Comparison of Index Hospitalization Costs Between Robotic CABG and Conventional CABG: Implications for Hybrid Coronary Revascularization

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Objectives: To compare the direct costs of the index hospitalization and 30-day morbidity and mortality incurred during robotic and conventional coronary artery bypass grafting at a single institution based on hospital clinical and financial records.

Design: Retrospective study, propensity-matched groups with one-to-one nearest neighbor matching.

Setting: University hospital, a tertiary care center.

Participants: Two thousand eighty-eight consecutive patients who underwent primary coronary artery bypass grafting (CABG) from January 2007 to March 2012.

Interventions: One hundred forty-one matched pairs were created and analyzed.

Measurements and Main Results: Robotic CABG was associated with a decrease in operative time (5.61 ± 1.1 *v* 6.6 ± 1.15 hours, $p < 0.001$), a lower need for blood transfusion (12.8% *v* 22.6%, $p = 0.04$), a shorter length of stay (6 [4-9]) *v* 7 [5-11] days, $p = 0.001$), a shorter ICU stay (31 [24-49] hours *v* 52 [32-96.5] hours, $p < 0.001$) and lower NY state complications composite rate (4.26% *v* 13.48%, $p = 0.01$). In spite of that, the cost of robotic procedures was not significantly different from matched conventional cases ($18,717.35 [11,316.1-34,550.6] versus $18,601 [13,137-50,194.75], $p = 0.13$), except 26 hybrid coronary revascularizations in which angioplasty was performed on the same admission (hybrid 25,311.1 [18,537.1-41,167.85] versus conventional 18,966.13 [13,337.75-56,021.75], $p = 0.02$).

Conclusion: Robotically assisted CABG does not increase the cost of the index hospitalization when compared to conventional CABG unless hybrid revascularization is performed on the same admission.

KEY WORDS: minimally invasive surgery, coronary stent, PCI, CABG, healthcare costs, robotic surgery

PROSPECTIVE RANDOMIZED studies have documented the superior long-term symptom relief and survival that multivessel coronary artery bypass grafting (CABG) affords compared with both medical therapy and percutaneous coronary intervention (PCI).[1–3] The major predictor of improved survival in most studies is a patent left internal thoracic artery (LITA) anastomosis to the left anterior descending coronary artery (LAD).[4–6] However, the SYNTAX trial demonstrated that PCI offers a lower level of invasiveness, more rapid recovery, and fewer short-term complications than CABG at the expense of an increased need for repeat revascularization.[3] The search for a less invasive surgical treatment, which would be associated with less morbidity and mortality, greater patient satisfaction, and faster recovery, led to the development of minimally invasive surgical approaches to coronary revascularization. Robotically assisted CABG is a minimally invasive procedure in which the LITA-to-LAD revascularization is performed on the beating heart through a limited left thoracotomy. It has been hypothesized that this approach can confer the survival advantages of conventional CABG while decreasing the complication rate and improving rapid recovery. The procedure is performed through small thoracic incisions, avoiding median sternotomy and cardiopulmonary bypass (CPB) in most patients, but it does not provide multivessel revascularization. The combination of robotic CABG and PCI for non-LAD coronary lesions (right coronary artery or circumflex), commonly referred to as hybrid coronary revascularization (HCR), may provide the advantages of robotically assisted CABG and full revascularization in a subset of patients.[7,8] No randomized prospective studies have been published thus far comparing the outcomes of conventional to robotic CABG or HCR. Robotically assisted CABG, alone or in combination with PCI, is a minimally invasive revascularization strategy that may decrease early complications and improve recovery when compared with conventional CABG. The costs of the index hospitalization incurred during robotic CABG may be higher than conventional CABG due to high equipment cost.

The escalating costs of American healthcare threaten to limit the ongoing pursuit of technologic advances. It is often unclear how such advances in minimally invasive cardiac surgery impact the overall costs of delivery of care to a complex group of patients. Although improvement in recovery might limit the costs of overall hospitalization, the upfront purchase cost of the technology can offset and potentially negate these savings. In this study, the authors sought to compare the financial and clinical hospital records of matched groups of patients undergoing robotic CABG and conventional CABG on cardiopulmonary bypass.

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1053-0770/2601-0001$36.00/0

http://dx.doi.org/10.1053/j.jvca.2015.07.031

MATERIAL AND METHODS

The study was approved by the authors' institution's institutional review board, protocol #10-02-048E. The clinical and demographic data were gathered from the hospital cardiac surgery database, which is used to populate the New York State database and the Society of Thoracic Surgeons (STS) database. Total primary isolated CABG cases were identified from January 2007 to March 2012, including robotically assisted and conventional CABG.

