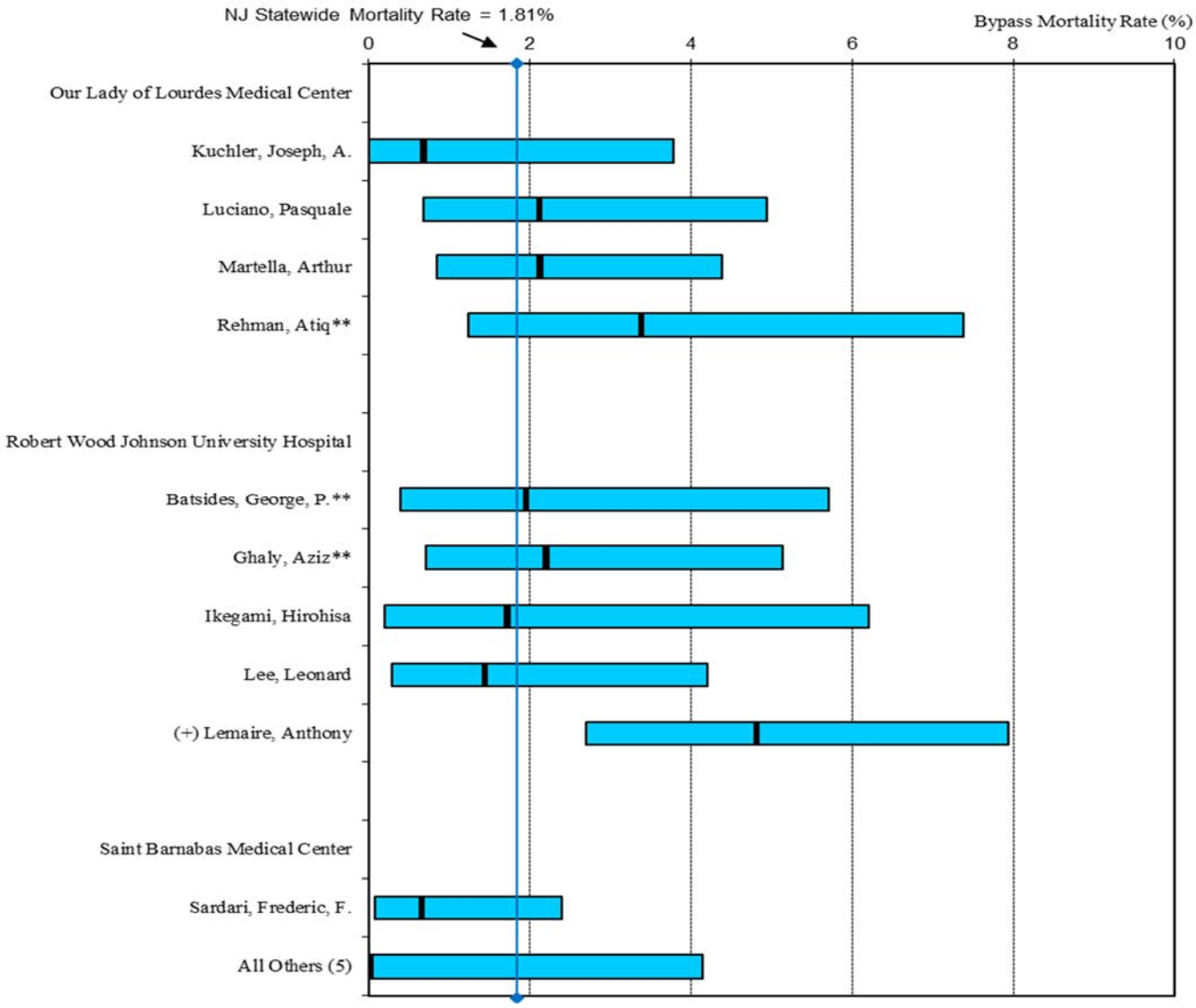
** = Surgeon not currently performing CABG surgery in this hospital.

Figure 4. Surgeon Risk-Adjusted Operative Mortality* Rate, 2017 - 2018 (continued)



