Off-Pump Techniques Disproportionately Benefit Women and Narrow the Gender Disparity in Outcomes After Coronary Artery Bypass Surgery

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Background—Women experience greater morbidity and mortality than men after conventional coronary artery bypass grafting (CABG) on cardiopulmonary bypass (CPB). The objective of this study was to determine whether off-pump CABG (OPCAB) alters this gender-based disparity.

Methods and Results—Retrospective review of risk factors and clinical outcomes for 11,413 consecutive patients having isolated CABG between January 1, 1997, and May 31, 2005, at a US academic center. Interventions were OPCAB or CABG/CPB, performed at the discretion of 14 faculty surgeons. Main outcome measures included in-hospital death, stroke, myocardial infarction or combined major adverse cardiac events (MACE). Odds ratios of adverse events, adjusted for 31 risk factors, were compared between women and men who had OPCAB versus CABG/CPB. Covariates included Propensity Score, Society of Thoracic Surgeons’ Predicted Risk, surgeon and body habitus. Female patients (n=3248) and those treated with OPCAB (n=4492) were older, had more comorbidities and higher predicted risk than male patients (n=8165) and those treated with conventional CABG/CPB (n=6921), respectively. Women treated with CABG/CPB had a risk-adjusted odds ratio of 1.60 for death (P=0.01), 1.71 for stroke (P=0.007), 2.26 for myocardial infarction (P=0.008) and 1.71 for MACE (P<0.001) compared with men who had CABG/CPB. In contrast, women treated with OPCAB had outcomes statistically similar to men who had either OPCAB or CABG/CPB. Among women, OPCAB was associated with a significant reduction in death (OR 0.39, P=0.001), stroke (OR 0.43, P=0.002) and MACE (OR 0.43, P<0.001).

Conclusions—OPCAB is associated with fewer major adverse cardiac events and benefits women disproportionately, thereby narrowing the gender disparity in clinical outcomes after CABG. (Circulation. 2007;116[suppl I]:I-192–I-199.)

Key Words: cardiopulmonary bypass surgery coronary disease

With few exceptions1–2 comparisons of outcomes for women versus men having coronary artery bypass grafting (CABG) have shown a higher incidence of morbidity and mortality for women.3–7 Motivated by a desire to reduce morbidity and mortality attributable to cardiopulmonary bypass (CPB)8–10 US surgeons performed over 20% of all coronary artery bypass operations off-pump—without the use of CPB (OPCAB)—in 2004.11 Importantly, most of the larger retrospective comparisons of outcomes between women and men did not include large numbers of OPCAB patients, usually because they were performed before OPCAB gained wide acceptance. Previous retrospective reviews have demonstrated that OPCAB is associated with decreased risk-adjusted morbidity and mortality compared with CABG on CPB,12–14 but have not specifically focused on outcomes among women. Randomized trials have demonstrated improved outcomes after OPCAB compared with CABG on CPB.15–18 However, these studies have inadequate statistical power to evaluate gender-specific outcomes or demonstrate improvements in infrequently occurring events such as death, stroke and myocardial infarction (MI).

The present study was designed to assess in-hospital outcomes for women and men having CABG to determine whether OPCAB may alter the gender-based disparity in morbidity and mortality.

Methods

Design, Setting and Patient Selection

In compliance with HIPPA regulations and the Declaration of Helsinki, and after institutional review board approval granted by Emory University, the Society of Thoracic Surgeons (STS) Adult Cardiac Database was queried for all patients who underwent isolated primary CABG at Emory University and Emory Crawford Long hospitals from January 1, 1997, to May 31, 2005. This yielded a study group of 11,413 patients (Figure 1). Figure 2 shows the

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Circulation is available at http://circ.ahajournals.org

DOI: 10.1161/CIRCULATIONAHA.106.678979

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trends in surgical procedure type over time by gender. Emergency cases were included; only redo CABG patients and those having CABG combined with valvular or other cardiac surgery were excluded. The time window for data sampling was chosen to include the entire period during which multivessel OPCAB has been practiced at Emory University. These medical records, prospectively entered and retrospectively reviewed, included demographic data, preexisting comorbidities, risk factors, operative strategy and clinical outcomes.

