# Are racial differences in hospital mortality after coronary artery bypass graft surgery real? A risk-adjusted meta-analysis

Umberto Benedetto, MD, PhD,[a] Mohamed K. Kamel, MD,[b] Faiza M. Khan, MD,[b] Gianni D. Angelini, MD,[a] Massimo Caputo, MD,[a] Leonard N. Girardi, MD,[b] and Mario Gaudino, MD[b]

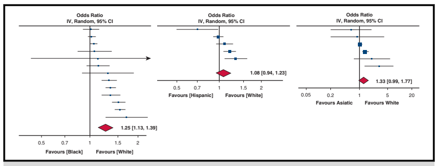
## ABSTRACT

**Background:** Despite several reports, there are still conflicting data on the influence of ethnicity on mortality rates associated with coronary artery bypass grafting (CABG). We aimed to get further insights into the effect of race on mortality following CABG by performing a risk adjusted meta-analysis.

**Methods:** Relevant studies were searched on PubMed, Embase, BioMed Central, and the Cochrane Central register. Pairwise meta-analysis was used to estimate the relative risk of hospital death of black, Hispanic, and Asian patients using white patients as reference. Risk adjusted meta-analytic estimates were obtained using generic inverse variance methods with random effect model.

**Results:** A total of 28 studies were selected for analysis. A total of 21 studies reported on hospital mortality in black (n = 222,892) versus white (n = 3,884,043) patients, 7 studies reported on Hispanic (n = 91,256) versus white (n = 1,458,524) and 9 studies reported on Asian (n = 27,820) versus white (n = 1,081,642). When compared with white patients, adjusted risk of hospital death was significantly greater for black patients (adjusted odds ratio [OR], 1.25; 95% confidence interval [CI], 1.13-1.39; $P < .001$), and not statistically different for Asian (OR, 1.33; 95% CI, 0.99-1.77; $P = .05$) and Hispanic patients (adjusted OR, 1.08; 95% CI, 0.94-1.23; $P = .26$). Meta-regression showed a significant trend toward lower mortality rates in most recent series in both black ($P = .02$) and white ($P = .0007$) and Asian ($P = .01$) but not for Hispanic ($P = .41$). However, as mortality rates were lower across the different races, the relative disadvantage between the study groups persisted, which may explain the lack of interaction between study period and race effect on mortality for black (adjusted $P = .09$), Asian (adjusted $P = .63$), and Hispanic (adjusted $P = .97$) patients.

**Conclusions:** The present meta-analysis showed that despite progress is being made in lowering in-hospital mortality rates among the major racial/ethnic groups, ethnical disparities in hospital mortality after CABG remain. (J Thorac Cardiovasc Surg 2019;157:2216-25)




Meta-analytic risk-adjusted estimates of race effect on operative mortality.

**Central Message**

Despite progress being made in lowering in-hospital mortality rates among the major racial/ethnic groups, ethnic disparities in hospital mortality after coronary bypass surgery remain.

**Prospective**

The effect of race on mortality after coronary bypass surgery remains uncertain, and current guidelines and risk stratification systems make no differentiation by race. We showed that despite progress being made in lowering in-hospital mortality rates among the major racial/ethnic groups, ethnic disparities in hospital mortality after CABG remain.

See Commentary on page 2226.

Although multiple studies have found that non-white patients, in particular black and Hispanic, have lower rates of cardiovascular procedures, including cardiac catheterization, percutaneous coronary intervention, and coronary artery bypass grafting (CABG),[1] there are still limited and conflicting data on the influence of ethnicity on mortality and complication rates associated with CABG.[2-6] One

From the [a]Bristol Heart Institute, University of Bristol, School of Clinical Sciences, Bristol, United Kingdom; and [b]Department of Cardiothoracic Surgery, Weill Cornell Medicine, New York, NY.

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Drs Benedetto and Kamel contributed equally to this manuscript.

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Address for reprints: Umberto Benedetto, MD, PhD, Bristol Heart Institute, University of Bristol, Upper Maudlin St, Bristol BS2 8HW United Kingdom (E-mail: umberto.benedetto@bristol.ac.uk).

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**Abbreviations and Acronyms**

CABG = coronary artery bypass grafting
CI = confidence interval
OR = odds ratio

potential concern is that if racial minorities are less likely to be referred for cardiac catheterization and coronary revascularization, then only those with particularly advanced disease or compelling indications may undergo these procedures, leading to worse outcomes.[2-4] Previous studies evaluating the impact of ethnicity on mortality following CABG surgery have had mixed conclusions. Several studies have reported greater mortality for black patients following the operation.[5,6] Other studies have suggested similar risk-adjusted survival for black patients following CABG surgery.[2-4] Therefore, the effect of race on mortality after CABG remains uncertain,[2] and current CABG guidelines[7] and risk-stratification systems[8,9] make no differentiation by race. We aimed to get further insights into the effect of race on mortality following CABG by performing a risk-adjusted meta-analysis of comparative studies.

## METHODS

### Literature Search Strategy

The search strategy adopted is in accordance with the Meta-analysis of Observational Studies in Epidemiology guidelines.[10] We searched PubMed, the Cochrane Central Register of Controlled Trials, and EMBASE from their inception to March 2017, without language restrictions. Search algorithm used was ''race'' OR ''ethnicity'' AND (''coronary artery bypass'' OR CABG OR ''bypass surgery'' OR ''coronary bypass''). In addition, reference lists of the identified reports and relevant reviews were manually screened by 2 reviewers (U.B., M.K.) to identify relevant studies. Studies reporting hospital outcomes after CABG across different ethnic groups including white, black, Hispanic, and Asian patients were selected. When centers have published duplicate trials with accumulating numbers of patients, only the largest reports were included for qualitative appraisal (Online Data Supplement). Non-English articles were not excluded. Abstracts, case reports, conference presentations, editorials, and expert opinions were excluded. Disagreements were resolved by consensus. The quality of included studies was assessed with the Newcastle–Ottawa scale for observational studies.[11] The total score was 9 stars, and the quality was graded as low level (<6 stars) or high level (≥6 stars). Baseline characteristics and hospital outcomes in different ethnic groups were independently abstracted by 2 investigators (U.B., M.K.). The primary outcome of the present meta-analysis was hospital mortality. Hospital mortality crude incidence rates for different ethnic groups were obtained from individual studies. As different ethnic groups can present different patient-level and hospital-level factors distribution, we also extracted fully adjusted estimates obtained by multivariate models from individual studies. Other operative outcomes investigated were stroke, wound infection, renal failure/dialysis, re-exploration for bleeding, and respiratory failure/tracheostomy.

### Statistical Analysis

Pairwise meta-analysis methods were used to estimate operative mortality relative risk for different ethnic groups (black, Hispanic, and Asian) using the white group as reference. A subgroup analysis was done to compare South Asian with white. Individual study and pooled operative mortality were reported as odds ratio (OR) with a 95% confidence interval (CI). Unadjusted pooled estimates were obtained using the model of DerSimonian and Laird.[12] Individual studies risk-adjusted estimates were pooled as log OR and standard error using the generic inverse variance method.[13]