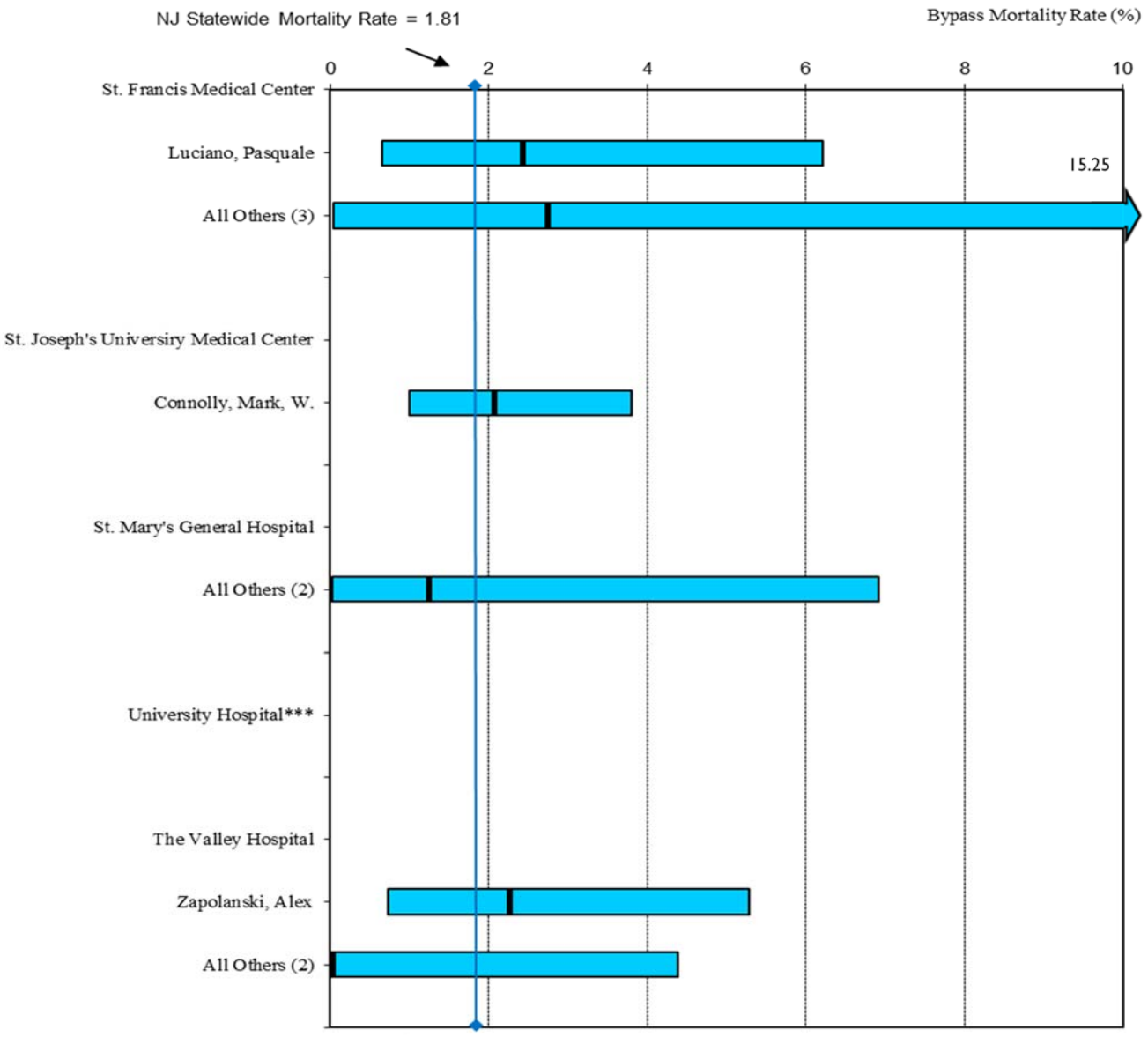
SOURCE: New Jersey Department of Health.

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

** = Surgeon not currently performing CABG surgery in this hospital.

Figure 4. Surgeon Risk-Adjusted Operative Mortality* Rate, 2017 - 2018 (continued)



SOURCE: New Jersey Department of Health.

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

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

** = Surgeon not currently performing CABG surgery in this hospital.

*** = Risk-adjusted mortality rate could not be reliably calculated for the hospital due to small volume.

As is the case for some in this report, it is possible for a surgeon to have no patient deaths and still have his/her bar cross the statewide line. Though not intuitive, this happens because the bar is the result of an upper and lower bound which includes standard errors of the estimated mortality rate. Although their rates were not statistically significantly different from the statewide rate, it is nevertheless notable that a few surgeons, including some who performed less than 100 bypass surgeries, had no bypass surgery death during the two-year period. Among surgeons who performed 100 or more bypass surgeries during the period 2017-2018, Dr. George Batsides, Dr. Elie Elmann from Hackensack University Medical Center.

Despite the variations in bypass mortality rates among surgeons, the quality of care delivered by most surgeons were similar to the statewide performance.

In addition to risk-adjusted mortality for surgeons, Table 2 also shows risk-adjusted patient length of stay for each surgeon who performed at least 100 bypass surgeries in the 2017-2018 reporting period. There is marked variation in length of stay among eligible surgeons where the shortest length of stay was 5.18 days and the longest was 8.49 days. The reasons behind the wide variation in lengths of stay are not clear and need further study.

Table 2. Risk-Adjusted Operative Mortality* Rate and Post-Surgery Length of Stay by Surgeon, 2017 - 2018

Hospital and Surgeon	Total Open Heart Procedures	Number of Isolated CABG Operations	Patient Operative Deaths*	Observed Patient Mortality(%)	Expected Patient Mortality(%)	Risk-Adjusted Patient Mortality (%)		95% Confidence Interval	Risk-Adjusted Post-Surgery Length of Stay
AtlantiCare Regional Medical Center - Mainland									
Axelrod, Howard	291	153	3	1.96	1.70	2.09		(0.42, 6.10)	5.63
Dralle, James, G.	284	155	2	1.29	1.34	1.75		(0.20, 6.31)	5.74
All Others (2)	22	19	1	5.26	1.84	5.17		(0.07, 28.75)	5.50
Lico, Serrie**	9	8	1						
Lotano, Vincent	13	11	0						
Cooper University Medical Center									
Highbloom, Richard	305	244	5	2.05	1.58	2.36		(0.76, 5.50)	5.18
All Others (18)	908	143	5	3.50	2.20	2.87		(0.93, 6.70)	5.89
Andrew, Constantine**	1	0	0						
Bariana, Christopher**	1	0	0						
Bowen, Frank	493	55	3						
Caputo, Francis**	3	0	0						
Chovanes, John**	3	0	0						
Derivaux, Christopher	4	0	0						
Fox, Nicole**	1	0	0						
Kuchler, Joseph, A.**	30	29	0						
Lombardi, Joseph	26	0	0						
Monteith, Duane**	1	0	0						
Porter, John**	3	0	0						
Rosenbloom, Michael	317	59	2						
Ross, Steven	1	0	0						
Shersher, David	12	0	0						
Steinberg, Jay**	1	0	0						
Trani, Jose	7	0	0						
Wang, Julin**	2	0	0						
Wydo, Salina**	2	0	0						
Deborah Heart and Lung Center									
Burns, Paul	514	218	1	0.46	2.06	0.40		(0.01, 2.25)	6.61
Ross, Ronald	474	178	0	0.00	3.22	0.00	**LO**	(0.00, 1.16)	6.28
Englewood Hospital and Medical Center									
Arnofsky, Adam	505	124	1	0.80	1.50	0.97		(0.01, 5.37)	6.01
Klein, James, J.**	339	182	1	0.55	1.63	0.61		(0.01, 3.39)	6.49
All Others (5)	159	85	1	1.18	1.65	1.29		(0.02, 7.17)	6.50
Elmann, Elie, M.	36	21	0						
Galla, Jan**	34	22	0						
Ng, Arthur**	3	1	0						
Somberg, Eric**	2	1	0						
Wohler, Alexander**	84	41	1						
Hackensack University Medical Center									
Anderson, Mark	557	211	4	1.90	2.03	1.69		(0.45, 4.32)	5.78
Batsides, George	258	118	0	0.00	1.42	0.00		(0.00, 3.98)	6.69
Elmann, Elie, M.	428	205	0	0.00	1.61	0.00		(0.00, 2.01)	8.05
All Others (2)	337	135	3	2.22	1.53	2.64		(0.53, 7.71)	7.40
Ng, Arthur	285	94	3						
Somberg, Eric, D.**	52	41	0						