Interventions, Surgeons and Surgical Technique
Each patient underwent one surgical session consisting of OPCAB or CABG on CPB, performed at the discretion of any of 14 faculty surgeons, who varied in their adoption of off-pump surgery. OPCAB was performed with one of several commercially available cardiac positioning and coronary artery stabilizing devices, using techniques that have been previously described. Conventional CABG on CPB was performed with standard techniques, using roller head pumps, membrane oxygenators, cardiotomy suction, arterial filters, cold antegrade and retrograde blood cardioplegia and moderate systemic hypothermia (30°C to 34°C). Patients who were converted intraoperatively from OPCAB to CABG on CPB or from CABG on CPB to OPCAB were entered into the database and analyzed according to the operation they ultimately received.

Data Management and Statistical Analysis
All data for consecutive patients were prospectively entered into a computerized cardiac surgical database, using the data fields and
definitions of the STS National Adult Cardiac Database. Rigorous checks for data quality are used both at the institutional level and before final entry into the STS national adult cardiac database. Data were managed by local database staff, and warehoused in locked, secure facilities, protected by computer passwords and firewalls.

Before analysis, 31 candidate risk factors were selected and deemed potentially important predictors of surgical group assignment (OPCAB or CABG on CPB) or clinical outcomes. Table 1 lists these risk factors. Diabetes was classified into 3 categories: none, noninsulin-dependent and insulin-dependent. Previous MI and time since MI were collapsed into one variable. A body size scale (hereafter called Body Size) from Habib et al was used to evaluate the body habitus of each patient, and this score was included in the final analysis to determine whether Body Size was a confounder of gender in influencing adverse outcomes. This score incorporates both body mass index (BMI) and body surface area (BSA) and divides patients into 5 classes. The classes are as follows: very small (BMI $\leq 1.70$); slightly small (1.70 $<$ BMI $\leq 1.85$); moderately obese (32 $<$ BMI $\leq 36$); very obese (BMI $>36$); and normal (BMI $>1.85$ and 22 $<$ BMI $\leq 32$). The STS Database management has developed a proprietary mathematical model that allows estimation of mortality risk based on preoperative patient characteristics. This STS Predicted Risk Model is widely reported and validated in the literature.

The database was populated prospectively and thoroughly; consequently, $<$4\% of all data points were missing. Multiple imputation strategies based on maximum likelihood described by Rubin et al were used to impute the few missing values. Data were 100\% complete for critical risk factors such as gender and surgery type complete for critical risk factors such as gender and surgery type before final entry into the STS national adult cardiac database. Data were managed by local database staff, and warehoused in locked, secure facilities, protected by computer passwords and firewalls.

The retrospective nature and low event rates of the study recommended the use of propensity scoring methods. This approach “balances” patients with respect to the effect of their preoperative risk factors on their probability of group assignment (OPCAB versus CABG on CPB). Importantly, gender, Body Size, and STS predicted risk of mortality were not used to estimate the propensity score, but were used in the final outcomes models, because their direct influence on the outcomes was of primary interest. As such, 28 risk factors (including surgeon identity) and several binary indicators of missing data were used nonparsimoniously in a multivariable logistic regression (MLR) model to predict surgery type. The resulting estimated probability of being treated with OPCAB, conditional on the risk factor values, is the propensity score. The propensity score was included as a covariate of risk in the final MLR models of outcomes.

To address the primary study end points, separate MLR models of outcomes were constructed that regressed the dichotomous end points (death, stroke, MI, major adverse cardiac events [MACE]) as a function of treatment (OPCAB versus CABG on CPB), gender and the interaction of treatment and gender. Additionally, Body Size, STS Predicted Risk of Mortality, surgeon identity and the propensity score were modeled as prespecified covariates of risk. Surgeon identity was modeled as a random effect because patients are “clustered” under surgeons in a random manner. The treatment of surgeon as a random effect allows for the generalization of the model inferences to other populations. These 4 models (one model per outcome) reflect a conservative approach in measuring the association between the outcomes and the risk factors because important covariates (Predicted Risk of Mortality, and Body Size) are directly adjusted and not mixed with other propensity covariates in a nonparsimonious fashion.

