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Examining Causes of Racial Disparities in General Surgical Mortality: Hospital Quality versus Patient Risk

Jeffrey H. Silber, MD, PhD,
Center for Outcomes Research, The Children's Hospital of Philadelphia, Philadelphia, PA

The Departments of Pediatrics, The Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA

Department of Anesthesiology and Critical Care, The Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA

Department of Health Care Management, The Wharton School, The University of Pennsylvania, Philadelphia, PA

The Leonard Davis Institute of Health Economics, The University of Pennsylvania, Philadelphia, PA

Paul R. Rosenbaum, PhD,
Department of Statistics, The Wharton School, The University of Pennsylvania, 473 Jon M. Huntsman Hall, 3730 Walnut Street, Philadelphia, PA 19104-6340; (T) 215-898-3120; (F) 215-898-1280

The Leonard Davis Institute of Health Economics, The University of Pennsylvania, Philadelphia, PA

Rachel R. Kelz, MD,
Department of Surgery, The Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA

Hospital of the University of Pennsylvania, 3400 Spruce Street, 4 Silverstein, Philadelphia, PA 19014-1035; (T) 215-662-2030; (F) 215-662-7476

Darrell J. Gaskin, PhD,
Center for Health Disparities Solutions, Johns Hopkins University and The Johns Hopkins School of Public Health

Department of Health Policy & Management, Johns Hopkins Bloomberg School of Public Health, 624 N. Broadway, Suite 441, Baltimore, MD 21205; (T) 443-287-0306; (F) 410-614-8964

Justin M. Ludwig, MA,
Center for Outcomes Research, The Children's Hospital of Philadelphia, 3535 Market Street, Suite 1029, Philadelphia, PA 19104; (T) 267-426-1263; (F) 215-590-2378

Richard N. Ross, MS,

Corresponding Author: Jeffrey H. Silber, Mailing Address: Center for Outcomes Research, The Children's Hospital of Philadelphia, 3535 Market Street, Suite 1029, Philadelphia, PA 19104; (T) 215-590-5635; (F) 215-590-2378; Silber@email.chop.edu.

Center for Outcomes Research, The Children's Hospital of Philadelphia, 3535 Market Street, Suite 1029, Philadelphia, PA 19104; (T) 215-590-1446; (F) 215-590-2378

Bijan A. Niknam, BS,
Center for Outcomes Research, The Children's Hospital of Philadelphia, 3535 Market Street, Suite 1029, Philadelphia, PA 19104; (T) 215-590-2484; (F) 215-590-2378

Alex Hill, BS,
Center for Outcomes Research, The Children's Hospital of Philadelphia, 3535 Market Street, Suite 1029, Philadelphia, PA 19104; (T) 215-590-5402; (F) 215-590-2378

Min Wang, MHS,
Center for Outcomes Research, The Children's Hospital of Philadelphia, 3535 Market Street, Suite 1029, Philadelphia, PA 19104; (T) 215-590-5635; (F) 215-590-2378

Orit Even-Shoshan, MS, and
Center for Outcomes Research, The Children's Hospital of Philadelphia, 3535 Market Street, Suite 1029, Philadelphia, PA 19104; (T) 215-590-2809; (F) 215-590-2378

The Leonard Davis Institute of Health Economics, The University of Pennsylvania, Philadelphia, PA

Lee A. Fleisher, MD
Department of Anesthesiology and Critical Care, The Perelman School of Medicine at the University of Pennsylvania Health System, 6 Dulles, Philadelphia, PA 19104-4283; (T) 662-3738; (F) 349-5341 (c) 215-873-9029

The Leonard Davis Institute of Health Economics, The University of Pennsylvania, Philadelphia, PA

Abstract

Background—Racial disparities in general surgical outcomes are known to exist but not well understood.

Objectives—To determine if black-white disparities in general surgery mortality for Medicare patients is attributable to poorer health status among blacks on admission or differences in the quality of care provided by the admitting hospitals.

Research Design—Matched cohort study using Tapered Multivariate Matching.

Subjects—All black elderly Medicare general surgical patients (N=18,861) and white matched controls within the same 6 states or within the same 838 hospitals.

Measures—30-day mortality (primary); others include in-hospital mortality, failure-to-rescue, complications, length of stay, and readmissions.

Results—Matching on age, sex, year, state, and the exact same procedure, blacks had higher 30-day mortality (4.0 vs. 3.5%, P<0.01), in-hospital mortality (3.9% vs. 2.9%, P<0.0001), in-hospital complications (64.3 vs. 56.8% P<0.0001), and failure-to-rescue rates (6.1 vs. 5.1%, P<0.0001), longer length of stay (7.2 vs. 5.8 days, P<0.0001), and more 30-day readmissions (15.0 vs. 12.5%, P<0.0001). Adding pre-operative risk factors to the above match, there was no significant difference in mortality or failure-to-rescue, and all other outcome differences were small. Blacks matched to whites in the same hospital displayed no significant differences in mortality, failure-to-rescue, or readmissions.

Conclusions—Black and white Medicare patients undergoing the same procedures with closely matched risk factors displayed similar mortality, suggesting that racial disparities in general surgical mortality are not due to differences in hospital quality. To reduce the observed disparities in surgical outcomes, the poorer health of blacks on presentation for surgery must be addressed.

Keywords

Racial Disparities; Multivariate Matching; General Surgery

INTRODUCTION

General surgery is routinely practiced at nearly all short-term acute care hospitals, with more than a quarter of a million procedures performed in the Medicare population each year. While it is known that racial disparities in general surgery exist, the etiology is not well understood.[1–3] Some studies using regression models have suggested that patient risk factors and hospital quality contribute to the disparities although they cannot isolate the individual effects.[1–3] Distinguishing between these factors is important when designing policies to eliminate disparities. To address this challenge, we present a multivariate matching[4–6] approach to examining racial disparities, comparing actual patients similar in specified ways, by performing a series of tapered matches of black and white patients.[7–9] Our method pairs blacks to whites undergoing the exact same ICD-9 principal procedure, while also carefully matching for comorbid conditions, expected procedure duration, and other important medical factors. In so doing, through examining the experience of all black patients undergoing general surgical procedures throughout six diverse states, we can describe both the extent of the observed disparity and its causes.