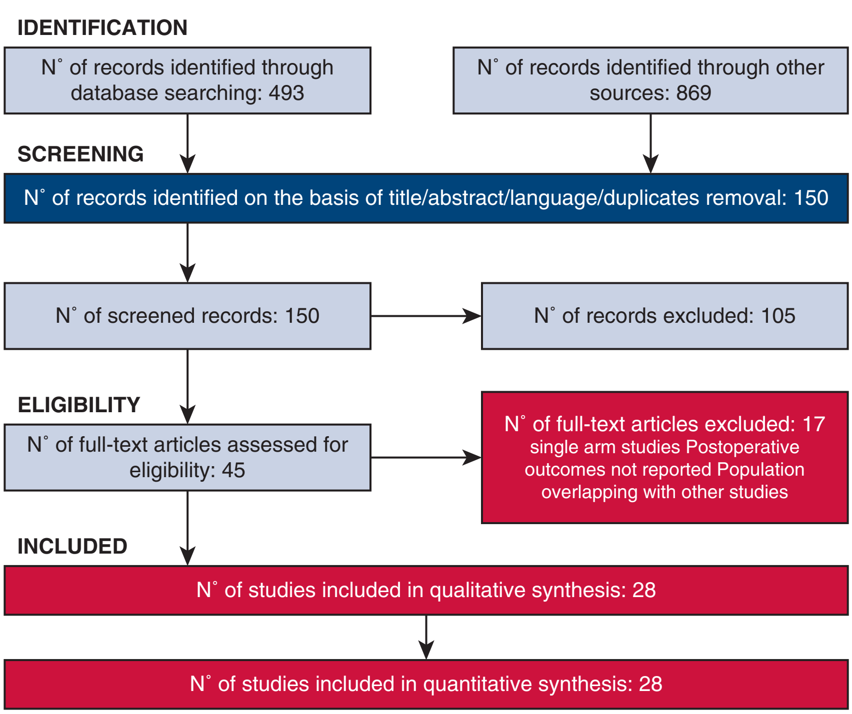



**FIGURE 1.** Study selection process for meta-analysis.

**TABLE 1. Overview of studies included in the meta-analysis**

| N of study | First author and year of publication | Country | Single vs multi-institution | Years of enrollment | Information on source of data | White patients (N) | Black patients (N) | Asian patients (N) | Hispanic Patients (N) | Race identification |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Anderson et al,[31] 2016 | US | Multi-institution | 2011-2012 | California CABG Reporting Program | 14,389 | 975 | 3196 | 4614 | * |
| 2 | Andrews et al,[34] 2015 | US | Multi-institution | 2009 | Healthcare Research and Quality (NIS) | 194,440 | 15,534 | | | * |
| 3 | Becker and Rahimi,[6] 2006 | US | Multi-institution | 1993-2002 | Healthcare Research and Quality (NIS) | 1,040,641 | 63,991 | 20,353 | 67,554 | * |
| 4 | Bridges et al,[5] 2000 | US | Multi-institution | 1994-1997 | Society of Thoracic Surgeons (STS) | 555,939 | 25,850 | | | Self-identified |
| 5 | Brister et al,[22] 2007 | Canada | Single institution | 1994-2003 | – | 917 | | 917 | | Self-identified & patients' name |
| 6 | Chowdhury et al,[33] 2017 | US | Single institution | 2006-2010 | – | 3107 | 389 | | | Self-identified |
| 7 | Cooper et al,[28] 2009 | US | Multi-institution | 1997-2007 | Society of Thoracic Surgeons (STS) | 10,841 | 2033 | | | * |
| 8 | Efird et al,[16] 2015 | US | Single institution | 1992-2011 | – | 11,395 | 2379 | | | Self-identified |
| 9 | Gasevic et al,[20] 2013 | Canada | Multi-institution | 1999-2003 | British Columbia Cardiac Registry | 1507 | | 180 | | Patients' name |
| 10 | Goldsmith et al,[37] 1999 | UK | Single institution | 1994-1997 | – | 190 | | 194 | | * |
| 11 | Gray et al,[25] 1996 | US | Single institution | 1984-1992 | – | 3113 | 115 | | | * |
| 12 | Hadjinikolaou et al,[36] 2010 | UK | Single institution | 2002-2007 | – | 2623 | | 274 | | Self-identified |
| 13 | Kaila et al,[18] 2014 | Canada | Multi-institution | 1999-2012 | APPROACH database | 737 | | 252 | | Patients' name |
| 14 | Keeling et al,[32] 2017 | US | Single institution | 2002-2014 | – | 13,569 | 2810 | | | * |
| 15 | Kim et al,[21] 2008 | US | Multi-institution | 2002-2005 | University HealthSystem Consortium | 63,487 | 8462 | | | * |
| 16 | Konety et al,[23] 2005 | US | Multi-institution | 1997-2000 | Medicare Provider and Analysis Review | 566,785 | 24,354 | | | * |
| 17 | Lucas et al,[35] 2006 | US/Canada | Multi-institution | 1994-1999 | Medicare Provider and Analysis Review | 829,037 | 33,367 | | | * |
| 18 | Maynard and Ritchie,[24] 2001 | US | Multi-institution | 1994-1999 | Veterans Affairs | 27,439 | 2380 | | | * |
| 19 | Mehta et al,[30] 2016 | US | Multi-institution | 2010-2011 | Society of Thoracic Surgeons (STS) | 136,362 | 14,375 | | | * |
| 20 | O'Neal et al,[29] 2014 | US | Single institution | 2002-2011 | – | 3460 | 970 | | | Self-identified |
| 21 | Pollock et al,[17] 2015 | US | Single institution | 2004-2011 | – | 6365 | 612 | | 593 | * |
| 22 | Rangrass et al,[19] 2014 | US | Multi-institution | 2007-2008 | Medicare Analysis Provider and Review | 159,043 | 9390 | | 3016 | * |
| 23 | Rumsfeld et al,[4] 2002 | US | Multi-institution | 1995-2001 | Veterans Affairs | 29,333 | 2570 | | 1525 | * |
| 24 | Smith et al,[27] 2006 | US | Multi-institution | 1993-2005 | Multi-institutional database | 1932 | 644 | | | * |

*(Continued)*

**TABLE 1. Continued**

| N of study | First author and year of publication | Country | Single vs multi-institution | Years of enrollment | Information on source of data | White patients (N) | Black patients (N) | Asian patients (N) | Hispanic Patients (N) | Race identification |
|---|---|---|---|---|---|---|---|---|---|---|
| 25 | Trivedi et al,[26] 2006 | US | Multi-institution | 1998-2001 | Healthcare Research and Quality (NIS) | 193,684 | 11,393 | | 11,393 | * |
| 26 | Yeo et al,[3] 2007 | US | Multi-institution | 2003 | California CABG Outcomes Reporting Program | 15,069 | 785 | 1772 | 2561 | * |
| 27 | Zacharias et al,[2] 2005 | US | Single institution | 1991-2003 | – | 6073 | 304 | | | * |
| 28 | Zindrou et al,[38] 2001 | UK | Single institution | 1993-1997 | – | 1458 | | 436 | | Self-identified |

*CABG*, Coronary artery bypass graft; *NIS*, National Inpatient Sample. *As reported in single/multiple institutional or national databases.

Random effect was used in all meta-analyses to obtain more conservative estimates.[14] We used the $I^2$ statistic, which estimates the percentage of total variation across studies that is due to heterogeneity rather than chance. Suggested thresholds for heterogeneity were used, with $I^2$ values of 25% to 49%, 50% to 74%, and ≥75%, indicative of low, moderate, and high heterogeneity.[15,16] For each study, median year of enrollment was obtained and changes in estimates across different eras were tested using meta-regression model (mixed-effects model). Meta-analytic estimates were computed using Review Manager (RevMan, Computer program, Version 5.2; The Nordic Cochrane Centre, The Cochrane Collaboration, 2012, Copenhagen, Denmark) and meta R package (R Core Team, 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria; https://www.R-project.org/).

## RESULTS

### Study Selection

A total of 1362 references were identified through electronic database searches and references lists. After exclusion of duplicate or irrelevant references, 45 potentially relevant articles were retrieved. After detailed evaluation of these articles, 28 studies were selected for analysis.[2-6,16-38] (Figure 1). Study overview, patients' characteristics, and severity of coronary artery disease are reported in Table 1, Table 2, and Table E1, respectively. A total of 21 studies reported on hospital mortality in black (n = 222,892) versus white (n = 3,884,043) patients, 7 studies reported on Hispanic (n = 91,256) versus white (n = 1,458,524) patients, and 9 studies reported on Asian (n = 27,820) versus white (n = 1,081,642) patients. Of the 9 studies that reported on Asian patients, 5 studies reported on South Asians, 1 study reported on South Asians and Chinese, and 3 studies did not distinguish between the different Asian ethnicities. Fully adjusted estimates including patient-level and hospital-level covariates were reported by 12 studies for black versus white comparison, 4 studies for Hispanic versus white comparison, and 4 studies for Asian versus white comparison. The methods and variables used in adjustment are listed in Table E2. Quality assessment of individual studies is reported in Table 3.