These final models were used to assess the association between the outcomes and the predictors and to generate adjusted odds ratios of exposure to adverse postoperative events. Five preplanned comparisons for each of the 4 MLR models were of interest: (1) female CABG on CPB versus female OPCAB, (2) male CABG on CPB versus male OPCAB, (3) female CABG on CPB versus male CPB, (4) female OPCAB versus male OPCAB, and (5) female OPCAB versus male CABG on CPB.

The data were primarily summarized using SAS Version 9.1. STATA version 9.1 was used to fit the logistic regression model (XTLOGIT function) with surgeon identity as the clustered random effect. All statistical tests were performed using a 2-tailed 0.05 level of significance. All comparisons and model terms were preplanned.

The authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the manuscript as written.

**Results**

**Preoperative Patient Characteristics**

Table 2 shows patient characteristics and risk factors for every combination of gender and surgery type within the population of 11,413 consecutive patients. Female patients (n = 3,248) were significantly older, had more comorbidities and had higher STS predicted risk of mortality (3.1\%) than...
TABLE 3. Raw Major Adverse Cardiac Outcomes by Gender and Surgery Type

<table>
<thead>
<tr>
<th>Outcome</th>
<th>F/CPB (n=1867)</th>
<th>F/OPCAB (n=1381)</th>
<th>M/CPB (n=5054)</th>
<th>M/OPCAB (n=3111)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death, No. (%)</td>
<td>76 (4.07)</td>
<td>21 (1.52)</td>
<td>91 (1.80)</td>
<td>40 (1.29)</td>
<td></td>
</tr>
<tr>
<td>Stroke, No.</td>
<td>59 (3.16)</td>
<td>23 (1.67)</td>
<td>82 (1.62)</td>
<td>32 (1.03)</td>
<td></td>
</tr>
<tr>
<td>MI, No.</td>
<td>27 (1.45)</td>
<td>11 (0.80)</td>
<td>27 (0.53)</td>
<td>19 (0.61)</td>
<td></td>
</tr>
<tr>
<td>MACE, No.</td>
<td>147 (7.87)</td>
<td>49 (3.55)</td>
<td>184 (3.64)</td>
<td>81 (2.60)</td>
<td></td>
</tr>
</tbody>
</table>

Risk-Adjusted Comparisons of Outcomes

The c-index for the propensity model was 0.905 which indicates that the model exhibits very good discrimination between those assigned to OPCAB and those assigned to CABG on CPB. Significant interactions existed between gender and surgery type when predicting death and MACE (P=0.01 for both) using the final MLR models, adjusted for the random effect of surgeon identity, STS predicted mortality risk and Body Size. Surgery type was associated with stroke (P=0.01); patients treated with CABG on CPB were more likely to experience stroke (Table 5). Female gender was significantly associated with increased incidence of postoperative MI (P=0.008). Importantly, the multiple logistic regression interaction term was significant (P=0.01) for both death and MACE, meaning that women benefited more from OPCAB than did men with respect to risk-adjusted incidence of death or MACE. However, no statistically significant interaction between gender and surgery type was

TABLE 4. Observed to Expected Mortality by Treatment and Gender

<table>
<thead>
<tr>
<th>Treatment/Gender</th>
<th>Observed Mortality (O)</th>
<th>Expected Mortality* (E)</th>
<th>O/E Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female/OPCAB</td>
<td>1.52</td>
<td>3.33</td>
<td>0.46</td>
</tr>
<tr>
<td>Female/CPB</td>
<td>4.07</td>
<td>2.95</td>
<td>1.38</td>
</tr>
<tr>
<td>Male/OPCAB</td>
<td>1.29</td>
<td>1.86</td>
<td>0.69</td>
</tr>
<tr>
<td>Male/CPB</td>
<td>1.80</td>
<td>1.73</td>
<td>1.04</td>
</tr>
</tbody>
</table>