METHODS

Patient Population

This research protocol was approved by the Institutional Review Board of The Children's Hospital of Philadelphia. For all Medicare fee-for-service (FFS) patients undergoing a general surgery procedure (defined below) we obtained Medicare claims for the years 2004–2007 in 6 states (California, Georgia, Maryland, New York, Ohio, and Pennsylvania). Each patient record was merged across Medicare Part A, Part B, outpatient claims and the beneficiary summary file that provided follow-up to December 31, 2008.

Definitions

Patient Characteristics—We defined race using self-reported data in the Medicare beneficiary summary file[10, 11] and compared blacks to non-Hispanic whites. Patient risk factors used in matching included (1) comorbidities such as congestive heart failure, diabetes, past acute myocardial infarction, stroke, hypertension, and 28 other conditions noted in the Appendix, which were defined with ICD9-CM codes[12] drawn from Medicare claims (inpatient, outpatient and physician bills) during a three-month period prior to admission. Other patient risk factors included: (2) predicted procedure time of each principal procedure, modified by secondary procedures performed on the same day[12–14] (a regression model for developing this score is presented in the Appendix); (3) estimated risk of death based on an external dataset that was not part of the matching population[15] using a model that did not include race (details in the Appendix); (4) transfer-in status; and (5) emergency admission.

Outcomes—The primary outcome is 30-day all-location mortality, although we also report in-hospital mortality. Complications were defined using a list of complications based on our previously published work.[12, 13, 16, 17] We defined two sets of complications, in-hospital complications and complications within 30 days of admission (defined as either in-hospital or occurring within 30 days of admission or during a readmission that occurred within 30 days of admission). Failure-to-Rescue, or the probability of dying after a complication, was defined as in our previous work[13, 16, 17] and applied the National Quality Forum-endorsed metrics for Failure-to-Rescue for in-hospital and 30-day definitions. Length of stay was reported using m-estimation[18] to down-weight some outlier values. Readmissions were defined as new admissions within 7 or 30 days of discharge.[19] Finally, operative time was based on the Medicare anesthesia bill, a metric that has been repeatedly validated using chart abstraction.[14, 20]

Statistical Analysis

Matching Methodology—Our matched comparisons gradually remove aspects of the differences between black and white populations at presentation to determine which aspects are plausible explanations of differences in outcomes. We used two approaches to matching, each addressing a different question by producing a sequence of more extensively controlled comparisons.

(1) Across-Hospital (Within-State) matches included all blacks at all hospitals and found the best white controls to form all pairs, regardless of where the white patients were treated. By comparing outcomes without controlling for the hospitals, we can determine the degree to which the black-white disparity is associated with demographic factors, risk factors, and differences in quality between the hospitals used by blacks and whites. We report two *Across-Hospital (Within-State)* matches: a “Procedure” match that matched black patients to white patients in the same state with the exact same ICD9 principal procedure and matched as closely as possible on age, sex, and year of procedure; and a “Risk-Factor” match that also exactly matched on procedure and included the same variables used in the Procedure match, but added in 33 patient risk factors, a risk score,[15] secondary procedure categories, a propensity score for black race,[4, 21] emergency admission, transfer status and predicted procedure time. The propensity score used for the risk-factor match came from a logistic regression of black-versus-white race on the variables to be controlled in the match (see Appendix). Matching on a propensity score tends to balance variables in the score.[4, 21] *(2) Inside-Hospital matches* paired black and white patients treated in the same hospital. The inside-hospital match answers a crucial question of whether black patients have worse outcomes than whites that were treated in the same hospital. In most hospitals, there are far

more white patients than black patients, and matching is easy, but in a small subset of hospitals, black patients outnumber white patients. When matching inside hospitals, we came close to creating the maximum possible number of pairs, whether that number was limited by the number of black patients or the number of white patients. The Inside-Hospital analysis used a subset of black-white pairs obtained using optimal subset matching,[4, 22] a multivariate matching method that discards a minimal number of individuals from both groups subject to conditions on the quality of the matched pairs.

Once the Inside-Hospital black population was determined, we used this same population of blacks for two subsequent across-hospital matches, using the Procedure and Risk-Factor variables described above. We report these results in the Appendix to compare with the initial Across-Hospital (Within-State) matches described above (revealing almost exactly the same results).

Some technical detail of the matching algorithm follows. We used exact fine balance for sex and "near-fine balance" for categories of age and year of procedure within groups of similar procedures (see Appendix). Near-fine balance[4, 23] matches by solving an optimization problem to make the distributions of specified covariates as similar as possible between the matched black and white groups. We also ensured the means of age and year of procedure were as close as possible between blacks and matched whites. The second, more refined matched analysis, the Risk-Factor match, used the same black patients but matched whites based on the characteristics in the Procedure match and additionally all risk factors noted above, plus the propensity score.

Matching was performed first, without viewing outcomes, so that we were not able to test multiple matching algorithms in order to achieve specific or desired outcome results.[24]

Statistical Tests

It is important to check that the match worked. As is commonly done, for each covariate we examined the black-white difference in means as a fraction of the standard deviation, the so-called "standardized difference," aiming for the conventional absolute value of 0.2 or less.[4, 25, 26] We also checked balance using two-sample randomization tests: the Wilcoxon rank sum test for continuous covariates,[27] and Fisher's exact test for binary covariates.