### Meta-Analysis

Meta-analysis of unadjusted rates (Figure 2) showed that when compared with white patients, black (unadjusted OR, 1.24; 95% CI, 1.20-1.28; $P < .001$) and Asian patients (unadjusted OR, 1.33; 95% CI, 1.05-1.69; $P = .02$) were associated with a significantly increased risk for hospital death whereas Hispanic patients presented a comparable risk (unadjusted OR, 0.98; 95% CI, 0.87-1.09; $P = .66$). This trend was confirmed when reported adjusted estimates for hospital mortality were pooled (Figure 3). When compared with white patients, adjusted risk of hospital death was significantly greater for black patients (adjusted OR, 1.25; 95% CI, 1.13-1.39; $P < .001$), and not statistically different for Asian (OR, 1.33; 95% CI, 0.99, 1.77; $P = .05$) and Hispanic patients (adjusted OR, 1.08; 95% CI, 0.94-1.23; $P = .26$).

A subgroup analysis showed that South Asian patients had greater risk of crude hospital mortality compared with white patients (unadjusted OR, 1.72; 95% CI, 1.12-2.66; $P = .01$). However, there was no difference in the risk of hospital mortality between South Asian and white patients after adjusting for possible confounding factors (adjusted OR, 1.73; 95% CI, 0.71-4.18; $P = .23$) (Figure E1).

Meta-regression (Figure 4) showed a significant trend toward lower mortality rates in most recent series in both black ($P = .02$) and white ($P = .0007$) and Asian ($P = .01$) patients but not for Hispanic patients ($P = .41$). However, as mortality rates were lower across the different races, the relative disadvantage between the study groups persisted, which may explain the lack of interaction between study period and race effect on mortality for black (unadjusted $P = .29$, adjusted $P = .09$), Asian (unadjusted $P = .15$, adjusted $P = .63$), and Hispanic (unadjusted and adjusted $P = .97$) patients.

### Postoperative Complications

For the comparison between black and white patients, several studies reported also on unadjusted rate of postoperative complication (Figure E2). Pooled estimates showed

**TABLE 2. Patients' characteristics in studies included in the meta-analysis**

| Study | Mean age, y | | | | % Female | | | | % Diabetes mellitus | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | White | Black | Asian | Hispanic | White | Black | Asian | Hispanic | White | Black | Asian | Hispanic |
| Anderson et al,[31] 2016 | | | | | | | | | | | | |
| Andrews et al,[34] 2015 | | | | | 27.10% | 42.60% | | | | | | |
| Becker and Rahimi,[6] 2006 | | | | | 28.40% | 44% | 27.70% | 31.40% | | | | |
| Bridges et al,[5] 2000 | 65 | 62 | | | 27.93% | 44.45% | | | 27.82% | 43.78% | | |
| Brister et al,[22] 2007 | 62 | | 61 | | 23.50% | | 23.60% | | 37.30% | | 39.40% | |
| Chowdhury et al,[33] 2017 | 58 | 56 | | | 10% | 21% | | | | | | |
| Cooper et al,[28] 2009 | 63 | 60 | | | 27% | 42% | | | 33.60% | 47.00% | | |
| Efird et al,[16] 2015 | 65 | 62 | | | 27.30% | 42% | | | 32.00% | 48.00% | | |
| Gasevic et al,[20] 2013 | | | | | 21% | | 18% | | 21.30% | | 31.00% | |
| Goldsmith et al,[37] 1999 | 58 | | 58 | | | | | | 11.60% | | 38.70% | |
| Gray et al,[25] 1996 | 67 | 65 | | | 21% | 35% | | | 23.00% | 36.00% | | |
| Hadjinikolaou et al,[36] 2010 | 66 | | 63 | | 19.70% | | 23% | | | | | |
| Kaila et al,[18] 2014 | | | | | 20.30% | | 21.40% | | 47.80% | | 44.40% | |
| Keeling et al,[32] 2017 | 64 | 61 | | | | | | | 37.10% | 50.30% | | |
| Kim et al,[21] 2008 | | | | | | | | | | | | |
| Konety et al,[23] 2005 | 74 | 72 | | | 34.40% | 51.40% | | | 8.30% | 18.40% | | |
| Lucas et al,[35] 2006 | | | | | 34.30% | 51.50% | | | | | | |
| Maynard and Ritchie,[24] 2001 | 64 | 63 | | | 1% | 1% | | | 30.00% | 34.00% | | |
| Mehta et al,[30] 2016 | 66 | 62 | | | 25.30% | 40.40% | | | 39.10% | 53.00% | | |
| O'Neal et al,[29] 2014 | 64 | 61 | | | 25% | 38% | | | 37.20% | 50.00% | | |
| Pollock et al,[17] 2015 | 65 | 62 | | 61 | 23.70% | 44% | | 27.50% | 37.10% | 46.60% | | 61.20% |
| Rangrass et al,[19] 2014 | 74 | | | | 30.50% | | | | 29.30% | | | |
| Rumsfeld et al,[4] 2002 | 63.6 | 62.2 | | 63.8 | 1.10% | 1.10% | | 0.50% | 31.40% | 38.10% | | 47.80% |
| Smith et al,[27] 2006 | 64.6 | 63.7 | | | 28.60% | 45.70% | | | 30.40% | 47.20% | | |
| Trivedi et al,[26] 2006 | | | | | | | | | | | | |
| Yeo et al,[3] 2007 | 66.91 | 63.17 | 65.6 | 64.02 | 25% | 43% | 27% | 31% | 33.00% | 49.00% | 47.00% | 56% |
| Zacharias et al,[2] 2005 | 64 | 62 | | | 29.80% | 46.10% | | | 32.40% | 43.40% | | |
| Zindrou et al,[38] 2001 | 61.6 | | 59.6 | | 15.98% | | 19.70% | | 17.50% | | 43.00% | |

that rate for stroke (unadjusted OR, 1.78; 95% CI, 1.49-2.13; $P < .001$), bleeding (unadjusted OR, 1.24; 95% CI, 1.09-1.41), tracheostomy/reintubation (unadjusted OR, 1.37; 95% CI, 1.15-1.61; $P = .0003$), and renal failure (adjusted OR, 1.54; 95% CI, 1.38-1.73; $P < .001$) but not wound infection (OR, 1.16; 95% CI, 0.98-1.36; $P = .09$) were greater among black patients.

## DISCUSSION

In the present study, we investigated the effect of race by performing a meta-analysis and meta-regression of comparative studies available. We showed that black race was associated with increased mortality rates when compared with white race also after adjusting for patient-level and hospital-level factors. We also showed that despite the fact that mortality rates declined over the years for black patients, a specular reduction in mortality was observed for white patients. Therefore, the gap between black and white patients remained stable. Black race was also shown to be associated with significant increased risk of postoperative complications, including bleeding, stroke, renal failure/dialysis, and respiratory failure/tracheostomy. Although not statistically significant, there was a strong trend toward an increased risk of mortality in Asian when compared with white subjects ($P = .05$). In contrast, Hispanic patients were consistently found to have mortality rates comparable with those observed in white patients without significant changes across different eras.

TABLE 3. Study quality assessment using Newcastle Ottawa Scale

| Study | Selection | Comparability | Exposure | Sum |
|---|---|---|---|---|
| Anderson et al,[31] 2016 | 4 | 2 | 3 | 9 |
| Andrews et al,[34] 2015 | 4 | 2 | 3 | 9 |
| Becker and Rahimi,[6] 2006 | 4 | 0 | 3 | 7 |
| Bridges et al,[5] 2000 | 4 | 0 | 3 | 7 |
| Brister et al,[22] 2007 | 4 | 2 | 3 | 9 |
| Chowdhury et al,[33] 2017 | 4 | 0 | 3 | 7 |
| Cooper et al,[28] 2009 | 4 | 2 | 3 | 9 |
| Efird et al,[16] 2015 | 4 | 0 | 3 | 7 |
| Gasevic et al,[20] 2013 | 4 | 0 | 3 | 7 |
| Goldsmith et al,[37] 1999 | 4 | 0 | 3 | 7 |
| Gray et al,[25] 1996 | 4 | 2 | 3 | 9 |
| Hadjinikolaou et al,[36] 2010 | 4 | 0 | 3 | 7 |
| Kaila et al,[18] 2014 | 4 | 2 | 3 | 9 |
| Keeling et al,[32] 2017 | 4 | 2 | 3 | 9 |
| Kim et al,[21] 2008 | 4 | 2 | 3 | 9 |
| Konety et al,[23] 2005 | 4 | 2 | 3 | 9 |
| Lucas et al,[35] 2006 | 4 | 2 | 3 | 9 |
| Maynard and Ritchie,[24] 2001 | 4 | 2 | 3 | 9 |
| Mehta et al,[30] 2016 | 4 | 2 | 3 | 9 |
| O'Neal et al,[29] 2014 | 4 | 0 | 3 | 7 |
| Pollock et al,[17] 2015 | 4 | 0 | 3 | 7 |
| Rangrass et al,[19] 2014 | 4 | 2 | 3 | 9 |
| Rumsfeld et al,[4] 2002 | 4 | 2 | 3 | 9 |
| Smith et al,[27] 2006 | 4 | 0 | 3 | 7 |
| Trivedi et al,[26] 2006 | 4 | 2 | 3 | 9 |
| Yeo et al,[3] 2007 | 4 | 0 | 3 | 7 |
| Zacharias et al,[2] 2005 | 4 | 2 | 3 | 9 |
| Zindrou et al,[38] 2001 | 4 | 0 | 3 | 7 |