* = 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.

** = Surgeon not currently performing CABG surgery in this hospital.

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

Table 2. Risk-Adjusted Operative Mortality* Rate and Post-Surgery Length of Stay by Surgeon, 2017 - 2018 (continued)

Hospital and Surgeon	Total Open Heart Procedures	Number of Isolated CABG Operations	Patient Operative Deaths*	Observed Patient Mortality(%)	Expected Patient Mortality(%)	Risk-Adjusted Patient Mortality (%)		95% Confidence Interval	Risk-Adjusted Post-Surgery Length of Stay
Jersey City Medical Center									
Krause, Tyrone	353	213	5	2.35	1.78	2.39		(0.77, 5.58)	5.80
All Others (1)	2	1	0						
Yarramneni, Akhila**	2	1	0						
Jersey Shore University Medical Center									
Asgarian, Kourosh	533	260	6	2.31	1.46	2.87		(1.05, 6.24)	5.26
Dejene, Brook	577	177	2	1.13	1.57	1.30		(0.15, 4.69)	5.31
Johnson, David, L.	388	204	5	2.45	1.50	2.96		(0.95, 6.90)	5.69
Simsir, Sinan**	288	195	4	2.05	1.87	1.99		(0.54, 5.10)	5.59
All Others (2)	27	13	0	0.00	2.50	0.00		(0.00, 20.41)	6.44
Greeley, Drew**	1	1							
Youdelman, Benjamin**	26	12							
Morristown Medical Center									
Brown III, John, M.	970	175	1	0.57	1.48	0.70		(0.01, 3.88)	6.86
Magovern, Christopher, J.	756	326	2	0.61	1.39	0.80		(0.09, 2.88)	6.77
Polomsky, Marek**	462	237	4	1.69	1.43	2.14		(0.57, 5.47)	6.99
Slater, James, P.	658	266	2	0.75	1.54	0.89		(0.10, 3.20)	6.58
Zaku, Bledi	310	240	5	2.08	2.02	1.87		(0.60, 4.36)	7.44
Newark Beth Israel Medical Center									
All Others (8)	1,186	229	7	3.06	2.00	2.77		(1.11, 5.71)	7.25
Camacho, Margarita	90	0	0						
Karanam, Ravindra	198	68	2						
Krause, Tyrone**	19	8	0						
Russo, Mark**	431	34	3						
Sardari, Frederic, F.	4	2	0						
Saunders, Craig, R.	325	96	1						
Strueber, Martin**	108	18	1						
Yanagida, Roh**	11	3	0						
Our Lady of Lourdes Medical Center									
Kuchler, Joseph, A.	185	159	1	0.63	1.67	0.68		(0.01, 3.79)	6.44
Luciano, Pasquale	215	207	5	2.42	2.09	2.09		(0.67, 4.89)	7.10
Martella, Arthur	554	320	7	2.19	1.87	2.12		(0.85, 4.36)	6.23
Rehman, Atiq**	444	159	6	3.77	2.03	3.37		(1.23, 7.34)	6.50
All Others (2)	33	9	0	0.00	1.46	0.00		(0.00, 50.55)	5.91
Stivala, Charles	5	5	0						
Vigilance, Deon**	28	4	0						
Robert Wood Johnson University Hospital									
Batsides, George, P.**	272	134	3	2.24	2.07	1.96		(0.39, 5.72)	6.02
Ghaly, Aziz**	427	246	5	2.03	1.66	2.21		(0.71, 5.17)	6.16
Ikegami, Hirohisa	205	117	2	1.71	1.80	1.72		(0.19, 6.20)	6.01
Lee, Leonard	662	295	3	1.02	1.27	1.45		(0.29, 4.24)	5.32
Lemaire, Anthony	291	177	15	8.47	3.16	4.86	**HI**	(2.72, 8.02)	7.08
All Others (1)	3	1	0						
Russo, Mark	3	1	0						

* = 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.

** = Surgeon not currently performing CABG surgery in this hospital.

LO = Risk-adjusted mortality rate significantly lower than the New Jersey statewide mortality rate based on 95 percent confidence internval.
HI = Risk-adjusted mortality rate significantly higher than the New Jersey statewide mortality rate based on 95 percent confidence internval.