When testing for difference in outcomes, Wilcoxon's sign-rank statistic[27] and McNemar's statistic[28] were used for continuous and binary outcomes, respectively, and Gart's test[29] was used to look for interactions between a binary outcome and a binary characteristic of matched pairs. Differences in hospital, physician, and socioeconomic characteristics between blacks and matched whites were assessed using the chi-square test for categorical variables and the Wilcoxon rank sum test for continuous ones.[27] Findings were considered significant if $P \leq 0.05$ using a two-tailed test. All matching was optimized subject to balance constraints using the MIPMatch function[14, 30] in R.[31] Statistical tests used SAS 9.2 for UNIX.[32]

RESULTS

Matching Quality

We identified 1,116 hospitals in the six-state dataset where at least one of the study procedures listed in Table 1 was performed during the study period. Of these, 838 hospitals were used by black general surgical patients, and there were 18,861 such patients operated on in these hospitals. We report matching quality for the 3 main matches in Table 2. The Appendix reports matching quality for other matches, where the quality was similar to Table 2. As noted in Methods, comparisons between different hospitals used all 18,861 black patients in 18,861 black-white pairs; however, comparison of blacks and whites treated in the same hospital had 14,917 pairs, which is close to the maximum possible number of pairs, namely 15,220, based solely on the number of blacks and whites in the same hospital undergoing the same procedures. The difference, 15,220–14,917 = 303 pairs, reflects instances in which black and white patients were available but were too different to be matched. A detailed accounting is provided in the Appendix. As seen in Table 2, the 14,917 black patients in the Inside-Hospital match look fairly similar to, though a tad healthier than, the 18,861 black patients in the Across-Hospital matches.

Table 2 displays matching quality for a few of the covariates controlled by matching. Each row of Table 2 lists a covariate controlled in at least 1 match. Columns compare matched blacks and whites in 3 matches. There were 117 principal procedures in the matching population, which are not listed in the table because they were always matched exactly. A full list of all procedures and covariates is provided in the Appendix. The risk factors look quite similar in the two matches that sought to control risk factors. The match at the far right, the Procedure match, matches exactly for 117 principal procedures and state, and otherwise controls for age, sex and year of procedure, but not risk factors, so we expect to see, and are interested in examining, the large black-white differences in risk factors. For example, when blacks and whites of the same age and sex undergo the same procedures, the rate of diabetes is far lower in whites, 26.9% for whites, 41.4% for blacks ($P < 0.0001$); the rate of renal failure history was 5.3% for whites, 11% for blacks ($P < 0.0001$); the rate of heart failure history was 20% for whites, 24.4% for blacks ($P < 0.0001$). These differences are almost entirely removed in the two Risk-Factor matches.

Outcome Results

Table 3 presents outcome differences for blacks and whites in three matched comparisons. Consider, first, the far right match in Table 3, the Procedure match. Death rates in-hospital were higher for blacks than matched whites (3.9 versus 2.9%, $P < 0.0001$) and also for 30-day mortality (4.0 versus 3.5%, $P < 0.01$). Both in-hospital and 30-day complication rates were higher for blacks (in-hospital: 64.3 versus 56.8%, $P < 0.0001$; 30-day: 70.7 versus 64.9%, $P < 0.0001$). In-hospital failure-to-rescue rates were significantly higher for blacks (6.1 versus 5.1%, $P < 0.0001$), though 30-day failure-to-rescue rates were not significantly different. Length of stay was 1.2 days longer for blacks ($P < 0.0001$) using m-estimates resistant to extreme outliers. Readmission rates within 30 days were higher in blacks (15 versus 12.5%, $P < 0.0001$). Finally, the length of the procedure as defined by the anesthesia bill was 11.6 minutes longer in blacks ($P < 0.0001$), despite matching for the same procedure.

The Across-Hospital (Within-State) Risk-Factor match adds control for patient risk factors left uncontrolled in the Procedure match. Having controlled for patient risk factors, the differences in outcomes are generally smaller. In Table 3, there is now no significant difference in in-hospital or 30-day mortality or failure-to-rescue for blacks as compared to whites. Complication rates were still significantly higher for blacks, but the differences are smaller (black-white 30-day complication rates were 70.7 vs. 68.6%, $P < 0.0001$). Length of stay differences remained statistically significant, but were smaller in size (0.7 days, $P < 0.0001$); similarly, the difference in readmission rates was statistically significant but smaller in magnitude. Finally, the difference in anesthesia time remained almost the same, at 11.2 minutes ($P < 0.0001$), despite matching exactly on the principal procedure and matching closely on both secondary procedures and predicted procedure time, likely due to a higher rate of teaching hospital admissions among blacks as compared to whites.[33]

The final match on the left in Table 3 compares 14,917 black patients and 14,917 white patients undergoing the same surgical procedure in the same hospital with similar risk factors. Here, there are no significant differences in mortality or failure-to-rescue rates, and still smaller differences in complication rates. Blacks displayed an in-hospital complication rate of 63.2 versus 60.9% for whites ($P < 0.0001$). Similar results were observed for 30-day complication rates. The length of stay difference was small but still significant at 0.5 days ($P < 0.0001$), but there was now no significant difference in readmission rates. Finally, anesthesia time remained longer in blacks, but this difference now fell to just 2.6 minutes ($P < 0.0001$).

Differences in Racial Disparity Across Subgroups (Hospitals and Patients)

We compared outcome differences by race in those hospitals with a higher percentage of black patients (>30%), representing 21.4% of black patients, to those in hospitals with a lower percentage (≤30%).[34–36] Using the Across-Hospital (Within-State) Risk-Factor matched white controls, 30-day mortality was not different between blacks and whites in hospitals where more than 30% of the patients were black (5.1 vs. 4.9%, $P = 0.621$), nor was it different in the remaining hospitals, (3.8% vs. 4.2%, $P = 0.069$), and the difference in these disparities, the difference-in-differences, did not significantly differ from zero ($P = 0.165$) by Gart's test,[29] suggesting that any black-white 30-day mortality disparity in hospitals with a higher concentration of blacks (compared to matched whites who went to any hospital in the state) was not different from the black-white disparity when blacks were admitted to hospitals with a lower concentration of blacks. In a parallel analysis of hospital teaching status, we found that 30-day mortality was not different between blacks and whites admitted to teaching hospitals (3.7% vs. 4.1%, $P = 0.083$), or to non-teaching hospitals (4.5% vs. 4.5%, $P = 0.939$), nor was the difference-in-difference significantly different from zero ($P = 0.253$).