Despite several studies that have suggested ethnic disparities in operative outcomes following CABG,[5,6] final conclusions are still lacking, and current CABG guidelines and risk stratification systems including the Society of Thoracic Surgeons scoring system (http://riskcalc.sts.org/stswebriskcalc/)[8] and the European System for Cardiac Operative Risk Evaluation (http://www.euroscore.org/)[9] make no differentiation by race in terms of operative mortality. The present study consistently demonstrated that black patients remain associated with a greater operative mortality, although this disparity was found to be relevant only among male patients.

There are a number of possible explanations for these persistent differences in outcomes between the different racial groups. First, it is well documented that disparities in access to health care system persist by race and black patients are likely to be referred to surgery with poorer health conditions.[39,40] Although the present National Inpatient Sample analysis and meta-analysis controlled for many more patient, organizational, and socioeconomic aspects of CABG patients' condition, there still may be other unmeasured social phenomena of the patient's background, health condition, or hospital stay that may help explain racial/ethnic differences. In addition, many aspects of the physician–patient relationship that involve patients' education, trust, and the physician's sensitivity to a patient's culture might also play a critical role.[40] Finally, others have identified genetic differences in race/ethnicity that could account for differences in outcomes. For patients with heart disease, some studies have suggested subtle differences among race/ethnicities in the biology of hypertension. Potential differences in the biology of hypertension may result in more frequent and more severe hypertension and ventricular hypertrophy in black patients.[41]

The present meta-analysis presents several limitations. The vast majority of the included studies did not mention the definitions used for race identification, a factor that may have influenced the results. Although we performed a risk-adjusted analysis, we cannot exclude the presence of residual confounding factors accounting for differences in outcomes between ethnic groups, which may have not been considered by individual studies. In particular, data on predicted risk of mortality (ie, SYNTAX score) were not provided in most of the studies. Moreover, detailed information on patients' socioeconomic status and surgeon and hospital volume were limited. The study focused primarily on operative mortality and did not compare the differences in long-term outcomes between the different race groups. Most of the series included in the present analysis were from US databases, and this might partially limit the generalizability of the present findings. In addition, despite we attempt to avoid cohort overlapping among different studies, we cannot exclude that different US nationwide databases might have reported on similar study populations. Finally, we acknowledge the difficulties and uncertainties that may sometimes be associated with defining individual patients' ethnicities, particularly for those residing in North America, where the population diversity may lead to racial mixing.

In conclusion, the present meta-analysis confirmed that despite progress is being made in lowering in-hospital mortality rates among the major racial/ethnic groups including black patients, significant disparities in outcomes still remain that warrant further investigation.


### Conflict of Interest Statement

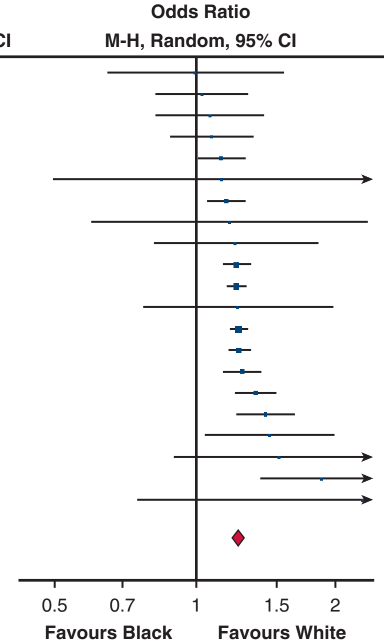
Authors have nothing to disclose with regard to commercial support.

## Black vs white

| Study or Subgroup | Black Events | Black Total | White Events | White Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Yeo 2007 | 22 | 785 | 422 | 15069 | 0.5% | 1.00 [0.65, 1.55] |
| Maynard 2001 | 86 | 2380 | 960 | 27439 | 1.7% | 1.03 [0.83, 1.29] |
| Efird 2015 | 68 | 2379 | 303 | 11395 | 1.2% | 1.08 [0.82, 1.41] |
| Rumsfeld 2002 | 107 | 2750 | 1056 | 29333 | 2.0% | 1.08 [0.89, 1.33] |
| Mehta 2015 | 331 | 14375 | 2757 | 136362 | 5.4% | 1.14 [1.02, 1.28] |
| Gray 1996 | 6 | 115 | 143 | 3113 | 0.1% | 1.14 [0.49, 2.65] |
| Trivedi 2006 | 490 | 11393 | 7166 | 193684 | 7.4% | 1.17 [1.07, 1.28] |
| Zacharias 2005 | 9 | 304 | 152 | 6073 | 0.2% | 1.19 [0.60, 2.35] |
| Anderson 2016 | 26 | 975 | 315 | 14389 | 0.5% | 1.22 [0.82, 1.84] |
| Bridges 2000 | 991 | 25850 | 17456 | 555939 | 11.8% | 1.23 [1.15, 1.31] |
| Lucas 2006 | 2229 | 33367 | 45597 | 829037 | 16.9% | 1.23 [1.18, 1.29] |
| Pollok 2015 | 20 | 612 | 169 | 6365 | 0.4% | 1.24 [0.77, 1.98] |
| Becker 2006 | 2118 | 63991 | 27889 | 1040641 | 16.6% | 1.24 [1.19, 1.30] |
| Konety 2005 | 1559 | 24354 | 29473 | 566785 | 14.6% | 1.25 [1.18, 1.31] |
| Andrews 2015 | 538 | 15534 | 5367 | 194440 | 7.8% | 1.26 [1.15, 1.38] |
| Rangrass 2014 | 438 | 9390 | 5567 | 159043 | 6.8% | 1.35 [1.22, 1.49] |
| Kim 2008 | 233 | 8462 | 1241 | 63487 | 3.8% | 1.42 [1.23, 1.64] |
| Keeling 2016 | 50 | 2810 | 168 | 13569 | 0.9% | 1.45 [1.05, 1.99] |
| Smith 2006 | 22 | 644 | 44 | 1932 | 0.3% | 1.52 [0.90, 2.55] |
| Cooper 2009 | 57 | 2033 | 195 | 12841 | 1.0% | 1.87 [1.39, 2.52] |
| Chowdhury 2016 | 4 | 389 | 14 | 3107 | 0.1% | 2.30 [0.75, 7.01] |
| **Total (95% CI)** | | **222892** | | **3884043** | **100.0%** | **1.24 [1.20, 1.28]** |
| Total events | 9404 | | 146454 | | | |

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 26.29$, df = 20 ($P = .16$); $I^2 = 24\%$

Test for overall effect: Z = 14.02 ($P < .00001$)