Table 2. Risk-Adjusted Operative Mortality* Rate and Post-Surgery Length of Stay by Surgeon, 2017 - 2018 (continued)

Hospital and Surgeon	Total Open Heart Procedures	Number of Isolated CABG Operations	Patient Operative Deaths*	Observed Patient Mortality(%)	Expected Patient Mortality(%)	Risk-Adjusted Patient Mortality (%)	95% Confidence Interval	Risk-Adjusted Post-Surgery Length of Stay
Saint Barnabas Medical Center								
Sardari, Frederic, F.	489	292	2	0.68	1.87	0.66	(0.07, 2.39)	7.08
All Others (5)	312	72	0	0.00	2.22	0.00	(0.00, 4.16)	7.03
Camacho, Margarita**	1	1						
Karanam, Ravindra, N.	3	1						
Russo, Mark**	244	24						
Saunders, Craig, R.	12	3						
Yanagida, Roh**	52	43						
Saint Michael's Medical Center								
Patel, Nilesh, U.	187	133	4	3.01	1.54	3.53	(0.95, 9.03)	6.50
All Others (2)	18	10	0					
Krause, Tyrone, J.**	9	6	0					
Shakir, Huzaifa**	5	4	0					
St. Francis Medical Center								
Luciano, Pasquale	181	179	4	2.23	1.65	2.45	(0.66, 6.28)	6.77
All Others (3)	52	33	1	3.03	1.97	2.78	(0.04, 15.49)	5.90
Martella, Arthur	35	21	1					
Rehman, Atiq**	6	4	0					
Shariff, Haji**	11	8	0					
St. Joseph's University Medical Center								
Connolly, Mark, W.	695	362	10	2.76	2.41	2.07	(0.99, 3.81)	5.50
All Others (4)	17	11	1	9.09	1.04	15.83	(0.21, 88.05)	8.49
Anastasi, John**	8	4	1					
Cerda, Luis	1	1	0					
Patel, Nilesh, U.**	7	5	0					
Prendergast, Thomas**	1	1	0					
St. Mary's General Hospital								
All Others (2)	114	89	1	1.12	1.64	1.24	(0.02, 6.92)	6.51
Patel, Nilesh	21	15	1					
Shakir, Huzaifa, A.**	93	74	0					
University Hospital								
All Others (2)	56	19	0					
Lovoulos, Constantinos	42	14	0					
Sambol, Justin, T.**	14	5	0					
The Valley Hospital								
Zapolanski, Alex	315	175	5	2.86	2.28	2.27	(0.73, 5.29)	5.76
All Others (3)	523	100	0	0.00	1.52	0.00	(0.00, 4.37)	5.77
Brizzio, Mariano	100	48						
Goncalves, John**	423	52						
State Total (2017 - 2018)	18,138	8,006	145	1.81	1.81	1.81		6.28

* = 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.

** = Surgeon not currently performing CABG surgery in this hospital.

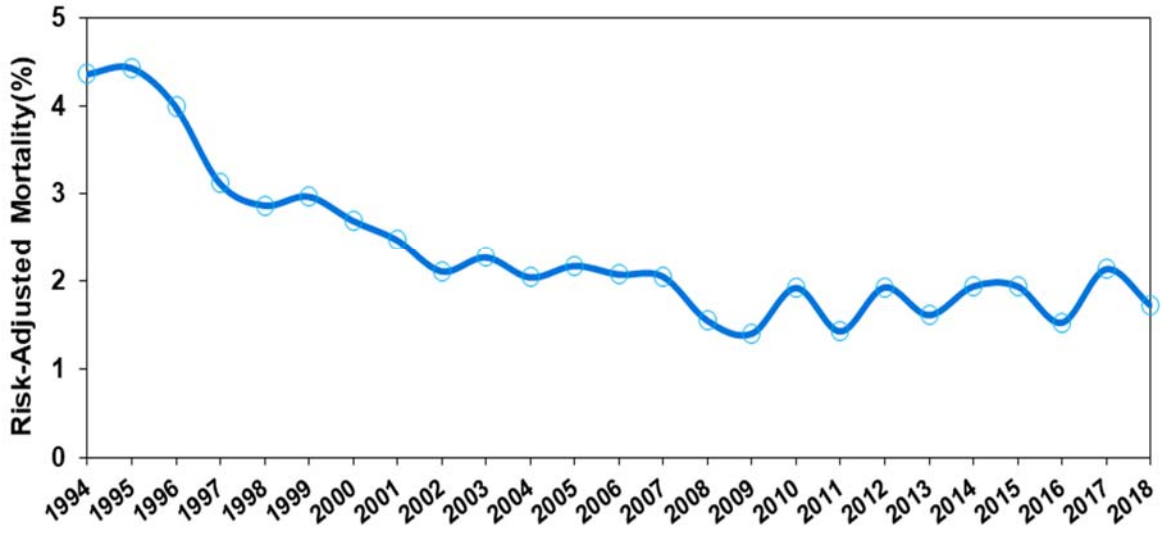
LO = Risk-adjusted mortality rate significantly lower than the New Jersey statewide mortality rate based on 95 percent confidence interval.
HI = Risk-adjusted mortality rate significantly higher than the New Jersey statewide mortality rate based on 95 percent confidence interval.

Statewide Trend in Risk-Adjusted Bypass Surgery Mortality Rate: Pooled Estimates

Figure 5 presents the statewide risk-adjusted mortality rate for years 1994 to 2018 derived by pooling data from all years (Sources: Appendix C; Appendix D, Table D3). When compared with 1994, the risk-adjusted operative mortality rate for bypass surgery declined by 59.8 percent in 2018.

Bypass mortality declined by 67.8 percent, and in absolute terms, at the rate of 0.18 from 1994 to 2009 and plateaued between 2009 and 2018 (see Appendix D).

Figure 5. Trend in Statewide Risk-Adjusted Bypass Surgery Operative Mortality Rate, 1994 - 2018



SOURCE: NJ Department of Health.

*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 A

Frequently Asked Questions

These are answers to some commonly asked questions that may be of interest to you as you read this report.

Q: Should I go only to the hospitals with below-average risk-adjusted mortality rates?

A: Not necessarily. There are many factors to consider in determining the best hospital for you. Among these are your own personal risk factors and the experience certain hospitals have treating patients with those risk factors. Before making up your mind, you should discuss this report with the physician, usually a cardiologist, who refers you for cardiac surgery. The cardiologist's knowledge and expertise will be a valuable guide in making your decision. You should also keep in mind that the data in this guide is from 2017-2018 and that a hospital's performance may have changed since then.