We studied general surgical procedures because they are performed at most acute care hospitals in the United States. General surgery includes a mix of low-risk and high-risk operations. Generally speaking, the magnitude of the case volume is inversely proportional to the case risk, making low-risk procedures of interest due to the volume of patients affected. Therefore, we next asked if there were differences in the relative size of the racial disparity in mortality when comparing high-risk procedures with death rates averaging about 10% (29 procedures and 2,760 matched black-white pairs), versus low risk procedures with death rates averaging about 3% (88 procedures and 16,101 matched black-white pairs). We found no difference for 30-day mortality in the relative disparities for any match, with no P-values less than 0.62.

Descriptors of the Attending Surgeon and Hospital Characteristics

Table 4 compares the hospitals that treated blacks and whites in the two Across-Hospital matches. The hospitals that treated the black patients treat more black patients and more poor patients. However, the structural characteristics of these hospitals show no consistent signs of their being typically inferior hospitals: they are more often teaching hospitals, typically larger hospitals, and typically hospitals whose nurses and surgeons have good credentials. Also, the hospitals in the 14,917-pair Inside-Hospital match look quite similar to the hospitals in the 18,861-pair Across-Hospital matches.

Examining Socioeconomic Variables

In Table 4 we also provide a description of the disparity in socioeconomic variables associated with the same three matches. Unsurprisingly, even in the Inside-Hospital match, black patients typically appear to be poorer than white patients. The percentage of dual-eligible Medicare patients was 15% in whites versus 32.5% in blacks (P < 0.0001). The average median neighborhood income was $48,243 for whites and $38,703 for blacks (P < 0.0001), with 11.4% of white patients in high poverty neighborhoods versus 18.2% of black patients (P < 0.0001). As has been found by others,[37] black patients also tended to come from neighborhoods with greater racial dissimilarity[38, 39] and isolation.[40] These differences were even larger in the Across-Hospital (Within-State) analyses. However, all our results taken together show that despite these socioeconomic differences, the 30-day mortality disparity is already fully explained by clinical factors, and requires no further explanation in terms of socioeconomic status.

We did notice significantly elevated complication rates and longer LOS among black patients, even when matched inside the same hospital and for all patient risk factors. As noted above, black patients are disproportionately poorer than white patients. Therefore, we fit a post-match adjustment model using m-estimation regression[41] on matched pair differences in dual-eligibility status, neighborhood median income, and neighborhood poverty levels. After adjustment, it appears that the higher rate of in-hospital complications among black patients is also experienced by similarly poor white patients (OR 1.02, 95% CI 0.96, 1.09, P = 0.493 after adjustment). Black patients still experienced significantly longer LOS even after adjustment for differences in socioeconomic status (excess 0.3 days, 95% CI 0.1, 0.4, P < 0.0001).

DISCUSSION

General surgery is practiced at nearly all hospitals in the United States, with a large number of cases and deaths. Nationwide in 2012, there were over 250,000 general surgical procedures (as defined by our study, and reported in Medicare claims), and over 10,000 deaths among the Medicare FFS population alone. Therefore, identifying potential disparities and their etiology in this population is of great importance.

We found that the large disparities observed following general surgical operations mostly vanished when blacks were compared to whites with similar risk factors upon presentation. Though we observed great differences in education and socioeconomic status between blacks and whites[42], we found that matching on medical risk factors mostly eliminated the observed surgical outcomes disparity, without including education and socioeconomic factors in the match. When blacks are compared to whites with similar risk factors on presentation, mortality and failure-to-rescue rates are similar. To remove the disparity in surgical outcomes, one needs to address the disparity in health at presentation.

We found no indication that hospital characteristics explained the black-white mortality disparity; nor did we find that blacks in Medicare undergoing general surgery typically go to worse hospitals than whites. Others also have observed that blacks, in fact, are much more likely to use urban, major teaching hospitals.[43]

We did observe slight differences in complication rates by race both for the Across-Hospital (Within-State) Risk-Factor match and the Inside-Hospital Risk-Factor Match. In our previous work we have advocated avoiding the use of complication rates to compare hospitals on quality because of potential differences in defining, observing, and recording complications across institutions. Indeed, we have argued that differences in hospital surgical complication rates are more of an indicator of patient severity than hospital quality.[17, 44, 45] It would be a mistake to infer that 30-day complication rate differences of, for example, 70.7 vs. 68.6% ($P < 0.0001$), between blacks and whites in the Across-Hospital (Within-State) Risk-Factor match suggests differences in hospital quality when the 30-day mortality rate differences for the same match were 4.0 vs. 4.3% respectively and not significantly different ($P = 0.192$).

While general surgical procedures are commonly performed at most acute care hospitals, our findings may not necessarily apply to more specialized surgery involving a subset of our hospital sample. Our findings are different from those examining racial disparities in complex procedures beyond general surgery such as cardiac, thoracic, and vascular surgery.[37, 46–48] Identifying potential disparities and their etiology in the broader general surgery population that includes a greater proportion of hospitals and patients is also highly important when considering policies to reduce disparities. Furthermore, the question as to whether a racial disparity can be reduced by changing the hospitals in which patients are treated is not new when studying outcome disparities in other diseases,[43, 49, 50] and results have varied depending on the specific disease studied and statistical methodology utilized. One approach, published by Barnato et al.[51], analyzed acute myocardial infarction data using regression models (both logistic regression fixed effects models and generalized estimating equations to account for hospital clustering) and argued that poor quality hospitals may be contributing to some excess deaths in blacks. This approach depends on correct model specification, something not required in the matching approach used in this report.