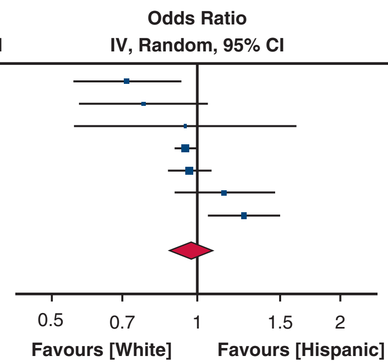

A

## Hispanic vs white

| Study or Subgroup | Hispanic Events | Hispanic Total | White Events | White Total | Weight | Odds Ratio IV, Random, 95% CI |
|---|---|---|---|---|---|---|
| Anderson 2016 | 73 | 4614 | 315 | 14389 | 11.0% | 0.72 [0.56, 0.93] |
| Rumsfeld 2002 | 43 | 1525 | 1056 | 29333 | 8.6% | 0.78 [0.57, 1.06] |
| Pollok 2015 | 15 | 593 | 169 | 6365 | 3.6% | 0.95 [0.56, 1.62] |
| Becker 2006 | 1729 | 67554 | 27889 | 1040641 | 26.3% | 0.95 [0.91, 1.00] |
| Trivedi 2006 | 410 | 11393 | 7166 | 193684 | 22.4% | 0.97 [0.88, 1.08] |
| Yeo 2007 | 82 | 2561 | 422 | 15069 | 11.9% | 1.15 [0.90, 1.46] |
| Rangrass 2014 | 132 | 3016 | 5567 | 159043 | 16.1% | 1.26 [1.06, 1.51] |
| **Total (95% CI)** | | **91256** | | **1458524** | **100.0%** | **0.98 [0.87, 1.09]** |
| Total events | 2484 | | 42584 | | | |

Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 18.08$, df = 6 ($P = .006$); $I^2 = 67\%$

Test for overall effect: Z = 0.45 ($P = .66$)



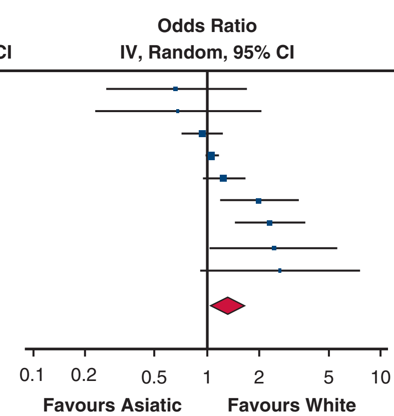

B

## Asiatic vs white

| Study or Subgroup | Asiatic Events | Asiatic Total | White Events | White Total | Weight | Odds Ratio IV, Random, 95% CI |
|---|---|---|---|---|---|---|
| Gasevic 2013 | 5 | 180 | 62 | 1507 | 5.2% | 0.67 [0.26, 1.68] |
| Kaila 2014 | 4 | 252 | 17 | 737 | 4.0% | 0.68 [0.23, 2.05] |
| Anderson 2016 | 66 | 3196 | 315 | 14389 | 17.6% | 0.94 [0.72, 1.23] |
| Becker 2006 | 584 | 20353 | 27889 | 1040641 | 21.9% | 1.07 [0.99, 1.17] |
| Yeo 2007 | 62 | 1772 | 422 | 15069 | 17.5% | 1.26 [0.96, 1.65] |
| Zindrou 2001 | 24 | 436 | 41 | 1458 | 11.1% | 2.01 [1.20, 3.37] |
| Brister 2007 | 29 | 1163 | 55 | 5028 | 12.5% | 2.31 [1.47, 3.64] |
| Hadjinikolaou 2010 | 7 | 274 | 28 | 2623 | 6.0% | 2.43 [1.05, 5.62] |
| Goldsmith 1999 | 13 | 194 | 5 | 190 | 4.2% | 2.66 [0.93, 7.61] |
| **Total (95% CI)** | | **27820** | | **1081642** | **100.0%** | **1.33 [1.05, 1.69]** |
| Total events | 794 | | 28834 | | | |

Heterogeneity: $Tau^2 = 0.07$; $Chi^2 = 25.95$, df = 8 ($P = .001$); $I^2 = 69\%$

Test for overall effect: Z = 2.33 ($P = .02$)



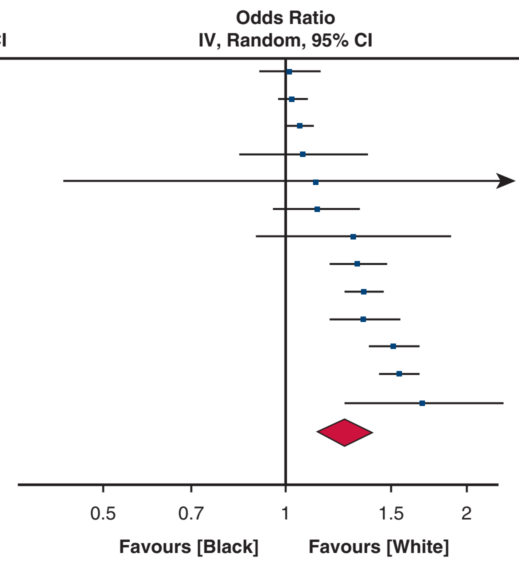

C

**FIGURE 2.** Meta-analytic unadjusted estimates of race effect on operative mortality (white as reference). *M-H*, Mantel-Haenszel; *CI*, confidence interval; *IV*, inverse variance.

## Black vs white

| Study or Subgroup | log [Odds Ratio] | SE | Weight | Odds Ratio IV, Random, 95% CI |
|---|---|---|---|---|
| Maynard 2001 | 0.0198 | 0.0582 | 8.9% | 1.02 [0.91, 1.14] |
| Konety 2005 | 0.0296 | 0.0306 | 9.7% | 1.03 [0.97, 1.09] |
| Lucas 2006 | 0.0583 | 0.0247 | 9.8% | 1.06 [1.01, 1.11] |
| Rumsfeld 2002 | 0.0677 | 0.1235 | 6.5% | 1.07 [0.84, 1.36] |
| Zacharias 2005 | 0.1212 | 0.4929 | 1.1% | 1.13 [0.43, 2.97] |
| Trivedi 2006 | 0.1222 | 0.0832 | 8.0% | 1.13 [0.96, 1.33] |
| Keeling 2016 | 0.2624 | 0.1876 | 4.5% | 1.30 [0.90, 1.88] |
| Rangrass 2014 | 0.2776 | 0.0529 | 9.1% | 1.32 [1.19, 1.46] |
| Becker 2006 | 0.3001 | 0.0352 | 9.6% | 1.35 [1.26, 1.45] |
| Mehta 2015 | 0.3001 | 0.0687 | 8.6% | 1.35 [1.18, 1.54] |
| Andrews 2015 | 0.4147 | 0.0464 | 9.3% | 1.51 [1.38, 1.66] |
| Becker 2006 | 0.4383 | 0.0376 | 9.5% | 1.55 [1.44, 1.67] |
| Cooper 2009 | 0.5247 | 0.1539 | 5.5% | 1.69 [1.25, 2.28] |
| **Total (95% CI)** | | | **100.0%** | **1.25 [1.13, 1.39]** |

Heterogeneity: $Tau^2 = 0.03$; $Chi^2 = 153.11$, df = 12 ($P < .00001$); $I^2 = 92\%$
Test for overall effect: Z = 4.22 ($P < .0001$)

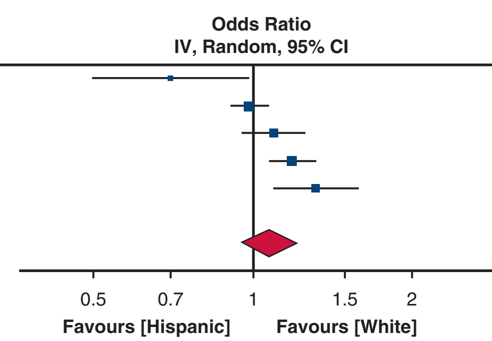



**A**

## Hispanic vs white

| Study or Subgroup | log [Odds Ratio] | SE | Weight | Odds Ratio IV, Random, 95% CI |
|---|---|---|---|---|
| Rumsfeld 2002 | −0.3567 | 0.1717 | 10.1% | 0.70 [0.50, 0.98] |
| Becker 2006 | −0.0101 | 0.043 | 25.3% | 0.99 [0.91, 1.08] |
| Trivedi 2006 | 0.0953 | 0.0695 | 21.7% | 1.10 [0.96, 1.26] |
| Becker 2006 | 0.174 | 0.0495 | 24.5% | 1.19 [1.08, 1.31] |
| Rangrass 2014 | 0.2776 | 0.093 | 18.4% | 1.32 [1.10, 1.58] |
| **Total (95% CI)** | | | **100.0%** | **1.08 [0.94, 1.23]** |