*Expected Mortality is the average of the STS Predicted Risk of Mortality for each group

male patients (n=8165; 1.8%; P<0.0001). Similarly, patients treated with OPCAB (n=4492) were older, had more comorbidities and had higher STS predicted risk of mortality (2.3%) than patients treated with conventional CABG on CPB (n=6921; 2.1%; P<0.0001). Women treated with OPCAB (n=1381) had more comorbidities and higher STS predicted risk of mortality (3.3%) than women treated with CABG on CPB (n=1867; 3.0%; P=0.004).

Unadjusted Outcomes

Women experienced significantly higher incidences of death (3.0 versus 1.6%), stroke (2.5 versus 1.4%), MI (1.2 versus 0.6%) and the combined end point of MACE (6.0 versus 3.3%) than men after coronary bypass surgery (Table 3). Patients who had OPCAB had significantly lower incidences of death (1.4 versus 2.4%), stroke (1.2 versus 2.0%) and the combined end point of MACE (2.9 versus 4.8%) than patients who had CABG on CPB. Observed (O) to expected (E) mortality ratios were highest for women who had CABG on CPB (O/E ratio 1.38) and lowest for women who had OPCAB (O/E ratio 0.46; see Table 4).
Some authors have proposed body habitus to be a confounder of the gender disparity in surgical outcomes after CABG. The present for either stroke or MI (P=0.49 and P=0.12, respectively).

Women treated with CABG on CPB had a risk-adjusted odds ratio of 1.60 for death (P=0.01), 1.71 for stroke (P=0.007), 2.26 for MI (P=0.008) and 1.71 for MACE (P<0.001) compared with men who had CABG on CPB. Women treated with OPCAB had outcomes statistically similar to men, with a risk-adjusted odds ratio of 0.71 for death (P=0.25), 1.36 for stroke (P=0.30), 1.08 for MI (P=0.85) and 0.96 for MACE (P=0.83) compared with men who had OPCAB. Among women, OPCAB was associated with fewer deaths (OR 2.56 CPB versus OPCAB, 0.001), stroke (OR 2.32 CPB versus OPCAB, 0.002) and MACE (OR 2.33 CPB versus OPCAB, P<0.001).

Indeed, treatment with OPCAB rendered women statistically similar to men in clinical outcomes: women treated with OPCAB had odds ratios of 0.63 (P=0.12) for death, 0.74 (P=0.28) for stroke, 1.69 for MI (P=0.22) and 0.73 (P=0.12) for MACE compared with men treated with CABG on CPB.

The benefit of OPCAB was less dramatic for men than for women. Among male patients, OPCAB was associated with statistically insignificant odds ratios for death, MI, and MACE compared with treatment with CABG on CPB, whereas stroke incidence (OR 1.85 CPB versus OPCAB; P=0.01) was significantly lower for OPCAB patients.

Possible Confounders of the Impact of Gender and Surgical Technique on Outcomes

Body Habitus

Some authors have proposed body habitus to be a confounder of the gender disparity in surgical outcomes after CABG. The classes of “high risk” body habitus defined by Habib et al10 and Body Size class frequencies for the present study were as follows: n=1128 very small; n=1707 slightly small; n=1622 moderately obese; n=1216 very obese; and n=5740 normal. Among the preoperative risk factors (Table 1) included directly (ie, not as part of the propensity score) in the MLR models used to derive the odds ratios presented in Table 5, were indices of unfavorable body habitus (Body Size). Body Size was included as preplanned covariate of risk in each of the final models of adverse outcomes. Body Size was not statistically significant in any of the 4 MLR models for death, stroke, MI or MACE indicating that body size does not confound the outcomes.

