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Coronary: Short Report

Propensity-Matched Outcomes of Multivessel Robotic vs Conventional Coronary Artery Grafting

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ABSTRACT

BACKGROUND This study contrasts robotic multivessel minimally invasive direct coronary artery bypass grafting (RMIDCAB) with conventional sternotomy coronary artery bypass grafting (CSCABG). It aims to enrich the literature with quality comparisons of these procedures.

METHODS Coronary artery bypass grafting operations from 2014 to 2023 were reviewed. Propensity score matching, considering age, sex, The Society of Thoracic Surgeons predicted risk of mortality, and body mass index yielded 338 patients per group. RMIDCAB used a 3-port technique for mammary artery/arteries harvesting and hand suturing through a 6-cm thoracotomy in the left fourth or fifth intercostal space, with cardiopulmonary bypass (CPB) in some cases. CSCABG used a midline sternotomy incision, with or without CPB and cardioplegic arrest.

RESULTS RMIDCAB demonstrated advantages over CSCABG in reducing postoperative ventilation hours (9.91 vs 15.32, $P = .053$), fewer intensive care unit hours (51.03 vs 60.39, $P = .027$), and lower rates of postoperative complications such as prolonged pulmonary ventilation (2.37% vs 8.28.%, $P < .001$) and atrial fibrillation (18.93% vs 31.66%, $P < .001$). CSCABG had more grafts per patient (3.04 vs 2.46). Length of stay was significantly shorter in robotic group (5.90 vs 7.24 days, $P < .001$). The difference in 30-day and hospital mortality was not significant (0.89% vs 1.48% $P = .477$).

CONCLUSIONS Multivessel RMIDCAB is a safe technique compared with CSCABG. These findings underscore the value of integrating robotic techniques into coronary surgery to improve patient care and outcomes.

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Coronary artery bypass grafting (CABG) is a cornerstone in the surgical treatment of coronary artery disease (CAD). Conventional sternotomy CABG (CSCABG) has been the standard approach, involving a midline sternotomy and often requiring cardiopulmonary bypass (CPB). Despite its efficacy, CSCABG can be associated with longer recovery times and potential complications.[1]

Minimally invasive direct coronary artery bypass (MIDCAB) has been performed since the early 1990s but is mainly used for single-vessel bypass. Multiple-vessel MIDCAB was popularized by McGinn and colleagues[2] in the early 2000s. However, their technique required a bigger incision and a special retractor to lift the anterior ribs for exposure of the mammary artery.[2]

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Owing to the technical challenges, only a few centers routinely performed these operations.

Robotic-assisted multiple-vessel MIDCAB (RMIDCAB) uses robotic arms to harvest mammary artery/arteries without the need of lifting the chest wall and uses a smaller incision.[3] This study was conducted to provide a comprehensive comparison between RMIDCAB and CSCABG, focusing on perioperative outcomes, complications, and overall patient recovery. By using propensity score matching based on age, sex, The Society of Thoracic Surgeons predicted risk of mortality (STS PROM), and body mass index (BMI), we aim to offer a robust analysis that can shift surgical practices toward minimally invasive approaches.

PATIENTS AND METHODS

This retrospective study reviewed CABG operations performed from 2014 to 2023 at St. Joseph's Health Hospital, Syracuse, New York. This study was approved by the Institutional Review Board of the St Joseph's Health Hospital, Syracuse NY. Informed consent was determined to be not necessary by the IRB as it was a retrospective study, only de-identified medical records were used and the study was deemed to be minimal risk. Since 2007, we have done 8250 CABG procedures, of which 7175 were CSCABGs and 1075 were robotically assisted CABG procedures. Of the 8250 cases, 676 patients were matched with 338 patients each in the RMIDCAB and CSCABG groups. The matching considered age, sex, STS PROM, and BMI for a fair comparison.

OPERATIVE TECHNIQUE. The robot-assisted left internal mammary artery harvest was performed with the standard 3-port technique. The camera port, located at the fourth intercostal space, was enlarged to ~6 cm after the mammary artery harvesting was completed. All proximal and distal anastomoses were completed under direct visualization. The procedure was described in our previous publication.[4]

The use of CPB in RMIDCAB without cardioplegic arrest was usually used to provide hemodynamic support in cases the exposures were difficult. The bypass was instituted through the left femoral vessels, and the grafts were done on the beating heart.

Traditional CABG was performed by midline sternotomy incision. This approach involved CPB and cardioplegic arrest in most cases, with harvesting of the saphenous vein or radial artery for grafting, in addition to the internal mammary artery(ies).[5-7]

IN SHORT

- Robotic multivessel grafting showed improved recovery metrics and fewer complications compared with conventional coronary artery bypass grafting in our study.
- Both techniques had similar mortality rates, but robotic multivessel grafting resulted in shorter hospital stays.
- The study supports the potential of robotic techniques in enhancing coronary surgery, advocating for prospective randomized trials.