Heterogeneity: $Tau^2 = 0.02$; $Chi^2 = 19.03$, df = 4 ($P = .0008$); $I^2 = 79\%$
Test for overall effect: Z = 1.11 ($P = .26$)

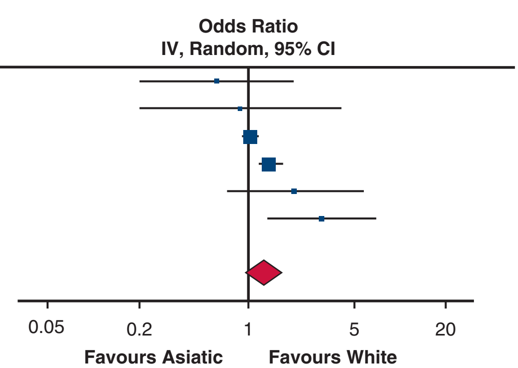



**B**

## Asiatic vs white

| Study or Subgroup | log [Odds Ratio] | SE | Weight | Odds Ratio IV, Random, 95% CI |
|---|---|---|---|---|
| Gasevic 2013 | −0.4463 | 0.5935 | 5.4% | 0.64 [0.20, 2.05] |
| Gasevic 2013 | −0.0943 | 0.773 | 3.4% | 0.91 [0.20, 4.14] |
| Becker 2006 | 0.0583 | 0.0613 | 38.4% | 1.06 [0.94, 1.20] |
| Becker 2006 | 0.3507 | 0.0859 | 36.1% | 1.42 [1.20, 1.68] |
| Hadjinikolaou 2010 | 0.72 | 0.52 | 6.7% | 2.05 [0.74, 5.69] |
| Brister 2007 | 1.1314 | 0.4056 | 10.0% | 3.10 [1.40, 6.86] |
| **Total (95% CI)** | | | **100.0%** | **1.33 [0.99, 1.77]** |

Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 15.68$, df = 5 ($P = .0008$); $I^2 = 68\%$
Test for overall effect: Z = 1.92 ($P = .05$)




**C**

**FIGURE 3.** Meta-analytic risk-adjusted estimates of race effect on operative mortality (white as reference). *SE*, Standard error; *IV*, inverse variance; *CI*, confidence interval.

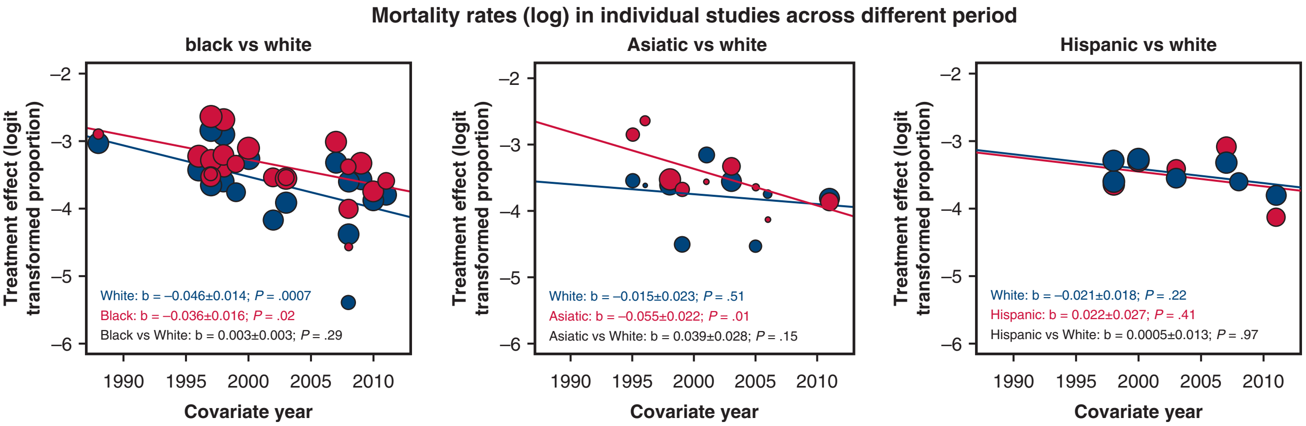



**FIGURE 4.** Meta-regression of crude mortality rate in separate ethnical groups and race effect on mortality across different study periods (median year of enrollment).

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**Key Words:** coronary artery bypass grafting, outcomes, meta-analysis, ethnicity, mortality



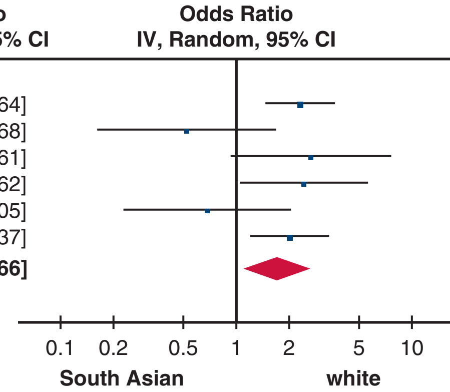
ORIGINAL SUBMISSION: Functional Evaluation of the Myocardial Ischemia After Coronary Artery Bypass Surgery Using Coronary Flow Velocity Reserve in Left Ventricular Hypertrophy. Kentaro Honda. Semin Thoracic Surg 2018: In press

Unadjusted risk of mortality

| Study or Subgroup | Asiatic Events | Asiatic Total | White Events | White Total | Weight | Odds Ratio IV, Random, 95% CI |
|---|---|---|---|---|---|---|
| **South Asian vs white** | | | | | | |
| Brister 2007 | 29 | 1163 | 55 | 5028 | 8.8% | 2.31 [1.47, 3.64] |
| Gasevic 2013 | 3 | 137 | 62 | 1507 | 3.0% | 0.52 [0.16, 1.68] |
| Goldsmith 1999 | 13 | 194 | 5 | 190 | 3.5% | 2.66 [0.93, 7.61] |
| Hadjinikolaou 2010 | 7 | 274 | 28 | 2623 | 4.8% | 2.43 [1.05, 5.62] |
| Kaila 2014 | 4 | 252 | 17 | 737 | 3.3% | 0.68 [0.23, 2.05] |
| Zindrou 2001 | 24 | 436 | 41 | 1458 | 8.0% | 2.01 [1.20, 3.37] |
| **Total (95% CI)** | | **2456** | | **11543** | **31.3%** | **1.72 [1.12, 2.66]** |
| Total events | 80 | | 208 | | | |

Heterogeneity: $Tau^2 = 0.13$; $Chi^2 = 9.49$, df = 5 ($P = .09$); $I^2 = 47\%$

Test for overall effect: Z = 2.47 ($P = .01$)




Adjusted risk of mortality

| Study or Subgroup | log [Odds Ratio] | SE | Weight | Odds Ratio IV, Random, 95% CI |
|---|---|---|---|---|
| **South Asian vs white** | | | | |
| Gasevic 2013 | −0.4463 | 0.5935 | 5.0% | 0.64 [0.20, 2.05] |
| Hadjinikolaou 2010 | 0.72 | 0.52 | 6.2% | 2.05 [0.74, 5.69] |
| Brister 2007 | 1.1314 | 0.4056 | 9.0% | 3.10 [1.40, 6.86] |
| **Total (95% CI)** | | | **20.3%** | **1.73 [0.71, 4.18]** |

Heterogeneity: $Tau^2 = 0.36$; $Chi^2 = 4.84$, df = 2 ($P = .09$); $I^2 = 59\%$

Test for overall effect: Z = 1.21 ($P = .23$)

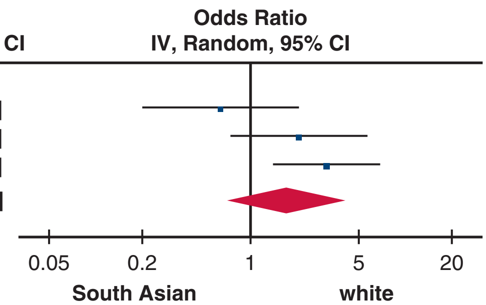
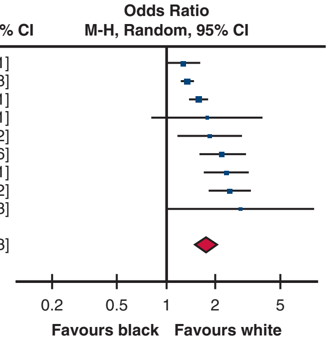



**FIGURE E1.** Meta-analytic unadjusted and adjusted risk of operative mortality in South Asian compared with white patients. *IV*, inverse variance; *CI*, confidence interval; *SE*, standard error.