Q: Should I avoid any surgeon whose volume is low in this report?

A: No, not necessarily. First, there are lower volume surgeons with good patient outcomes. Second, there may be a good explanation for why a surgeon had a low volume that is unrelated to his/her experience. For example, the surgeon may have recently moved from another state, where he/she performed a high volume of these procedures. It is best to discuss your concerns with your referring doctor.

Q: Should I refuse to go to a hospital or a surgeon for heart surgery if that hospital or surgeon has a worse than average mortality record?

A: Important decisions in areas such as cardiac surgery should be made after considering all available information. The statistics in this report are a starting point for discussions with your doctor. But they do not tell the complete story. That is why it is critical to bring your concerns and questions to your doctor.

Q: Is it better to go to a hospital with a high volume of cases?

A: National studies have demonstrated that, in general, hospitals with higher volumes have better results. However, some hospitals with high volumes have relatively high mortality rates, while others with low volumes have lower mortality rates.

Notes on Data:

The data used in this study were reported by hospitals according to criteria established by the Department, with assistance from the clinical experts. Additionally, 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 (STS). The data were audited by an independent reviewer under contract to the Department.

Throughout the process of developing 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 risk-adjust the reported 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 continue working to improve data collection procedures so that this report contains the best possible information.

APPENDIX B

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

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Director, Cooper Heart Institute
Chief of Cardiology

Mary T. Abed, MD, FACC
Chief, Division of Cardiology
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APPENDIX C

Statewide Observed In-hospital and Operative Mortality Rate, 1994-2018

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	1.81

SOURCE: NJ Department of Health.

*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 D

Summary of Methods Used in This Report

Background

Five states, including New Jersey, have issued reports on isolated Coronary Artery Bypass Graft (CABG or bypass) surgery outcomes for hospitals and surgeons. New York first published a bypass surgery report in 1990 presenting 1989 data, with the latest report released in August 2020 using 2015-2017 data. Starting with its 1990 data, Pennsylvania has published several cardiac surgery reports, with its latest report released in January 2017 using January 2014 to March 2016 data. California has also published several cardiac surgery reports, with the most recent data released in July 2021 using 2019 data. Massachusetts published its first report on bypass surgery in October 2004 using 2002 data and released its latest report on a fiscal year basis (October 1, 2013 to September 30, 2014) in November 2016. In 1997, New Jersey began reporting on patient mortality for bypass surgery hospitals and surgeons, using 1994 and 1995 data combined.

The experience from these states is that disclosures have contributed to hospital quality improvement initiatives and significant reductions in bypass surgery mortality rate.

Factors That Affect a Patient's Risk of Bypass Surgery Mortality

The observed patient bypass surgery mortality rate for a hospital or surgeon 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 the bypass surgery.

Unfortunately, this observed patient mortality rate is not a complete measure of the quality of care provided by a hospital or a surgeon, because it does not account for how sick the patients were before surgery. If one hospital had considerably sicker patients than another hospital, it would be expected that its observed mortality rate would be somewhat higher. Therefore, it would not be fair to evaluate surgeons and hospitals performing bypass surgery solely on the basis of the percentage of their patients that died. For instance, an 85-year-old who had certain type of cerebrovascular disease and was in cardiogenic shock at the time of surgery would be at higher risk during this surgery than a 50-year-old who had no history of chronic disease.

To perform an even-handed analysis of the quality of surgical care provided by surgeons and hospitals performing bypass surgery, the Department adjusts the patient mortality rates for each surgeon and each hospital by the pre-surgery risk factors of each patient. This method gives hospitals and surgeons who operate on less healthy patients "extra credit." Such hospitals and surgeons are not at a disadvantage when the outcome of the surgical care they provide is presented next to that of other hospitals and surgeons. Additionally, as stated earlier, 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.

The risk adjustment method is a statistical approach that uses results of a logistic regression analysis to assess the average risk of a bypass surgery for a patient. Key elements of the health histories of patients who have undergone bypass surgery in the same period, as well as their socio-demographic characteristics, are taken into account to estimate the expected outcome of a bypass surgery.

Assessing Patient Risk Factors

A logistic regression model which included all the before-surgery health and demographic factors was fitted to the data for the period covered by this report to identify those risk factors that were important in predicting whether a patient would die after a bypass surgery. The general form of a logistic regression model for estimating the "logit" of the probability of dying (p), denoted by Yi, 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,...,n; k = 0,1,2,...,K,
βk= Logistic regression coefficient for risk factor Xk,
K = Number of risk factors in the model,
n = Number of patients,
εi = Random error term i.

The statistically significant risk factors for this report (X_k) identified by the stepwise logistic regression analysis method are presented in Table D1. Table D1 also includes estimates of coefficients for the statistically significant risk factors, an indication of the level of statistical significance (p-values), and odds ratios. The list of risk factors includes only those that were statistically significant in predicting bypass surgery mortality with p-values of 0.05 or smaller.

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 D1, the odds ratio represents how much as likely a patient is to die when compared to a patient who is in the reference group. So, for example, Table D1 shows that a patient who had cerebrovascular disease is more than one and half times (odds ratio = 1.66) as likely to die during or after bypass surgery compared to a patient who did not have the risk factor. This is based on the assumption that both patients have the same set of other risk factors presented in the table.

Similarly, the odds of dying during or after bypass surgery for a patient who is in cardiogenic shock at the time of surgery is close to ten times as likely (odds ratio= 9.46) compared with the odds of a patient who is not in cardiogenic shock at the time of surgery.