Completeness of Revascularization

Similarly, some authors have proposed that poorer outcomes for women after CABG are caused by less complete or effective revascularization, perhaps attributable to the small coronary arteries often found in women. To evaluate this possible explanation, the number of diseased vessels was included in the multivariable logistic regressions that generated the propensity score reported above. Moreover, an index of completeness of revascularization (ICOR) was calculated for each patient and compared between groups. ICOR was defined as the number of distal anastomoses constructed divided by the number of diseased vessels reported on the preoperative coronary arteriogram. Table 6 shows that the number of diseased vessels, the number of distal coronary artery anastomoses constructed and the ICOR were all slightly, but significantly, lower in females than in males and slightly, but significantly, lower in patients treated with...
OPCAB than in those treated with CABG on CPB. ICOR was lower for women treated with OPCAB than for those treated with CABG on CPB. The longer-term clinical implications of these differences are unknown. It is clear, however, that the improvement in clinical outcomes for women after OPCAB compared with conventional CABG on CPB is not attributable to more complete revascularization during OPCAB.

Surgeon Identity
The 11 413 CABG surgeries analyzed in this report were performed by 14 different academic surgeons over 8 years (Figure 2). One hypothetical explanation for improved surgical outcomes after OPCAB versus conventional CABG on CPB might be that the surgeon(s) performing OPCAB surgery are more skilled than those performing the older, conventional operation, rather than any inherent benefit of the technique itself. Furthermore, the distribution of cases by gender and surgery type might hypothetically affect outcome (see Table 7 and Figure 3). To address this theoretical concern, surgeon identity was included as a random effect in the final MLR models. The rationale for this approach is guided by the fact that patients are independently observed and treated except for the random effect of which surgeon is assigned to their case. The final MLRs are adjusted for the effect of surgeon identity, and thus the odds ratios for group comparisons in Table 5 reflect this adjustment.

Discussion
In this retrospective review of a large prospective database from a US academic center, preoperative risk factors and postoperative outcomes were analyzed for 11 413 consecutive patients who underwent isolated, primary coronary artery revascularization as OPCAB surgery compared with conventional CABG on CPB.

### TABLE 6. Extent of Coronary Disease and Completeness of Revascularization

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Subset Comparisons (mean, SD)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of diseased vessels</td>
<td>Females (2.46, 0.74) Males (2.57, 0.65)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female OPCAB (2.35, 0.78) Male OPCAB (2.46, 0.72)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female CPB(2.54,0.71) Male CPB (2.63, 0.64)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female OPCAB (2.35, 0.78) Female CPB (2.54, 0.71)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Male OPCAB (2.46, 0.72) Male CPB (2.63, 0.64)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. of distal anastomoses</td>
<td>Females (3.04, 1.07) Males (3.41, 1.08)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female OPCAB (2.66, 1.06) Male OPCAB (3.00, 1.07)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female CPB (3.31, 0.99) Male CPB (3.67, 1.01)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female OPCAB (2.66, 1.06) Female CPB (3.31, 0.99)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Male OPCAB (3.00, 1.07) Male CPB (3.67, 1.01)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICOR</td>
<td>Females (1.28, 0.54) Males (1.38, 0.54)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female OPCAB (1.19, 0.50) Male OPCAB (1.27, 0.49)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female CPB (1.36, 0.56) Male CPB (1.45, 0.56)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Female OPCAB (1.19, 0.50) Female CPB (1.36, 0.56)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Male OPCAB (1.27, 0.49) Male CPB (1.45, 0.56)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*2-sample t test, unadjusted for other covariates