Patients were selected for robotic CABG if there was a high-grade, frequently complex proximal LAD lesion. Subsets of robotic CABG patients included those with predominantly isolated LAD disease or those with multivessel disease who were deemed candidates for HCR after review by the heart team or revascularization of vessels other than the LAD was deemed unfeasible by surgery or PCI. Patients with isolated ostial left main lesions also were considered candidates for robotic CABG. Patients with severe chronic obstructive pulmonary disease who could not tolerate single-lung ventilation and those patients who had prior left chest surgery were excluded as candidates for robotic CABG.

The surgical techniques for robotically assisted CABG have been described in detail previously.[7,8] Briefly, the robot is used for LITA takedown, pericardiotomy, and vessel identification. The LITA-LAD anastomosis then is performed on the beating heart through a small left anterior thoracotomy with minimal rib spreading. All patients undergoing conventional CABG had revascularization through a sternotomy on the arrested heart with the support of cardiopulmonary bypass. Patients undergoing off-pump CABG through a sternotomy or emergency CABG and those having concomitant procedures were not included in this study. Patients in the robotic group were included according to intention to treat and were not excluded if converted to sternotomy or performed on CPB.

Statistical Analysis and Cost Data

Preoperative variables from the STS database[9] were compared between robotically assisted and conventional CABG groups (age, body mass index [BMI], gender, race, ethnicity, left ventricular ejection fraction [LVEF], diabetes, chronic obstructive pulmonary disease, cerebral vascular disease, end-stage renal disease requiring dialysis, previous myocardial infarction, and same-day admission status). As randomization is not used in clinical practice, groups of patients receiving different treatments may differ in ways that are relevant to outcomes. To reduce this source of bias, propensity scores were calculated to match patients on the previously mentioned variables with BMI dichotomized to 30 and LVEF to 35%. The order of patients in the dataset was randomized prior to matching procedure. The greedy match was performed in STATA statistical software 12.1 (STATA Corp., College Station, TX) with the user-written command "psmatch2", to do nearest-neighbor one-to-one matching on common support with caliper 0.02[10] and ties broken randomly. Propensity score test from STATA-user written command was utilized to assess the groups' balance, and a standardized difference of less than 10% was considered acceptable.[11–14] After matched pairs were formed, McNemar's test was applied to compare 30-day mortality, discharge status, NY perioperative complications rate composite, and 30-day readmission rate; hospitalization cost and the length of stay (LOS) were compared by paired t-test if data distributed normally and Wilcoxon test otherwise.[12]

The costs for the index hospitalization included in this report were derived from internal financial systems. Ancillary costs were developed by applying relevant ratios of costs to charges, while inpatient nursing areas applied per-day cost factors. Direct costs represent costs specific to the cost center/area, and included adult beds, blood bank, dialysis, drugs, electrocardiogram (ECG), electroencephalogram (EEG), emergency room, intensive care unit, coronary care units, recovery room, laboratory, medical/surgical supplies, operating room (OR), physical therapy, radiology therapy, diagnostic, radioisotopes, and respiratory therapy. Indirect costs are costs shared by the entire medical center (such as capital, administrative expenses, graduate medical education, and facility services) and are excluded from this analysis. Surgeon and cardiologist fees were excluded from the analysis. Because the cost of the robot purchase was not included in direct cost, an adjustment to hospital direct costs was necessary. The authors calculated the robot cost (the da Vinci system [Intuitive Surgical Inc., Sunnyvale, CA] was utilized at the time in the study) per case based on total price of the equipment used divided by the number of cases the robot can perform over its useful life. Based on a $1.5 million purchase price, 5-year life, and robot usage of 1,625 procedures over 5 years by the different subspecialties including cardiac, the authors estimated a cost of $923.08 per case. For hospitals that already have made the investment in a robotic surgical program, this cost should be treated as a fixed cost. The robot maintenance cost of $110,000 per year was divided by the approximate number of cases per year and added to the robotic cost of $338.50 per case. The cost of disposable robotic equipment was included in the medical/surgical supply cost, and the cost of the stents was included in catheterization laboratory cost.

In-hospital complications, such as reoperation for bleeding, respiratory failure, stroke, etc., resulted in additional days of care, laboratory tests, and radiologic procedures and were included in the initial hospital cost according to these categories. Since some patients had PCI during the same admission as part of the HCR procedure and other patients had diagnostic catheterization during the same admission, the authors added the catheterization cost. Hospital readmission within 30 days of discharge was confirmed by the hospital electronic record. Since their study's time horizon was 30 days, no discounting was applied to costs or outcomes.

Descriptive statistics were calculated with continuous data presented as mean and standard deviation (SD) if approximately normally distributed or median and 25% to 75% percentile range if not. The cost data were presented as median and 5% to 95% percentile range. Categorical data were presented as frequencies and percentages. Cost analysis was performed for all matched pairs; additional analysis was performed to compare HCR cases performed on the same admission to the rest of the robotic cases and to their corresponding conventional cases.

RESULTS

A total of 2,088 CABG procedures were performed from January 2007 to March 1, 2012, including 150 robotic CABG