Estimation of Risk-Adjusted Mortality Rates

The risk factors presented in Table D1 were used in the fitted logistic regression model to predict the probability of death from bypass surgery for each patient. The sum of predicted probabilities of dying for patients operated on in each hospital divided by the number of patients operated on in that hospital provides the predicted (or expected) death rate associated with the hospital. A similar analysis for a surgeon results in the expected death rate associated with that surgeon. 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:

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

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

To assess the performance of each hospital or surgeon, we compared the observed patient mortality with the expected or predicted patient mortality, based on the existing risk factors for the hospital's or surgeon's patients. First, the observed patient mortality is divided by the expected mortality. If the resulting ratio is higher than one, the hospital or surgeon has a higher patient mortality than expected on the basis of their patient mix. If the ratio is lower than one, the hospital or surgeon has a lower mortality 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 or the surgeon.

The risk-adjusted mortality rate represents the best estimate the fitted model provides using the statistically significant health risk factors. The risk-adjusted patient mortality rate represents what a hospital's or surgeon'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, ironed out differences among hospitals and surgeons in patient mortality arising from the severity of illness of their patients.

The statistical methods described above are 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 the analysis of data for this report, 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 D1, was used to evaluate model performance. 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 the tendency of the predicted mortality for patients in the sample that died to be higher than that for patients who were discharged alive and were also alive 30 days after bypass surgery. The 2017-2018 model C-statistic is 78.9 percent and is fairly high, suggesting that the model has strong predictive power.

Table D1. Risk Factors Identified for Isolated CABG Surgery Operative Mortality*, 2017 -2018

Patient Risk Factors Identified	Proportion of patients (%)	Logistic Regression Results		
		Coefficient	P-Value	Odds Ratio
Demographic factors				
Age-squared	-	0.0004	<.0001	1.000
Female	22.40	0.5838	0.0013	1.793
Health factors				
Cerebrovascular Disease	20.00	0.5042	0.0069	1.656
Peripheral Vascular Disease	14.74	0.7354	0.0001	2.086
Previous Cardiac Surgery	1.54	1.4573	<.0001	4.294
Renal Failure with Dialysis	3.58	0.9467	0.0020	2.577
Factors related to functioning of the heart				
AMI 1-7 Days	24.62	0.6015	0.0014	1.825
AMI 8-21 Days	5.96	0.6267	0.0311	1.871
Cardiogenic Shock at Surgery	1.65	2.2465	<.0001	9.455
Ejection Fraction 1-29%	5.82	1.0075	<.0001	2.739
Intercept	-6.9873			
C-Statistic	0.789			
Number of CABGs (N)	8,006			

SOURCE: NJ Department of Health.

*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-Adjusted Patient Mortality Rate Estimates

This section presents the results of our analysis including:

1) Comparisons of risk-adjusted patient mortality rates for hospitals to the statewide rate in 2017-2018.
2) Comparisons of the statewide risk-adjusted patient mortality rate for each year in 1994-2018 to the rate for the whole period.

The risk-adjusted mortality rate estimates are presented in percentage points. The results also include the lowest and the highest risk-adjusted mortality rate estimates one would expect, using a 95 percent confidence level*.

Patient Bypass Surgery Mortality Rate by Hospital Compared with the Statewide Rate in 2017-2018

The risk-adjusted patient mortality estimates from bypass surgery for each hospital in 2017-2018 are presented in Table D2. The results compare each hospital's risk-adjusted patient mortality rate with the statewide mortality rate.

After adjusting for how sick the patients were before surgery at each hospital, we present the estimates of risk-adjusted patient mortality rate for each hospital in the sixth column of Table D2. Table D2 presents the bypass volume, observed mortality, observed mortality rate, expected mortality rate, risk-adjusted mortality rate and its confidence interval, as well as risk-adjusted length of stay following bypass surgery for each of the 18 hospitals.

The observed operative mortality rate statewide in 2017-2018 for bypass patients was 1.81 percent, based on 145 deaths out of 8,006 bypass operations performed.

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

Despite the variations in bypass mortality rates among hospitals and surgeons, the quality of care delivered by most hospitals and surgeons were similar to the statewide performance. In 2017-2018, one hospital, Deborah Heart and Lung Center, had a statistically significantly lower risk-adjusted mortality rate than the statewide rate. One hospital, Robert Wood Johnson University Hospital, had a statistically significantly higher risk-adjusted mortality rate than the statewide rate. Although its rate was not statistically significantly different from the statewide rate, it is nevertheless notable that University Hospital had no bypass surgery deaths in the two-year period.

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* 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, E = Predicted or Expected mortality, and S = Statewide rate.

Source: Liddell, F. D. K., Simple Exact Analysis of the Standardized Mortality Ratio. Journal of Epidemiology and Community Health, 1984, 38, 85-88.

Table D2. Risk-Adjusted Operative Mortality* Rate and Post-Surgery Length of Stay by Hospital, 2017 - 2018