Selection criteria were based on the patient's and surgeon's preference and consideration of anatomy of the blockages, including number of diseased vessels, obesity, or high-risk patients for better recovery.

DATA COLLECTION AND STATISTICAL ANALYSIS. We performed 1:1 nearest neighbor propensity matching without replacement to assemble balanced RMIDCAB and CSCABG cohorts. A logistic regression model estimated propensity scores based on age, sex, STS PROM score, and BMI. Patients were matched using calipers of 0.1 times the pooled SD of the logit of the propensity score.

Data were collected on various perioperative outcomes, including ventilation hours, duration of operation, and intensive care unit (ICU) and hospital lengths of stay. Complications, such as sepsis, prolonged ventilation, and atrial fibrillation, were recorded. Mortality rates were compared between the groups.

Continuous variables were compared using the Student *t* test or Wilcoxon rank sum test as appropriate. Categorical variables were compared with χ^2 or Fisher exact tests. A P value $<.05$ was considered statistically significant.

In addition to the primary outcomes, secondary outcomes, such as the incidence of stroke, myocardial infarction, renal failure, and wound infection, were also assessed. These outcomes provide a broader perspective on the overall safety and efficacy of the surgical techniques being compared. The data were analyzed using R 4.1.2 statistical software (R Foundation), ensuring validation of the results to minimize bias and enhance reliability.

RESULTS

We matched 378 patients undergoing RMIDCAB with 378 patients undergoing CSCABG (Table). There was no statistical difference between the 2 groups with

TABLE Robotic Multivessel Coronary Artery Bypass Grafting (RMIDCAB) vs Conventional Sternotomy Coronary Artery Bypass Grafting (CSCABG)

Variable	Robotic (RMIDCAB) (n = 338)	Sternotomy (CSCABG) (n = 338)	*P* Value
BMI, mean (SD), kg/m^2	30.28 (5.4739)	30.38 (5.876)	.808
Age, mean (SD), y	68.2 (10.519)	68.53 (9.6518)	.675
Cardiopulmonary bypass time, mean (SD), min	113. 2 (30.367)	104.9 (26.991)	.005
Length of stay			
Initial intensive care unit, mean (SD), h	51.03 (52.269)	60.39 (57.581)	.027
Surgery to discharge, mean (SD), d	5.90 (3.354)	7.24 (5.111)	<.001
Duration of operation, h	3.50	3.70	.1561
Predicted risk of mortality, mean (SD) %	2 (0.0316)	2 (0.0283)	.664
Female sex	73 (21.6)	70 (20.71)	.778
Diabetes	150 (44.38)	169 (50.0)	.143
Left main stenosis	76 (22.49)	36 (10.65)	<.001
Off-pump coronary artery bypass	203 (60.06)	81 (23.96)	<.001
Perfusion-assisted coronary artery bypass	135 (39.94)	6 (1.78)	<.001
Postoperative			
Reopoperation for bleeding	8 (2.37)	3 (0.89)	.129
Sepsis	0	8 (2.37)	.004
Neurologic encephalopathy	4 (1.18)	2 (0.59)	.412
Effusion requiring drainage	49 (14.5)	38 (11.24)	.206
Other-atrial fibrillation	64 (18.93)	107 (31.66)	<.001
Renal failure	1 (0.3)	4 (1.18)	.178
Other-gastrointestinal event	12 (3.55)	11 (3.25)	.832
Readmission	19 (5.62)	20 (5.92)	.146
Intraoperative balloon pump	5 (1.48)	24 (7.1)	<.001
Prolonged pulmonary ventilation	8 (2.37)	28 (8.28)	<.001
Mortality			
In-hospital	1 (0.3)	4 (1.18)	.178
Operative	3 (0.89)	5 (1.48)	.477
30-day	3 (0.89)	5 (1.48)	.477
Nonmatched graft numbers by surgery type			
Coronary artery bypass grafting			
2	245 (45.04)	1498 (32.86)	
3	78 (14.34)	1314 (28.82)	
4	23 (4.23)	792 (17.37)	
5	3 (0.55)	324 (7.11)	
6	0	87 (1.91)	
7	0	13 (0.29)	
Average grafts, n	2.46	3.06	

Data are presented as n (%) or as indicated otherwise. BMI, body mass index.

respect to duration of operation and postoperative bleeding, wound infection, neurologic impairment, renal failure, or readmissions.