### TABLE 7. Distribution of Cases by Gender, Surgery Type, and Surgeon

<table>
<thead>
<tr>
<th>Outcome</th>
<th>F/ON (n=1867)</th>
<th>F/OFF (n=1381)</th>
<th>M/ON (n=5054)</th>
<th>M/OFF (n=3111)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeon 1</td>
<td>270 (29.57)</td>
<td>5 (0.55)</td>
<td>624 (68.35)</td>
<td>14 (1.53)</td>
<td>913</td>
</tr>
<tr>
<td>Surgeon 2</td>
<td>115 (25.33)</td>
<td>9 (1.98)</td>
<td>313 (68.94)</td>
<td>17 (3.74)</td>
<td>454</td>
</tr>
<tr>
<td>Surgeon 3</td>
<td>17 (7.91)</td>
<td>39 (18.14)</td>
<td>79 (36.73)</td>
<td>80 (37.21)</td>
<td>215</td>
</tr>
<tr>
<td>Surgeon 4</td>
<td>381 (27.59)</td>
<td>14 (1.01)</td>
<td>977 (70.75)</td>
<td>9 (0.65)</td>
<td>1381</td>
</tr>
<tr>
<td>Surgeon 5</td>
<td>240 (25.75)</td>
<td>0 (0)</td>
<td>691 (74.14)</td>
<td>1 (0.11)</td>
<td>932</td>
</tr>
<tr>
<td>Surgeon 6</td>
<td>307 (18.14)</td>
<td>183 (11.00)</td>
<td>834 (50.12)</td>
<td>340 (20.43)</td>
<td>1664</td>
</tr>
<tr>
<td>Surgeon 7</td>
<td>189 (8.23)</td>
<td>476 (20.73)</td>
<td>502 (21.86)</td>
<td>1129 (49.17)</td>
<td>2296</td>
</tr>
<tr>
<td>Surgeon 8</td>
<td>4 (30.77)</td>
<td>1 (7.69)</td>
<td>8 (61.54)</td>
<td>0 (0)</td>
<td>13</td>
</tr>
<tr>
<td>Surgeon 9</td>
<td>1 (25)</td>
<td>0 (0)</td>
<td>3 (75)</td>
<td>0 (0)</td>
<td>4</td>
</tr>
<tr>
<td>Surgeon 10</td>
<td>121 (10.74)</td>
<td>228 (20.23)</td>
<td>263 (23.24)</td>
<td>515 (45.70)</td>
<td>1127</td>
</tr>
<tr>
<td>Surgeon 11</td>
<td>139 (9.39)</td>
<td>255 (17.22)</td>
<td>497 (33.56)</td>
<td>590 (39.84)</td>
<td>1481</td>
</tr>
<tr>
<td>Surgeon 12</td>
<td>3 (42.86)</td>
<td>1 (14.28)</td>
<td>3 (42.86)</td>
<td>0 (0)</td>
<td>7</td>
</tr>
<tr>
<td>Surgeon 13</td>
<td>2 (1.14)</td>
<td>48 (27.27)</td>
<td>3 (1.70)</td>
<td>123 (69.89)</td>
<td>176</td>
</tr>
<tr>
<td>Surgeon 14</td>
<td>78 (10.40)</td>
<td>122 (16.27)</td>
<td>257 (34.27)</td>
<td>293 (39.07)</td>
<td>750</td>
</tr>
</tbody>
</table>
bypass surgery since the gradual adoption of OPCAB techniques began in 1997. Female patients were generally sicker and older than male patients at the time of surgery. Their predicted risk of mortality was therefore higher than that of their male counterparts. Importantly, even when adjusted for preoperative risk factors, female patients experienced a significantly increased early incidence of death, stroke, MI or the combined end point of MACE. Thus, this dataset confirmed a gender disparity in clinical outcomes after CABG. This was independent of 30 other risk factors (including surgeon identity) which were included in the multivariable and propensity score analyses used to adjust for preoperative nongender differences between patients. Most striking was the finding that female patients benefited more from the avoidance of cardiopulmonary bypass during coronary artery bypass grafting than did male patients. This was demonstrated by the adjusted odds ratios in Table 5 and by the fact that the observed to expected mortality ratio was lowest for females who had OPCAB, and highest for females who had CABG on CPB (Table 4).