Hospital	Number of Isolated CABG Operations	Patient Operative Deaths*	Observed Patient Mortality (%)	Expected Patient Mortality (%)	Risk-Adjusted Patient Mortality (%)		95% Confidence Interval	Risk-Adjusted Patient Post-Surgery LOS (days)
AtlantiCare Regional Medical Center - Mainland	327	6	1.83	1.54	2.16		(0.79, 4.70)	5.68
Cooper Hospital/University Medical Center	387	10	2.58	1.81	2.59		(1.25, 4.80)	5.43
Deborah Heart and Lung Center	396	1	0.25	2.58	0.18	**LO**	(0.00, 0.99)	6.46
Englewood Hospital and Medical Center	392	3	0.77	1.60	0.87		(0.17, 2.54)	6.33
Hackensack University Medical Center	669	7	1.05	1.69	1.12		(0.45, 2.31)	6.91
Jersey City Medical Center	214	5	2.34	1.77	2.39		(0.77, 5.59)	5.79
Jersey Shore University Medical Center	849	17	2.00	1.60	2.26		(1.31, 3.62)	5.46
Morristown Medical Center	1244	14	1.13	1.56	1.30		(0.71, 2.19)	6.91
Newark Beth Israel Medical Center	229	7	3.06	2.00	2.77		(1.11, 5.72)	7.25
Our Lady of Lourdes Medical Center	854	19	2.22	1.91	2.11		(1.19, 3.18)	6.52
Robert Wood Johnson University Hospital	970	28	2.89	1.89	2.76	**HI**	(1.82, 3.97)	5.99
Saint Barnabas Medical Center	364	2	0.55	1.94	0.51		(0.06, 1.85)	7.07
Saint Michael's Medical Center	143	4	2.80	1.59	3.19		(0.85, 8.07)	6.63
St. Francis Medical Center	212	5	2.36	1.70	2.51		(0.80, 5.79)	6.63
St. Joseph's University Medical Center	373	11	2.95	2.37	2.25		(1.12, 4.02)	5.57
St. Mary's General Hospital	89	1	1.12	1.64	1.24		(0.02, 6.92)	6.51
The Valley Hospital	275	5	1.82	2.01	1.64		(0.53, 3.82)	5.76
University Hospital**	19	0	0.00	N/A	N/A		N/A	N/A
Statewide	8,006	145	1.81	1.81	1.81			6.28

SOURCE: New Jersey Department of Health.

* = 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 = Risk-adjusted mortality rate significantly lower than the New Jersey statewide mortality rate based on 95 percent confidence interval.
HI = Risk-adjusted mortality rate significantly higher than the New Jersey statewide mortality rate based on 95 percent confidence interval.

** = Risk-adjuated mortality rate and length of stay can not be reliably calculated for the hospital due to small volume.

Annual Risk-Adjusted Mortality Rate Compared to the Combined 1994 - 2018 Mortality Rate

Table D3 presents the results of an analysis to identify the trend in the statewide mortality rate of patients who underwent bypass surgery using a statistical model based on the pooled data collected over the period 1994-2018. For each of the years, the table presents the observed patient mortality rate, the expected patient mortality rate, and the statewide 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 further exhibits whether the risk-adjusted mortality rate for the year is statistically different from the pooled mortality rate for the 1994-2018 period.

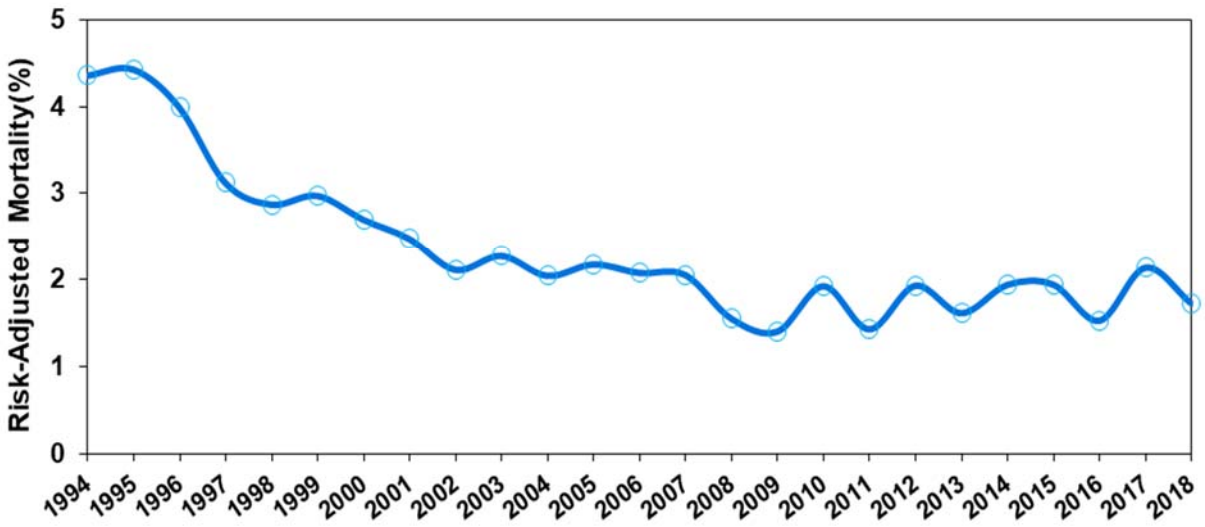
Table D3 also shows that between 2017 and 2018, the number of bypass surgeries performed in New Jersey decreased from 4,059 to 3,947 or by 2.8 percent. Over the same time period, the number of deaths decreased from 81 to 64 or by 20.1 percent. On a risk-adjusted basis, the mortality rate decreased by 18.0 percent between 2017 and 2018, which was not statistically significant. Nevertheless, since 1994 risk-adjusted mortality rate has decreased by 59.8 percent, which is statistically significant. Statewide risk-adjusted mortality rate for bypass surgery declined by 67.8 percent from 1994 to 2009 and plateaued between 2009 and 2018. According to the fitted regression lines, operative mortality from bypass surgery had been declining, in absolute terms, at the rate of 0.18 percentage points per year between 1994 and 2009 ($R^2 = 0.88$) and plateaued between 2009 and 2018 (Figure D1).