## Stroke

| Study or Subgroup | Black Events | Black Total | White Events | White Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Rumsfeld 2002 | 80 | 2750 | 675 | 29333 | 14.1% | 1.27 [1.01, 1.61] |
| Bridges 2000 | 566 | 25850 | 9006 | 555939 | 18.0% | 1.36 [1.25, 1.48] |
| Mehta 2015 | 255 | 14375 | 1536 | 136362 | 16.9% | 1.59 [1.39, 1.81] |
| Zacharias 2005 | 7 | 304 | 79 | 6073 | 4.0% | 1.79 [0.82, 3.91] |
| Anderson 2016 | 22 | 975 | 176 | 14389 | 8.5% | 1.86 [1.19, 2.92] |
| Cooper 2009 | 52 | 2033 | 150 | 12841 | 11.7% | 2.22 [1.61, 3.06] |
| Efird 2015 | 60 | 2379 | 124 | 11395 | 11.9% | 2.35 [1.72, 3.21] |
| Keeling 2016 | 67 | 2810 | 133 | 13569 | 12.3% | 2.47 [1.83, 3.32] |
| Chowdhury 2016 | 5 | 389 | 14 | 3107 | 2.6% | 2.88 [1.03, 8.03] |
| Total (95% CI) | | 51865 | | 783008 | 100.0% | 1.78 [1.49, 2.13] |
| Total events | 1114 | | 11893 | | | |

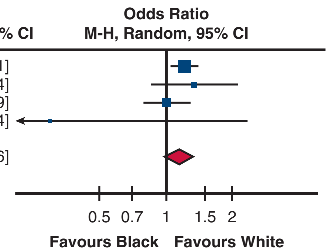
Heterogeneity: $Tau^2 = 0.04$; $Chi^2 = 34.79$, df = 8 ($P < .0001$); $I^2 = 77\%$
Test for overall effect: Z = 6.37 ($P < .00001$)




## Wound infection

| Study or Subgroup | Black Events | Black Total | White Events | White Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Bridges 2000 | 202 | 25850 | 3558 | 555939 | | 1.22 [1.06, 1.41] |
| Efird 2015 | 24 | 2379 | 85 | 11395 | | 1.36 [0.86, 2.14] |
| Mehta 2015 | 71 | 14375 | 668 | 136362 | | 1.01 [0.79, 1.29] |
| Smith 2006 | 1 | 644 | 10 | 1932 | | 0.30 [0.04, 2.34] |
| Total (95% CI) | | 43248 | | 705628 | | 1.16 [0.98, 1.36] |
| Total events | 298 | | 4321 | | | |

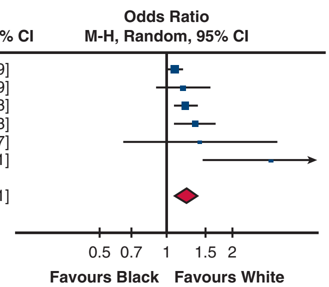
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 3.89$, df = 3 ($P = .27$); $I^2 = 23\%$
Test for overall effect: Z = 1.72 ($P = .09$)




## Bleeding

| Study or Subgroup | Black Events | Black Total | White Events | White Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Bridges 2000 | 650 | 25850 | 12731 | 555939 | 33.3% | 1.10 [1.02, 1.19] |
| Keeling 2016 | 62 | 2810 | 251 | 13569 | 13.7% | 1.20 [0.90, 1.59] |
| Mehta 2015 | 316 | 14375 | 2454 | 136362 | 28.9% | 1.23 [1.09, 1.38] |
| Rumsfeld 2002 | 96 | 2750 | 763 | 29333 | 18.5% | 1.35 [1.09, 1.68] |
| Smith 2006 | 9 | 644 | 19 | 1932 | 2.5% | 1.43 [0.64, 3.17] |
| Zacharias 2005 | 9 | 304 | 61 | 6073 | 3.1% | 3.01 [1.48, 6.11] |
| Total (95% CI) | | 46733 | | 743208 | 100.0% | 1.24 [1.09, 1.41] |
| Total events | 1142 | | 16279 | | | |

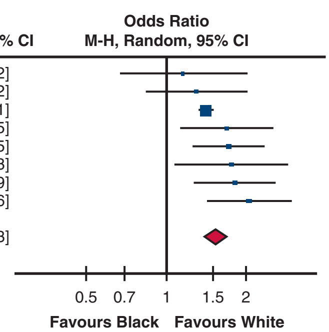
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 11.70$, df = 5 ($P = .04$); $I^2 = 57\%$
Test for overall effect: Z = 3.24 ($P = .001$)




## Renal Failure/Dialysis

| Study or Subgroup | Black Events | Black Total | White Events | White Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Zacharias 2005 | 14 | 304 | 242 | 6073 | 3.9% | 1.16 [0.67, 2.02] |
| O'Neal 2014 | 28 | 970 | 77 | 3460 | 6.0% | 1.31 [0.84, 2.02] |
| Bridges 2000 | 1113 | 25850 | 17067 | 555939 | 50.2% | 1.42 [1.34, 1.51] |
| Chowdhury 2016 | 30 | 389 | 146 | 3107 | 6.8% | 1.69 [1.13, 2.55] |
| Rumsfeld 2002 | 47 | 2750 | 293 | 29333 | 10.9% | 1.72 [1.26, 2.35] |
| Efird 2015 | 22 | 2379 | 60 | 11395 | 4.9% | 1.76 [1.08, 2.88] |
| Keeling 2016 | 43 | 2810 | 115 | 13569 | 8.8% | 1.82 [1.28, 2.59] |
| Smith 2006 | 52 | 644 | 79 | 1932 | 8.4% | 2.06 [1.43, 2.96] |
| Total (95% CI) | | 36096 | | 624808 | 100.0% | 1.54 [1.38, 1.73] |
| Total events | 1349 | | 18079 | | | |

Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 8.78$, df = 7 ($P = .27$); $I^2 = 20\%$
Test for overall effect: Z = 7.51 ($P < .00001$)




## Prolonged ventilation/Tracheostomy

| Study or Subgroup | Black Events | Black Total | White Events | White Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| O'Neal 2014 | 9 | 970 | 43 | 3460 | 4.4% | 0.74 [0.36, 1.53] |
| Mehta 2015 | 1585 | 14375 | 12933 | 136362 | 22.7% | 1.18 [1.12, 1.25] |
| Zacharias 2005 | 24 | 304 | 394 | 6073 | 9.2% | 1.24 [0.80, 1.90] |
| Rumsfeld 2002 | 231 | 2750 | 1966 | 29333 | 19.9% | 1.28 [1.11, 1.47] |
| Bridges 2000 | 2053 | 25850 | 33634 | 555939 | 22.9% | 1.34 [1.28, 1.40] |
| Keeling 2016 | 439 | 2810 | 1117 | 13569 | 20.9% | 2.06 [1.83, 2.32] |
| Total (95% CI) | | 47059 | | 744736 | 100.0% | 1.37 [1.15, 1.61] |
| Total events | 4341 | | 50087 | | | |

Heterogeneity: $Tau^2 = 0.03$; $Chi^2 = 72.73$, df = 5 ($P < .00001$); $I^2 = 93\%$
Test for overall effect: Z = 3.64 ($P = .0003$)

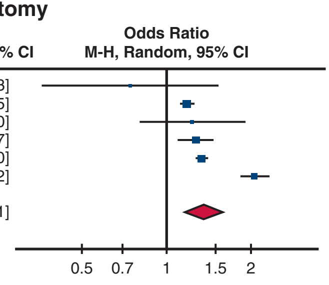



**FIGURE E2.** Meta-analytic estimates of unadjusted effect of black vs white race on postoperative complications. *M-H*, Mantel-Haenszel; *CI*, confidence interval.