While our study is large, and capitalizes on the detail in Medicare claims as fully as possible, we still did not have the ability to perform actual chart review, and as such, we acknowledge limitations associated with studies lacking detailed physiologic data. Of course, our study, like others,[1–3] suggests black patients admitted for general surgery are sicker than whites. We found similar outcomes between blacks and whites despite the lack of detailed chart review, once we fully utilized the available claims data through careful matching.

In summary, there is a large racial disparity in mortality among Medicare patients undergoing common general surgery procedures across six states. However, black and white patients undergoing the same procedures with closely matched risk factors displayed similar outcomes. This was true when black patients were matched to whites from within the same hospital or from within the same state. These results suggest that the observed racial disparity in general surgical mortality must be addressed by designing interventions to improve the overall health status of black patients requiring general surgery and that policies designed to incentivize patient flow to different hospitals will not address the mortality disparity observed for the majority of general surgical patients. Addressing the observed racial disparity in surgical outcomes requires reducing the elevated risks that black patients have on admission to the hospital.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

List of Procedure Groups and ICD9-CM Principal Procedure Codes, and Number of Matched Pairs from Each Procedure Group

	Inside the Same Hospital Match N = 14,917 Matched Pairs		Across-Hospital Matches N = 18,861 Matched Pairs		
Procedure Group	**N**	**%**	**N**	**%**	**ICD-9-CM Principal Procedure Codes**
Large Bowel Resections	4,012	26.9	4,746	25.2	1731, 1732, 1733, 1734, 1735, 1736, 1739, 4571, 4572, 4573, 4574, 4575, 4576, 4579, 458, 4581, 4582, 4583
Gallbladder Procedures	3,753	25.2	4,068	21.6	5122, 5123, 5124, 5132, 5136, 5137, 5141, 5151
Breast Procedures	1,313	8.8	1,667	8.8	8522, 8523, 8541, 8542, 8543, 8544, 8545, 8546, 8547, 8548
Lysis of Adhesions	1,056	7.1	1,252	6.6	5451, 5459
Small Bowel Resections	698	4.7	845	4.5	4561, 4562, 4563
Thyroid Procedures	547	3.7	777	4.1	062, 0631, 0639, 064, 0650, 0651, 0652
Incisional and Abdominal Hernias	493	3.3	593	3.1	5361, 5369, 5372, 5375, 537
Inguinal Hernia Procedures	486	3.3	759	4.0	1711, 1712, 1713, 1721, 1722, 1723, 1724, 5300, 5301, 5302, 5303, 5304, 5305, 5310, 5311, 5312, 5313, 5314, 5315, 5316, 5317
Stomach Procedures	453	3.0	796	4.2	4342, 435, 436, 437, 4389, 4399, 4429, 4438, 4439, 4466, 4467, 4469, 4495
Rectal Procedures	414	2.8	561	3.0	4849, 485, 4850, 4851, 4852, 4859, 4862, 4863, 4869, 4875, 4876, 4879
Appendectomies	366	2.5	448	2.4	4701, 4709
Parathyroidectomy	336	2.3	453	2.4	0681, 0689
Ostomy Procedures	198	1.3	411	2.2	4601, 4603, 4610, 4611, 4613, 4620, 4621, 4622, 4623, 4639, 4642, 4651, 4652
Pancreatic Procedures	152	1.0	205	1.1	5252, 5259, 526, 527
Ventral Hernia Repairs	125	0.8	227	1.2	5351, 5359
Umbilical Hernia Procedures	100	0.7	194	1.0	5341, 5349
Bowel Procedures, Other	77	0.5	188	1.0	4673, 4674, 4675, 4679
Ulcer Surgeries	75	0.5	148	0.8	4441, 4442
Splenectomy	53	0.4	88	0.5	415
Liver Procedures	49	0.3	62	0.3	5022, 5029, 503, 5059
Adrenal Procedures	45	0.3	73	0.4	0722, 0729, 073
PD Access Procedure	41	0.3	91	0.5	5493
Bowel Anastomoses	27	0.2	91	0.5	4590, 4591, 4592, 4593, 4594, 4595

Procedure Group	Inside the Same Hospital Match N = 14,917 Matched Pairs		Across-Hospital Matches N = 18,861 Matched Pairs		ICD-9-CM Principal Procedure Codes
	N	**%**	**N**	**%**	
Femoral Hernia Procedures	24	0.2	56	0.3	5321, 5329
Esophageal Procedures	–*	0.1	40	0.2	4240, 4241, 4242, 427
Repair of Vaginal Fistulas	< 11	0.0	22	0.1	7072, 7073, 7074, 7075
Total:	**14,917**	**100**	**18,861**	**100**	

* True number of pairs is masked to comply with CMS cell size suppression rules.