It has been long noted that women fared less well than men after cardiac surgery, and there have been numerous explanations offered, usually in the form of risk factors that might be confounders of the impact of gender on outcomes. None of these has been proven. In the present analysis the most credible explanations, namely body habitus, completeness of revascularization and surgeon identity, were tested as variables within our multivariable and propensity analyses. All were found to influence adverse cardiac events independent of gender and surgical technique. Their inclusion in these multivariable and propensity analyses did not negate the impact of gender or surgical technique on the risk-adjusted odds ratios for negative outcomes.

This study has several limitations. Its retrospective, observational nature does not permit complete accounting for all sources of bias, despite advanced statistical methodology designed to correct for both treatment selection bias and potential confounders of outcomes in preplanned analyses. In addition, the STS database used in this study reported surgical outcomes according to the ultimate surgery type performed until January 1, 2004, when STS introduced a data field to document intraoperative conversions from OPCAB to CABG on CPB. Because the large majority of this dataset predates the introduction of the conversion field, an intention-to-treat analysis of the entire dataset was not feasible. This meant that patients whose CABG was initially attempted without CPB and who required conversion to CPB (typically attributable to hemodynamic instability) were included in the CABG on CPB group. This may disadvantage CABG on CPB in comparison of outcomes with OPCAB. Reciprocally, patients converted from CABG on CPB to OPCAB (usually attributable to intraoperative discovery of severe aortic atherosclerosis) were included in the OPCAB group. Their increased incidence of complications may disadvantage OPCAB in comparison to CABG on CPB. Virtually all patients undergoing cardiac surgery at Emory since 1996 have had intraoperative epiarterial ultrasound scanning performed early in the procedure; thus, conversions from planned CABG on CPB to OPCAB without aortic manipulation occur on an infrequent but regular basis. Fortunately, intraoperative conversion is generally an infrequent event, affecting only ~2% of cases. To test whether intraoperative conversion of patients from OPCAB to CABG on CPB could possibly have confounded the present analyses, all patients in the present dataset whose surgery was performed after January 1, 2004 (when the data field for conversion was introduced) were examined separately in a post hoc analysis. Among these 1611 patients, 25 (1.55%) were converted intraoperatively from a planned OPCAB to CABG on CPB. None (0) of these 25 patients experienced 30-day mortality or perioperative MI. One (4%) experienced stroke. It therefore seems unlikely that intraoperative conversion of patients from OPCAB to CABG on CPB could have meaningfully confounded the present analyses.

Finally, although the 14 surgeons who performed CABG in this study varied greatly in their interest in OPCAB (several rarely performed OPCAB, whereas several used OPCAB in the majority of their cases), Emory University has maintained...
a strong institutional interest in OPCAB since 1997. Thus, faculty surgeons in the present study may have average experience with OPCAB that exceeds the national norm, limiting generalizability of these results.

Conclusion

Women undergoing coronary artery bypass surgery are at increased risk of death, stroke or MI or the composite end point of death/stroke/MI compared with men. This gender disparity in clinical outcomes is narrowed by off-pump coronary artery bypass—a surgical technique that avoids the use of cardiopulmonary bypass and cardioplegic arrest during coronary bypass grafting. Further studies are needed to determine both why female patients experience increased complications during conventional CABG and why they may benefit disproportionately from avoidance of cardiopulmonary bypass.

Acknowledgments

The authors express their gratitude to staff members Kim Baio, MSN, for project oversight and preparation of the manuscript and to Deborah Canup for data acquisition.

Source of Funding

This study was internally funded solely by Emory Healthcare, through the Clinical Research Unit of the Division of Cardiothoracic Surgery, without contribution from any outside corporate entity.

Disclosures

J.P., O.L., and R.G. are consultants to Medtronic, Inc. J.P. and R.G. are also consultants to Boston Scientific.

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Off-Pump Techniques Disproportionately Benefit Women and Narrow the Gender Disparity in Outcomes After Coronary Artery Bypass Surgery
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doi: 10.1161/CIRCULATIONAHA.106.678979

_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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http://circ.ahajournals.org/content/116/11_suppl/I-192

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