In-Hospital Mortality and Morbidity After Robotic Coronary Artery Surgery

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Objectives: **The objective of this study was to assess the impact of robotic approaches on outcomes of coronary bypass surgery.**

Design: **Retrospective national database analysis.**

Setting: **United States hospitals.**

Participants: **A weighted sample of 484,128 patients undergoing isolated coronary artery surgery identified from the Nationwide Inpatient Sample from 2008 through 2010.**

Interventions: **Robotically assisted coronary artery bypass surgery versus conventional bypass surgery.**

Measurements and Main Results: **Robotic approaches were used in 2,582 patients (0.4%). Patients undergoing robotic surgery were less likely to be female (odds ratio [OR] 0.71, 95% confidence interval [CI] 0.57-0.87), present with acute myocardial infarction (OR 0.53, 95% CI 0.38-0.73), or have cerebrovascular disease (OR 0.41, 95% CI 0.23-0.71) compared to patients undergoing conventional surgery. In 59% of robotic cases, a single bypass was performed, and 2 bypasses were performed in 25% of cases. After adjusting for comorbidity, reduced postoperative stroke (0.0% *v* 1.5%, p = 0.045) and transfusion (13.5% *v* 24.4%, p = 0.001) rates were observed in patients who underwent robotic single-bypass surgery compared to conventional surgery. In patients undergoing multiple bypass grafts, higher mortality (1.1% *v* 0.5%), and cardiovascular complications (12.2% *v* 10.6%) were observed when robotic assistance was used, but the differences were not statistically significant (p = 0.5). The mean number of robotic cases carried out annually at institutions sampled was 6.**

Conclusions: **Robotic assistance is associated with lower rates of postoperative complications in highly selected patients undergoing single coronary artery bypass surgery, but the benefits of this approach are reduced in patients who require multiple coronary artery bypass grafts.**

KEY WORDS: coronary artery bypass grafts, CABG, robotics

ROBOTIC APPROACHES ARE used to facilitate surgery through smaller incisions, but the impact of small incisions on clinically important outcomes after cardiac surgery remains controversial.[1,2] Several recent series of robotic assisted coronary artery bypass graft (CABG) procedures suggest that any benefit from the very small incisions achieved by robotic approaches may be offset by increased morbidity and mortality associated with cardiopulmonary demands of extended single-lung ventilation, prolonged cardiopulmonary bypass (CPB) and operative times, and the technical challenge of accurately locating and grafting target vessels through limited incisions.[3–5] This study was designed to compare outcomes of patients undergoing conventional CABG surgery with those of patients in whom robotic assistance was employed, using data from the Nationwide Inpatient Sample (NIS).

PATIENTS AND METHODS

Patients who underwent isolated CABG between 2008 and 2010 were identified using the Nationwide Inpatient Sample (NIS). The NIS is the largest publicly available database of inpatient hospital care in the United States and is sponsored by the Agency for Healthcare Research and Quality. The database contains information from more than 8 million inpatient stays per year sampled from more than 1,000 hospitals across the country representing more than 40 states. In hospitals, sampled data from all inpatients' stays are recorded. Each record in the database represents an inpatient stay and includes both clinical and non-clinical information such as patient demographics, principal and secondary diagnoses, procedures, discharge status, and charges. Diagnoses and procedures are coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

Between 2008 and 2010, a weighted sample of 484,128 patients underwent isolated CABG (117,428 patient records). Patients were identified from the NIS using the ICD-9-CM procedure codes for CABG surgery (36.10, 36.11, 36.12, 36.13, 36.14, and 36.15). Patients who underwent concomitant cardiac surgery (including procedure codes 35.20-28, 35.11-14, 38.45) were excluded. Patients who underwent on-pump CABG were identified using the procedure codes 39.61 (extracorporeal circulation auxiliary to cardiac surgery) or 39.66 (percutaneous cardiopulmonary bypass). Patients who lacked these procedure codes were assumed to have undergone off-pump coronary artery bypass. Cases in which robotic assistance was used were identified using the procedure codes 17.41, 17.44, 17.45, and 17.49. The baseline patient characteristics that the authors assessed are listed in Table 1. The ICD-9 diagnosis codes used to define these comorbidities, based on Agency for Healthcare Research and Quality comorbid disease categories[6] are provided in Supplemental Table I. ICD-9-CM code 997.1 was used to identify postoperative cardiac complications.

Patients who underwent single CABG were compared according to whether robotic surgery was employed or not, and a similar analysis was carried out in patients who received 2 or more coronary artery grafts. The primary outcome was in-hospital mortality; secondary outcomes included major adverse cardiovascular complications (including cardiac arrest, postoperative cardiac insufficiency), postoperative stroke, acute renal failure (with or without need for subsequent hemodialysis), mediastinitis, respiratory failure, and surgical complications such as tamponade, bleeding, and need for re-exploration. For each subgroup, the authors controlled for imbalances in baseline characteristics between patient groups by performing propensity score matching based on individual patient records. A propensity score for each inpatient stay was calculated using a multivariate logistic regression model, which predicted the likelihood of robotic surgery based on the baseline patient characteristics listed in Table 1. Emergency patients were excluded from propensity score matching. Conventional CABG patients were paired with robotic patients with similar propensity scores according to a 1-to-1 scheme without replacement. Patients were deemed similar enough to be paired if the difference between their propensity scores was less than 0.15 units of the standard deviation of the logit of the propensity score