Table 2

The Quality of the Matches

Type of Match:	Inside the Same Hospital Risk-Factor Match			Across-Hospital, Within-State Risk-Factor Match			Across-Hospital, Within-State, Procedure Match[++]		
Variable[+]	**Matched Blacks N=14,917**	**Matched Whites N=14,917**	**DIFFAVE After Match**	**All Blacks N=18,861**	**Matched Whites N=18,861**	**DIFFAVE After Match**	**All Blacks N=18,861**	**Matched Whites N=18,861**	**DIFFAVE After Match**
Variables Included in All Matches									
Age (years, mean) (SD)	75.6 (7.3)	75.7 (7.1)	−0.01	75.6 (7.3)	75.6 (7.2)	0.00	75.6 (7.3)	75.6 (7.3)	0.00
Year of Procedure (mean) (SD)	2005.2 (1.0)	2005.2 (1.0)	0.01	2005.2 (1.0)	2005.2 (1.0)	0.00	2005.2 (1.0)	2005.2 (1.0)	0.00
Sex (% male)	33.3	33.3	0.00	33.5	33.5	0.00	33.5	33.5	0.00
Variables Included Only in the Inside-Hospital and Risk-Factor Matches									
Predicted Anesthesia Time (minutes, mean) (SD)	135.7 (42.0)	135.8 (42.1)	0.00	137.3 (43.1)	137.3 (43.1)	0.00	137.3 (43.1)	137.7 (43.2)	−0.01
Probability of 30-day Death	0.0527	0.0543	−0.02	0.0571	0.0576	−0.01	0.0571	0.0514	0.07[d]
Propensity Score for Black Race	0.1290	0.1258	0.04	0.1356	0.1329	0.03	0.1356	0.0958	0.51[d]
ER Admission	41.1	40.5	0.01	41.2	41.1	0.00	41.2	33.7	0.15[d]
Transfer-in	0.6	0.7	−0.02	0.6	0.6	0.00	0.6	0.7	−0.02
Major Sec. Procedure (same day)	32.9	33.3	−0.01	33.5	33.5	0.00	33.5	33.3	0.00
Congestive Heart Failure	24.4	24.6	0.00	25.7	25.7	0.00	25.7	20.0	0.13[d]
Past Myocardial Infarction	7.2	7.4	−0.01	7.0	7.1	0.00	7.0	7.9	−0.03[b]
Past Arrhythmia	21.6	21.5	0.00	21.7	21.6	0.00	21.7	23.5	−0.04[d]
Angina	3.5	3.5	0.00	3.5	3.5	0.00	3.5	3.1	0.02[a]
Valvular Disease	17.8	18.3	−0.01	17.4	17.4	0.00	17.4	19.2	−0.05[d]
Unstable Angina	1.6	1.7	−0.01	1.7	1.7	0.00	1.7	1.6	0.01
Hypertension	87.4	86.6	0.02[a]	87.5	87.5	0.00	87.5	75.2	0.32[d]
Hypothyroidism	11.1	11.9	−0.02[a]	10.8	10.9	0.00	10.8	18.8	−0.23[d]
Diabetes	41.4	40.9	0.01	42.0	42.0	0.00	42.0	26.9	0.32[d]
Renal Dysfunction	17.8	17.3	0.01	19.0	18.8	0.01	19.0	9.7	0.27[d]

Type of Match:	**Inside the Same Hospital Risk-Factor Match**			**Across-Hospital, Within-State Risk-Factor Match**			**Across-Hospital, Within-State, Procedure Match[++]**		
Variable[+]	**Matched Blacks N=14,917**	**Matched Whites N=14,917**	**DIFFAVE After Match**	**All Blacks N=18,861**	**Matched Whites N=18,861**	**DIFFAVE After Match**	**All Blacks N=18,861**	**Matched Whites N=18,861**	**DIFFAVE After Match**
Renal Failure	11.0	10.7	0.01	11.9	11.7	0.01	11.9	5.3	0.24[d]
Liver Disease	12.0	12.1	0.00	11.8	11.8	0.00	11.8	10.1	0.05[d]
Cancer	46.6	46.8	0.00	46.8	46.8	0.00	46.8	48.2	−0.03[b]
Specific Abdominal Cancer	4.2	4.0	0.01	4.4	4.3	0.01	4.4	4.3	0.01
COPD	20.6	20.8	0.00	20.8	20.9	0.00	20.8	24.9	−0.10[d]
Asthma	9.6	9.6	0.00	9.7	9.6	0.00	9.7	7.7	0.07[d]
Post-inflamm. Pulm. Fibrosis	2.3	2.3	0.00	2.3	2.3	0.00	2.3	3.1	−0.05[d]
Dementia	9.3	9.2	0.00	10.0	10.0	0.00	10.0	6.4	0.13[d]
Stroke	10.9	11.0	0.00	11.6	11.6	0.00	11.6	7.4	0.14[d]
Seizure	1.2	1.0	0.02[a]	1.3	1.3	0.01	1.3	0.8	0.06[d]
Paraplegia	3.1	3.1	0.00	3.5	3.4	0.00	3.5	1.4	0.14[d]
Congenital Coagulopathy	3.9	4.1	−0.01	4.0	4.0	0.00	4.0	4.1	0.00
Collagen Vascular Disease	4.1	3.9	0.01	4.0	4.0	0.00	4.0	4.4	−0.02[a]
AIDS	0.2	0.2	0.02	0.2	0.1	0.03[b]	0.2	0.1	0.05[d]
Chronic Peptic Ulcer	0.4	0.3	0.02	0.5	0.4	0.02	0.5	0.5	0.00
Electrolyte/Fluid Abnormality	12.0	11.7	0.01	12.7	12.6	0.00	12.7	9.8	0.09[d]
Hemoglobinopathy	0.1	0.1	0.00	0.1	0.0	0.02	0.1	0.0	0.02[a]
Obesity	5.5	5.3	0.01	5.5	5.5	0.00	5.5	4.6	0.05[d]
Morbid Obesity	3.4	3.4	0.00	3.4	3.4	0.00	3.4	2.6	0.05[d]

P-value Legend:

[a] $P < 0.05$;

[b] $P < 0.01$;

[c] $P < 0.001$;

[d] $P < 0.0001$.

P-values were calculated using two-sample balance tests: Fisher's exact test for categorical variables, and Wilcoxon rank sum test for continuous variables.

DIFFAVE = standardized difference in means in units of standard deviations

+Note: All black-white pairs were exactly matched for ICD9-CM principal procedure code

++Note: The Procedure Match did not match on any variables listed below age, year of surgery and sex.

Complete results for all matched variables can be found in the Appendix.