Table D3. Annual Risk-Adjusted Operative Mortality* Rate Derived from the Pooled Data for the Period 1994 -2018

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 1994 Risk-Adjusted Mortality Rate (%)
1994	6,957	274	3.94	2.30	4.36	**HI**	----	----
1995	7,553	327	4.33	2.49	4.43	**HI**	0.07	1.6
1996	8,262	341	4.13	2.63	3.99	**HI**	-0.44	-8.4
1997	8,286	280	3.38	2.75	3.12	**HI**	-0.87	-28.3
1998	8,377	252	3.01	2.67	2.87	**SA**	-0.25	-34.1
1999	8,108	268	3.31	2.83	2.97	**HI**	0.10	-31.8
2000	8,220	220	2.68	2.53	2.70	**SA**	-0.27	-38.1
2001	8,045	202	2.51	2.58	2.48	**SA**	-0.22	-43.2
2002	7,391	159	2.15	2.59	2.11	**LO**	-0.36	-51.5
2003	6,817	159	2.33	2.61	2.27	**SA**	0.16	-47.8
2004	6,177	122	1.98	2.46	2.04	**LO**	-0.23	-53.1
2005	5,576	117	2.10	2.46	2.18	**SA**	0.13	-50.1
2006	5,211	104	2.00	2.45	2.08	**LO**	-0.10	-52.4
2007	4,943	99	2.00	2.49	2.05	**LO**	-0.02	-52.9
2008	4,620	68	1.47	2.42	1.55	**LO**	-0.50	-64.4
2009	4,497	59	1.31	2.38	1.40	**LO**	-0.15	-67.8
2010	4,302	84	1.95	2.59	1.92	**LO**	0.52	-55.9
2011	3,709	50	1.35	2.40	1.43	**LO**	-0.49	-67.2
2012	3,735	75	2.01	2.65	1.93	**LO**	0.50	-55.7
2013	3,881	61	1.57	2.48	1.62	**LO**	-0.31	-63.0
2014	3,874	76	1.96	2.58	1.94	**LO**	0.32	-55.5
2015	3,945	79	2.00	2.63	1.94	**LO**	0.00	-55.4
2016	4,121	63	1.53	2.55	1.53	**LO**	-0.41	-64.9
2017	4,059	81	2.00	2.38	2.14	**SA**	0.61	-51.0
2018	3,947	64	1.62	2.36	1.75	**LO**	-0.38	-59.8
1994-2018	144,613	3,684	2.55	2.55	2.55			

SOURCE: New Jersey Department of Health.
*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 1994-2016 combined when evaluated with a 95 percent confidence interval.
SA - The risk-adjusted patient mortality is same as the mortality for the 1994-2016 combined when evaluated with a 95 percent confidence interval.
HI - The risk-adjusted patient mortality is significantly higher than the mortality for the 1994-2016 combined when evaluated with a 95 percent confidence interval.

Figure D1. Trend in Risk-Adjusted Operative Mortality* Rate, 1994 - 2018



SOURCE: NJ Department of Health.

*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

In an attempt to predict a patient's post-operative length of stay, we fitted a generalized linear regression model 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 died during the bypass surgery hospitalization were excluded from analysis as were patients who stayed fewer than two days in hospital and those who stayed over 30 days.

Table D4 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 (only 17.2 percent). Such low predictive power is usually common when one fits a regression model using individual level data as large as these.

Please note that the coefficients provided in Table D4 are in log form and interpretation of the values should take that into consideration.

Table D4. Risk Factors Identified for Isolated CABG Surgery Length of Stay, 2017 -2018

Patient Risk Factors Identified	Proportion of Patients(%)	Generalized Linear Regression Results	
		Coefficient	P-Value
Demographic factors			
Ages 60 to 64	17.85	0.05845	<.0001
Ages 65 to 69	19.26	0.07854	<.0001
Ages 70 to 74	17.38	0.09444	<.0001
Ages 75 to 79	12.18	0.14437	<.0001
Ages 80 to 84	6.13	0.22945	<.0001
Ages 85 and over	2.09	0.27969	<.0001
Female	22.11	0.05587	<.0001
Non-hispanic Black	7.40	0.08502	<.0001
Non-hispanic Other Race	11.94	0.04342	0.0015
Hispanic	9.17	0.04099	0.0070
Health factors			
Cerebrovascular Accident	3.40	0.05798	0.0003
Cerebrovascular Disease - Non-CVA	14.00	0.04657	0.0003
Diabetes - Insulin	16.48	0.05161	<.0001
Immunosuppressive Thearapy	3.68	0.07282	0.0015
Lung Disease - Moderate	4.16	0.05532	0.0107
Lung Disease - Severe	2.83	0.09654	0.0002
Obesity	13.81	0.08324	<.0001
Renal Failure without Dialysis	2.83	0.20256	<.0001
Renal Failure with Dialysis	3.40	0.12351	<.0001
Peripheral Vascular Disease	14.39	0.05267	<.0001
Smoker - Ever	58.04	0.02817	0.0016
Factors related to functioning of the heart			
Angina - Unstable	41.93	0.02314	0.0236
Arrhythmia	13.62	0.07867	<.0001
Cardiogenic Shock at Surgery	1.33	0.12976	0.0017
Congestive Heart Failure	19.25	0.09048	<.0001
Ejection Fraction 1 - 29%	5.46	0.18079	<.0001
Ejection Fraction 30 - 49%	25.32	0.06740	<.0001
IABP Received - Preop	6.86	0.07528	<.0001
MI - Same Day	2.14	0.08741	0.0071
MI - 1 to 7 Days	2.43	0.02638	0.0160
NYHA - II	33.78	0.04405	<.0001
NYHA - III	24.60	0.04901	0.0001
NYHA - IV	6.61	0.06314	0.0019
Number of Diseased Vessels - Two	17.78	0.06553	0.0064
Number of Diseased Vessels - Three	78.36	0.13057	<.0001
Resuscitation	0.50	0.29851	<.0001
Intercept	1.4303		
R-Square	17.17		
Number of CABGs (N)*	7,797		

SOURCE: New Jersey Department of Health.

* 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.

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Limited copies are available by writing to the New Jersey Department of Health, Office of Health Care Quality Assessment, P.O. Box 360, Trenton, NJ 08625; or by phone at (800) 418-1397; or email to hcqa@doh.state.nj.us.

The report is also posted on our website at https://www.nj.gov/health/healthcarequality/health-care-professionals/cardiac-stroke-services/cardiac-surgery/

Cardiac Surgery In New Jersey,