**TABLE E1. Severity of coronary artery disease in studies included in the meta-analysis**

| | EF, % | | | | | | Triple-vessel disease, % | | | | | Left main coronary artery disease, % | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study | EF expressed as | White | Black | Asian | South Asian | Hispanic | White | Black | Asian | South Asian | Hispanic | White | Black | Asian | South Asian | Hispanic |
| Anderson et al,[31] 2016 | | | | | | | | | | | | | | | | |
| Andrews et al,[34] 2015 | | | | | | | | | | | | | | | | |
| Becker and Rahimi,[6] 2006 | | | | | | | | | | | | | | | | |
| Bridges et al,[5] 2000 | Mean (SD) | 51% (14) | 48% (14) | | | | 70% | 69% | | | | 20% | 19% | | | |
| Brister et al,[22] 2007 | | | | | | | 76% | | | 79% | | 22% | | | 8% | |
| Chowdhury et al,[33] 2017 | | | | | | | | | | | | | | | | |
| Cooper et al,[28] 2009 | Mean | 50% | 49% | | | | | | | | | 23% | 20% | | | |
| Efird et al,[16] 2015 | | | | | | | 66% | 68% | | | | 21% | 21% | | | |
| Gasevic et al,[20] 2013 | | | | | | | 28% | | 28% | 27% | | 3% | | 5% | 3% | |
| Goldsmith et al,[37] 1999 | Good EF | 52% | | | 56% | | 63% | | | 66% | | | | | | |
| Gray et al,[25] 1996 | | | | | | | 64% | 68% | | | | 24% | 22% | | | |
| Hadjinikolaou et al,[36] 2010 | EF ≥ 30% | 93% | | | 95% | | | | | | | | | | | |
| Kaila et al,[18] 2014 | EF >35% | 72% | | | 68% | | | | | | | 7% | | | 6% | |
| Keeling et al,[32] 2017 | Mean (SD) | 52% (12) | 50% (13) | | | | | | | | | | | | | |
| Kim et al,[21] 2008 | | | | | | | | | | | | | | | | |
| Konety et al,[23] 2005 | | | | | | | | | | | | | | | | |
| Lucas et al,[35] 2006 | | | | | | | | | | | | | | | | |
| Maynard and Ritchie,[24] 2001 | | | | | | | | | | | | | | | | |
| Mehta et al,[30] 2016 | Median | 55% | 53% | | | | 95% | 94% | | | | 32% | 29% | | | |
| O'Neal et al,[29] 2014 | | | | | | | 67% | 68% | | | | 26% | 27% | | | |
| Pollock et al,[17] 2015 | Mean (SD) | 49% (14) | 47% (16) | | | 47% (14) | | | | | | 29% | 28% | | | 29% |
| Rangrass et al,[19] 2014 | | | | | | | | | | | | | | | | |
| Rumsfeld et al,[4] 2002 | EF >35% | 89% | 87% | | | 88% | 72% | 73% | | | 76% | | | | | |
| Smith et al,[27] 2006 | EF >40% | 78% | 75% | | | | | | | | | | | | | |
| Trivedi et al,[26] 2006 | | | | | | | | | | | | | | | | |
| Yeo et al,[3] 2007 | EF >30% | 92% | 89% | | | 89% | 77% | 77% | | | 78% | 24% | 23% | | | **23**% |
| Zacharias et al,[2] 2005 | Mean (SD) | 50% (11) | 49% (12) | | | | 72% | 73% | | | | 19% | 18% | | | |
| Zindrou et al,[38] 2001 | EF >35% | 88% | | | 85% | | | | | | | 1% | | | 1% | |

*EF*, Ejection fraction; *SD*, standard deviation.

**TABLE E2. Methods and variables used in adjusting for hospital mortality**

| Study | Adjustment methods | Adjustment variables: Patient-level factors | Adjustment variables: Hospital-level factors |
|---|---|---|---|
| Anderson et al,[31] 2016 | Logistic regression analysis | Age, age–sex interaction, sex | All patient-refined DRG |
| Becker and Rahimi,[6] 2006 | Logistic regression analysis | Admission type, sex, insurance status, procedure characteristics, SES, smoking, year of procedure, cardiomyopathy, COPD, CHF, CLD, CRF, CVD, dysrhythmias, DM, HD, HTN, MI, obesity, previous CABG, PVD, RF, unstable angina, valve disease | |
| Brister et al,[22] 2007 | Logistic regression analysis | Age, EF, HTN, and unstable angina | |
| Cooper et al,[28] 2009 | Logistic regression analysis | Age, anticoagulants, beta blockers, BMI, BSA, diuretics, EF, sex, height, IABP, immunosuppressive therapy, inotropes, nitrates, last creatinine level, resuscitation, smoking, status, weight, cardiogenic shock, COPD, CVA, CVD, DM, HD, HF, HLD, HTN, left main disease, MI, number of diseased vessels, PVD, RF | |
| Gasevic et al,[20] 2013 | Logistic regression analysis | Age, distance from nearest hospital, sex, SES, time from MI to revascularization, arrhythmia, ARF, cancer, cardiogenic shock, CHF, CRF, CVD, DM, severity of CAD | |
| Hadjinikolaou et al,[36] 2010 | Logistic regression analysis | BMI, logistic EuroSCORE, DM, previous PCI | |
| Keeling et al,[32] 2017 | Logistic regression analysis | Age, creatinine level, EF, sex, height, IABP, immunosuppressive therapy, resuscitation, single/multiple graft, status, weight, angina, arrhythmia, cardiogenic shock, COPD, CVD, DM, endocarditis, HF, HTN, MI, PAD, previous CV intervention, RF, valve disease | |
| Konety et al,[23] 2005 | Logistic regression analysis | Admission priority, age, sex, SES, year of surgery, DM, CAD, CHF, COPD, CRF, CVD, HTN, PVD, previous CABG or PCI | |
| Lucas et al,[35] 2006 | Logistic regression analysis | Age, sex, SES, urgency of admission, year of operation, Charlson comorbidity score | Hospital volume, clustering by hospital |
| Maynard and Ritchie,[24] 2001 | Logistic regression analysis | Age, IMA grafting, Deyo score, COPD, DM, HTN, MI | |
| Mehta et al,[30] 2016 | Logistic regression analysis | Patient characteristics, surgeon, SES | Hospital identity |
| Rangrass et al,[19] 2014 | Logistic regression analysis | Age, emergency admission, sex, SES, Elixhauser comorbidity index | Hospital quality |
| Rumsfeld et al,[4] 2002 | Logistic regression analysis | Age, BSA, EF, sex, IMA graft use, number of anastomoses, preoperative ECG, preoperative diuretics and IV nitroglycerin, preoperative IABP, priority of surgery, serum creatinine, smoking, CAD, COPD, CVD, DM, HTN, MI, NYHA class, preoperative mortality risk, previous heart surgery, previous PCI, PVD, 3-vessel CAD | |
| Trivedi et al,[26] 2006 | Logistic regression analysis | Age, sex, urgency of admission, COPD, CHF, DM, Elixhauser comorbidity index, PVD, HTN, MI | Hospital volume and clustering by hospital |
| Zacharias et al,[2] 2005 | Logistic regression analysis | Age, beta blockers, BSA, EF, sex, insurance status, preoperative IABP, priority of procedure, procedure characteristics, SES, smoking, arrhythmia, CHF, CVA, CVD, COPD, DM, double vessel disease, HLD, HTN, left main disease, MI, NYHA class, obesity, PVD, RF, triple-vessel disease, unstable angina. | |

*DRG*, Diagnosis-Related Group; *SES*, socioeconomic status; *COPD*, chronic obstructive pulmonary disease; *CHF*, congestive heart failure; *CLD*, chronic liver disease; *CRF*, chronic renal failure; *CVD*, cerebrovascular disease; *DM*, diabetes mellitus; *HD*, hemodialysis; *HTN*, hypertension; *MI*, myocardial infarction; *CABG*, coronary artery bypass graft; *PVD*, peripheral vascular disease; *RF*, renal failure; *EF*, ejection fraction; *BMI*, body mass index; *BSA*, body surface area; *IABP*, intra-aortic balloon pump; *CVA*, cerebrovascular accident; *HF*, heart failure, *HLD*, hyperlipidemia; *ARF*, acute renal failure; *CAD*, coronary artery disease; *PAD*, peripheral arterial disease; *CV*, cardiovascular; *PCI*, percutaneous coronary intervention; *IMA*, internal mammary artery; *ECG*, electrocardiogram; *IV*, intravenous; *NYHA*, New York Heart Association.