Table 3

Clinical Outcomes after Matching

Type of Match:	Inside the Same Hospital Risk-Factor Match			Across-Hospital, Within-State, Risk-Factor Match			Across-Hospital, Within-State, Procedure Match		
Variable	**Matched Blacks N=14,917%**	**Matched Whites N=14,917%**	**Odds Ratio (95% CI)**	**All Blacks N = 18,861%**	**Matched Whites N = 18,861%**	**Odds Ratio (95% CI)**	**All Blacks N = 18,861%**	**Matched Whites N = 18,861%**	**Odds Ratio (95% CI)**
Mortality									
Inpatient	3.3	3.3	1.00 0.87, 1.14	3.9	3.7	1.08 0.96, 1.21	3.9	2.9	1.39[d] 1.23, 1.56
30-day	3.6	3.8	0.92 0.81, 1.05	4.0	4.3	0.93 0.83, 1.04	4.0	3.5	1.17[b] 1.05, 1.31
Complications									
Inpatient	63.2	60.9	1.14[d] 1.08, 1.20	64.3	60.9	1.23[d] 1.17, 1.29	64.3	56.8	1.48[d] 1.41, 1.55
30-day	69.6	68.4	1.08[b] 1.02, 1.14	70.7	68.6	1.14[d] 1.08, 1.20	70.7	64.9	1.37[d] 1.31, 1.44
Failure-to-Rescue *									
Inpatient	5.2	5.4	0.99 0.85, 1.16	6.1	6.0	1.03 0.91, 1.16	6.1	5.1	1.25[c] 1.10, 1.44
30-day	5.1	5.6	0.93 0.81, 1.07	5.7	6.3	0.89 0.80, 1.00	5.7	5.4	1.07 0.94, 1.21
Readmission									
7-day	5.9	6.3	0.94 0.85, 1.04	6.2	6.2	1.01 0.93, 1.10	6.2	5.7	1.10[a] 1.01, 1.20
30-day	14.2	13.7	1.04 0.97, 1.11	15.0	13.5	1.14[d] 1.07, 1.21	15.0	12.5	1.24[d] 1.17, 1.31
Continuous Outcomes			**B-W Difference**			**B-W Difference**			**B-W Difference**
Length of Stay & CI (days, m-est.) + **(Upper/Lower Quartiles)**	6.9 6.8, 7.0 (3, 12)	6.3 6.2, 6.4 (3, 11)	0.5[d] 0.4, 0.6 (−3, 4)	7.2 7.1, 7.3 (3, 13)	6.3 6.2, 6.3 (3, 11)	0.7[d] 0.7, 0.8 (−2, 5)	7.2 7.1, 7.3 (3, 13)	5.8 5.7, 5.8 (2, 10)	1.2[d] 1.1, 1.3 (−2, 6)
Anesthesia Time CI (min, m-est.) + **(Upper/Lower Quartiles)**	144.9 143.6, 146.1 (105, 195)	142.2 141.1, 143.4 (103.5, 190.5)	2.6[d] 1.5, 3.7 (−36, 43.5)	146.6 145.6, 147.8(105, 199.5)	135.0 134.1, 136.1 (97.5, 184.5)	11.2[d] 10.1, 12.3 (−34.5, 58.5)	146.6 145.6, 147.8(105, 199.5)	135.0 134.0, 135.9 (97.5, 184.5)	11.6[d] 10.4, 12.8 (−37.5, 60)

P-value Legend:

[a] $P < 0.05$;

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[b] $P < 0.01$;

[c] $P < 0.001$;

[d] $P < 0.0001$.

P-values were calculated using paired one-sample tests: McNemar's test for categorical variables, and Wilcoxon signed-rank test for continuous variables.

[*] Note, rates reflect the distribution of Failure-to-Rescue among all blacks or matched whites, while the odds ratio and statistical tests use only pairs where both patients had a qualifying Failure-to-Rescue event.

[+] Estimates for continuous outcomes and paired differences in continuous outcomes were produced using m-estimation.

Table 4

Black-White Differences in Hospital Characteristics, Surgeon Characteristics and Patients' Socioeconomic Status

Type of Match:	Inside the Same Hospital Risk-Factor Match+			Across-Hospital Risk- Factor Match			Across-Hospital Procedure Match		
SDs are provided for all continuous variables. Variables	**Matched Blacks N = 14,917**	**Matched Whites N = 14,917**	**P-value**	**All Blacks N = 18,861**	**Matched Whites N = 18,861**	**P-value**	**All Blacks N = 18,861**	**Matched Whites N = 18,861**	**P-value**
Hospital Characteristics									
Resident-to-bed (R:B) ratio									
% Major (RB > 0.25)	21.2	21.2	1.0000	22.9	12.9	<0.0001	22.9	13.4	<0.0001
% Minor (0 < RB ≤ 0.25)	30.1	30.1		29.6	24.5		29.6	24.8	
% Non-teaching (RB = 0)	48.6	48.6		47.2	62.5		47.2	61.7	
% Unknown/Missing	0.1	0.1		0.2	0.2		0.2	0.2	
Bed Size									
% Large (Size > 250)	76.8	76.8	1.0000	76.1	64.0	<0.0001	76.1	64.4	<0.0001
% Medium (101≤ Size ≤ 250)	19.5	19.5		19.8	27.1		19.8	26.8	
% Small (Size ≤ 100)	3.6	3.6		3.9	8.8		3.9	8.6	
% Unknown/Missing	0.1	0.1		0.2	0.2		0.2	0.2	
Nurse-to-bed (N:B) Ratio*									
% High (N:B > 1.0)	49.2	49.2	1.0000	46.3	49.6	<0.0001	46.3	50.7	<0.0001
% Moderate (0.5 ≤ N:B ≤ 1.0)	41.6	41.6		43.1	41.9		43.1	40.4	
% Low (N:B ≤ 0.5)	9.1	9.1		10.3	8.4		10.3	8.7	
% Unknown/Missing	0.1	0.1		0.2	0.2		0.2	0.19	
Nurse Mix #									
% Advanced Staff (mix > 90% RN)	51.6	51.6	1.0000	49.7	47.5	<0.0001	49.7	47.7	<0.0001
% Moderate Staff (75% ≤ RN ≤ 90%)	35.7	35.7		37.4	37.0		37.4	36.8	
% Elementary Staff (mix < 75% RN)	11.1	11.1		11.4	14.6		11.4	14.5	
% Unknown/Missing	1.7	1.7		1.6	0.9		1.6	1.0	
Technology Index †									
% High Technology	57.5	57.5	1.0000	56.1	51.9	<0.0001	56.1	51.7	< 0.001
%Unknown/Missing	0.1	0.1		0.2	0.2		0.2	0.2	