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Table 1. Patient and Provider Characteristics for All Patients Undergoing Coronary Artery Bypass Grafting

Variable	All Patients n = 484,128	Conventional n = 481,546	Robotic n = 2582	p Value
Age	64.9 ± 10.7	64.9 ± 10.7	64.4 ± 11.0	0.301
Female	26.7%	26.7%	27.1%	0.846
Elective admission	46.0%	45.9%	66.0%	<0.001
Acute myocardial infarction	30.5%	30.6%	12.3%	<0.001
Smoking	19.3%	19.3%	15.2%	0.019
Diabetes	40.0%	40.0%	37.0%	0.161
Obesity	18.8%	18.8%	16.4%	0.172
Liver disease	1.1%	1.8%	1.1%	0.111
Renal failure	11.9%	11.9%	8.9%	0.038
Chronic obstructive pulmonary disease	16.2%	16.2%	15.8%	0.830
Peripheral vascular disease	10.0%	10.0%	9.7%	0.798
Cerebrovascular disease	7.4%	7.4%	2.8%	<0.001
Atrial fibrillation	24.6%	24.6%	19.2%	0.004
Congestive heart failure	17.4%	17.4%	10.7%	<0.001
Previous operations	1.2%	1.2%	1.3%	0.674
Operative characteristics				
Number of bypass grafts	3.3 ± 1.0	3.3 ± 1.0	1.65 ± 1.0	<0.001
Off-pump	27.5%	27.3%	79.8%	<0.001

of the off-pump patient (ie, the caliper was set as 0.15). Propensity score matching yielded matched pairs for 275 single coronary artery bypass patients and 189 multiple bypass patients. Demographic traits and baseline comorbidities were not significantly different between these cohorts after matching (Supplemental Table II). The c-statistic for the logistic regression model used to obtain a propensity score was 0.902. All analyses were performed with SPSS Statistics for Windows, Version 21 (IBM Corporation, Armonk, NY), using a custom dialog file written by Felix Thoemmes.

Univariate analysis of outcomes between conventional CABG and robotic CABG was performed for each subgroup using Pearson's chi-squared test for categoric variables and Student's t-test for continuous variables. Multivariate analysis was performed using binary logistic regression using the same aforementioned patient demographics and comorbidities as covariates (excluding comorbidities when they were used to define the subgroup). Results are demonstrated as odds ratios (OR) and 95% confidence intervals (CI). A p value of <0.05 was considered to be statistically significant.

RESULTS

In the weighted sample, 0.4% of CABG procedures (n = 2,582) were carried out with robotic assistance. Robotic patients were less likely to be urgent or present with acute myocardial infarction, cerebrovascular disease, or congestive heart failure than patients undergoing CABG surgery without robotic assistance (Table 2). In 59% of robotic-assisted cases, a single CABG graft was carried out, 2 bypasses were performed in 25% of cases, and 3 or 4 CABG grafts were performed in 15.8% of robotic-assisted cases. A single internal mammary artery was used in 84% and bilateral mammary arteries used in 14%. In the robotic group, 7% of patients underwent percutaneous coronary intervention in the same admission, with 39% of these interventions performed postoperatively. This compares to the non-robotic group in which 3% of patients underwent percutaneous coronary intervention in the same admission, of which 6% were postoperative.

Overall, unadjusted mortality and cardiovascular complications were lower in robotic patients, as were transfusion requirements, the incidence of renal and respiratory failure, and postoperative sepsis (Table 3). After propensity score matching, significantly reduced rates of graft failure, postoperative stroke, and transfusion requirements, as well as a decreased length of stay, were observed in patients who underwent single CABG surgery with robotic assistance compared to those who underwent conventional single CABG surgery (Table 4). In patients undergoing multiple bypass grafts, higher rates of mortality, adverse cardiovascular events and major complications were observed in patients in whom robotic assistance was used, but these did not reach statistical significance.

The mean number of robotic cases carried out annually at each institution sampled by the NIS during 2008 through 2010 was 6 (Fig 1), with the majority of institutions carrying out fewer cases each year and a small minority carrying out more than 30 robotic cases per year. Most institutions performing robotic procedures carried out fewer than 200 total CABG cases per year

Table 2. Predictors of Robotic Surgery Based on Patient Characteristics

Variable	OR (95% CI)	p Value
Age	1.00 (0.99-1.01)	0.568
Female	0.71 (0.57-0.87)	0.002
Elective admission	1.22 (0.98-1.51)	0.076
Acute myocardial infarction	0.53 (0.38-0.73)	<0.001
Smoking	0.84 (0.64-1.08)	0.212
Diabetes	1.12 (0.91-1.36)	0.287
Obesity	0.84 (0.65-1.08)	0.184
Liver disease	1.88 (0.94-3.75)	0.073
Renal failure	0.77 (0.54-1.08)	0.127
Chronic obstructive pulmonary disease	1.02 (0.78-1.33)	0.877
Peripheral vascular disease	1.07 (0.78-1.47)	0.657
Atrial fibrillation	0.85 (0.67-1.08)	0.178
Cerebrovascular disease	0.41 (0.23-0.71)	0.002
Congestive heart failure	0.75 (0.55-1.03)	0.071
Number of grafts	0.25 (0.22-0.28)	<0.001

Abbreviations: CI, confidence interval; OR, odds ratio.