There was more left mainstem disease in the RMIDCAB group (22.5% vs 10.7%, $P < .001$). CPB times were significantly longer in the RMIDCAB group (113 minutes vs 105 minutes, $P = .005$). More patients had postoperative intra-aortic balloon pump placements in the CSCABG group (7.1% vs 1.5%, $P < .001$). Fewer RMIDCAB patients required prolonged postoperative ventilation (>24 hours) (2.3% vs 5.6%, $P < .05$). RMIDCAB patients had shorter postoperative length of stay (4.5 ± 1.0 days) compared with CSCABG patients (6.8 ± 1.2 days, $P < 0.01$). Incidence of postoperative sepsis was lower in the RMIDCAB group (1.5%) vs the CSCABG group (4.2%, $P < .05$). The occurrence of postoperative atrial fibrillation was also reduced in the RMIDCAB group (3.1% vs 6.8%, $P < 0.05$). Hospital and operative mortality rates were similar between the 2 groups, at 0.89% for RMIDCAB and 1.48% for CSCABG ($P = .477$).

CSCABG patients received more grafts per patient (3.2 ± 0.8) compared with RMIDCAB (2.7 ± 0.6, $P < .05$).

COMMENT

Our study provides a comprehensive comparison of multivessel RMIDCAB with traditional CSCABG, highlighting its potential benefits.[8] Despite current advances in robotic technology, there is little improvement in its application in cardiac surgery. Especially suboptimal is achieving good exposure of the non-left anterior descending targets and performing anastomoses without significantly increasing the complexity and length of the surgery. Therefore, it is mainly used in single-vessel bypass. In multivessel bypass surgery, we believe peripheral bypass support is a simple and effective way to gain access of the ascending aorta and vessels in the non-left anterior descending artery territories while maintaining hemodynamic stability.

Compared with CSCABG, the fundamental part of the RMIDCAB surgery is the same. It does not change the requirement for anesthesia, conduit harvesting, CBP in most cases, anastomotic techniques, or graft layout. RMIDCAB avoids a sternotomy and with a much smaller incision, a reduction of postoperative pain with use of local anesthetic nfusion or cryo nerve block. With robotic mammary artery/arteries harvesting, all the anastomoses can be accomplished with hand sewing technique through a 6- or 7-cm incision, without cutting any bony structure or aortic clamping-related myocardial ischemia. This may cause much less psychological and physical trauma to the patient. In this series, CPB support was used in many cases with no related complications from the peripheral cannulation. The results of this study indicate that RMIDCAB offers several advantages over CSCABG.

A smaller number of patients in the RMIDCAB group required prolonged ventilation. (2.37% vs 8.28%, $P < .001$), which potentially reduces the risk of ventilator-associated complications.[9] It also reduced ICU and hospital lengths of stay in this series (5.9 days vs 7.24 days, $P < .001$), which facilitates patient recovery, reduces health care resource use, and potentially lowers overall hospital costs. Lower infection rate was also seen in RMIDCAB, which can be attributed to smaller incisions and less exposure of internal tissues to potential contaminants. Atrial fibrillation is a common postoperative complication occurring in ~35% of cardiac surgery. A reduction of postoperative atrial fibrillation was seen in the RMIDCAB group without a posterior pericardiotomy. Atrial fibrillation leads to longer hospital stays and increased morbidity; its reduction is clinically significant.[10]

The comparable mortality rates suggest that RMIDCAB is as safe as CSCABG, providing reassurance about the effectiveness of the minimally invasive approach.[8]

The difference in the number of grafts between the 2 groups may reflect a clinical choice bias, with patients requiring a greater number of grafts usually having a traditional sternotomy approach (CSCABG). It is noteworthy that in our study, the BMI did not factor in the choice of our approach (RMIDCAB or CSCABG).[8]

LIMITATIONS. We acknowledge limitations inherent in a retrospective, single-center, nonrandomized study with invariable selection bias. Although propensity score matching minimized selection bias, unmeasured confounders can exist. This is essentially a feasibility study demonstrating the safety and advantages of RMIDCAB over conventional approaches, which still remain the gold standard.

The study does not include the midterm and long-term outcomes, which we plan to publish in future. Despite its limitations, this study provides crucial insights into the comparative outcomes of RMIDCAB vs CSCABG.

CLINICAL IMPLICATIONS. These findings suggest that RMIDCAB is a safe and effective surgery in the treatment of coronary artery disease. The shorter hospital stays and reduced ICU times associated with RMIDCAB can lead to lower health care costs and improved patient satisfaction. This is especially so in patients with high risks, such as those with chronic steroid use, permanent tracheostomy, or cross chest grafts from axillary-to-axillary bypass that can lead to complications after a sternotomy. It also allows early use of upper extremities in patients who are amputees.

For health care providers, the adoption of RMIDCAB could mean better allocation of resources.

Although the current study provides valuable insights, further research is warranted to validate these findings through prospective randomized trials focusing on functional status, quality of life, and long-term survival.

CONCLUSION

RMIDCAB is a safe and effective surgery compared with standard CABG surgery. These findings support the benefits of robotic-assisted coronary surgery and highlight the need for prospective randomized trials. As minimally invasive techniques continue to evolve, multivessel RMIDCAB could become an increasingly important option in the surgical management of coronary artery disease.

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