Type of Match:	Inside the Same Hospital Risk-Factor Match+			Across-Hospital Risk- Factor Match			Across-Hospital Procedure Match		
SDs are provided for all continuous variables. Variables	**Matched Blacks N = 14,917**	**Matched Whites N = 14,917**	**P-value**	**All Blacks N = 18,861**	**Matched Whites N = 18,861**	**P-value**	**All Blacks N = 18,861**	**Matched Whites N = 18,861**	**P-value**
Type of Financial Control									
% Not-for-profit	79.2	79.2		76.3	80.6		76.3	80.9	
% Private	8.0	8.0	1.0000	9.7	7.2	<0.0001	9.7	7.3	<0.0001
% Government	12.9	12.9		14.1	12.3		14.1	11.9	
Urbanicity									
% Urban	91.9	91.9	1.0000	92.3	82.7	<0.0001	92.3	82.8	<0.0001
Racial Composition of Hospitals' Patients									
% Admitted to Hospitals > 30% Black	12.5	12.5		21.4	2.6		21.4	2.3	
% Admitted to Hospitals 6-30% Black	64.3	64.3	1.0000	58.6	39.5	<0.0001	58.6	38.8	<0.0001
% Admitted to Hospitals < 6% Black	23.2	23.2		20.0	57.9		20.0	58.9	
Socioeconomic Status of Hospitals' Patients (Overall, Census 2000 5-digit ZIP)									
% Patients from ZIP ≥ 20% Below Poverty Line	8.4	8.4		14.4	4.4		14.4	4.1	
% Patients from ZIP 10-20% Below Poverty Line	50.6	50.6	1.0000	49.4	44.9	<0.0001	49.4	44.9	<0.0001
% Patients from ZIP < 10% Below Poverty Line	41.1	41.1		36.1	50.7		36.1	51.0	
Surgeon Characteristics									
Board-Certified (%)									
Yes	38.8	39.6		38.5	38.8		38.5	38.8	
No	19.7	19.8	0.6549	17.8	19.3	0.0054	17.8	18.9	0.0704
Missing	41.4	40.5		43.7	41.9		43.7	42.4	
Attending Surgeon Years Since Graduation									
Number of years (mean)	22.9 (10.5)	23.0 (10.4)	0.5349	23.1 (10.5)	22.6 (10.2)	<0.0001	23.1 (10.5)	22.5 (10.2)	<0.0001
% Missing	2.0	1.6		2.7	1.4		2.7	1.8	
Patient Socioeconomic Characteristics									
Dual-eligible (%)	32.5	15.0	<0.0001	34.4	14.7	<0.0001	34.4	12.5	<0.0001
Usual Source of Primary Care (%)	59.5	64.0	<0.0001	58.2	64.8	<0.0001	58.2	64.3	<0.0001

Type of Match:	Inside the Same Hospital Risk-Factor Match[+]			Across-Hospital Risk- Factor Match			Across-Hospital Procedure Match		
SDs are provided for all continuous variables. Variables	**Matched Blacks N = 14,917**	**Matched Whites N = 14,917**	**P-value**	**All Blacks N = 18,861**	**Matched Whites N = 18,861**	**P-value**	**All Blacks N = 18,861**	**Matched Whites N = 18,861**	**P-value**
Number of Health Care Encounters 2 to 8 Months Prior to Surgery (mean)	4.1 (4.1)	4.7 (4.5)	<0.0001	4.0 (4.3)	4.7 (4.6)	<0.0001	4.0 (4.3)	4.6 (4.5)	<0.0001
Neighborhood Census Median Income ($, mean)	38,703 (15,877)	48,243 (18,113)	<0.0001	34,821 (15,595)	44,266 (17,682)	<0.0001	34,821 (15,595)	44,554 (18,072)	<0.0001
Neighborhood Census Below Poverty Level (mean, %)	18.2 (10.9)	11.4 (8.4)	<0.0001	18.9 (11.1)	10.5 (7.3)	<0.0001	18.9	10.4 (7.2)	<0.0001
Neighborhood Census High School Grads (mean, %)	74.9 (11.6)	81.0 (11.0)	<0.0001	74.1 (12.0)	81.3 (10.1)	<0.0001	74.1 (12.0)	81.6 (10.0)	<0.0001
Neighborhood Isolation Index[^] (mean)	0.61 (0.16)	0.60 (0.17)	<0.0001	0.63 (0.16)	0.54 (0.21)	<0.0001	0.63 (0.16)	0.54 (0.21)	<0.0001
Neighborhood Dissimilarity Index[^^] (mean)	0.68 (0.10)	0.67 (0.10)	<0.0001	0.68 (0.10)	0.64 (0.11)	<0.0001	0.68 (0.10)	0.64 (0.11)	<0.0001

P-values were calculated using the Chi-square test.

Data for hospital characteristics was taken from Medicare Providers of Service (POS) file for 2005, the midpoint of the study data used for matching. Surgeon characteristics were obtained from Medicare Physician Identification and Eligibility Records (MPIER).

+ In the Inside-Hospital Match, blacks and whites are always matched within the same hospital, so the distribution of hospitals in this match is identical.

* Nurse-to-bed ratio is calculated by dividing the number of full-time equivalent (FTE) nurses (registered nurses and licensed practical nurses) by the total number of beds.

Nurse mix is the ratio of registered nurses to the number of full-time equivalent nurses.

† High technology is noted as the presence of a burn unit, or the provision of coronary artery bypass graft (CABG) or organ transplantation at the hospital.

^ The isolation index is a measure of the likelihood of minorities and whites coming onto contact with each other (1 = lowest exposure of minorities to whites).

^^ The dissimilarity index is a measure of the evenness of distribution of races- the proportion of minorities who would have to change locations for race to be evenly distributed (1 = complete segregation; 0 = complete integration).