Integrated Coronary Revascularization

Percutaneous Coronary Intervention Plus Robotic Totally Endoscopic Coronary Artery Bypass

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Background—Robotic totally endoscopic coronary artery bypass (TECAB) of the left anterior descending artery (LAD) coupled with percutaneous coronary intervention (PCI) of a second coronary artery has been investigated in patients with multivessel disease to provide a minimally invasive therapeutic option.

Methods and Results—TECAB of the LAD was performed using the left internal mammary artery (LIMA). A second lesion was treated with PCI before surgery, simultaneously, or after surgery. Three-month angiographic follow-up was performed in all patients and was subject to independent review. A total of 27 patients requiring double vessel revascularization were treated at 7 centers. Eleven patients underwent PCI before surgery, 12 patients underwent PCI after surgery, and 4 patients underwent simultaneous surgical and percutaneous intervention. Ten patients (37%) were treated with bare metal stents, whereas 17 patients (63%) were treated with drug-eluting stents. Postoperative angiographic evaluation demonstrated an overall LIMA anastomotic patency of 96.3% and PCI vessel patency of 66.7%. There were no deaths or strokes. One patient experienced a perioperative myocardial infarction. Eight of 27 patients (29.6%) required reintervention, 1 LIMA anastomotic stenosis (3.7%), 3 after bare metal stent (30%), and 4 after drug-eluting stent placement (23.5%).

Conclusions—Integrated revascularization treatment plans provide minimally invasive options for patients with multivessel coronary artery disease. This approach may be accomplished with no mortality, low perioperative morbidity, and excellent angiographic LIMA patency. The reintervention rate after PCI in this series was higher than that reported elsewhere and should be investigated further. The choice of suitable vessel, type of stent and timing of the treatment must be carefully considered before implementing this hybrid strategy. **(*Circulation*. 2006;114[suppl I]:I-473–I-476.)**

Key Words: angioplasty ■ coronary disease ■ revascularization ■ surgery ■ robotics ■ stents ■ hybrid ■ da Vinci surgery

Advances in both the percutaneous and surgical fields have opened opportunities for patients to benefit from less invasive more durable coronary revascularization strategies. Integrated or hybrid coronary revascularization combines the most proven and promising approaches to coronary artery disease.[1] It is well-documented that bypassing the left anterior descending artery (LAD) with the left internal mammary artery (LIMA) is not only the longest lasting intervention but also an approach that provides a survival benefit.[2,3] Robotic technology is evolving to facilitate the least invasive approach for coronary bypass surgery.[4–8] Robotic totally endoscopic coronary artery bypass (TECAB) has, however, been limited to revascularization of the anterior cardiac surface (LAD, diagonal distribution). Because the TECAB procedure has developed and offered patients the opportunity for shorter hospital stays, lower complication rates, and more rapid return to full activity,[9] many have looked to broaden the base of patients with coronary artery disease who could be eligible for this approach.

We report on a multicenter experience of patients prospectively planned to receive an integrated approach to treat multivessel coronary artery disease, these patients were a subpopulation of a larger trial in which intention to treat with a hybrid approach was determined preoperatively.[9] The data from these patients were retrospectively reviewed. Completely endoscopic robotically assisted LIMA to LAD placement was combined with catheter based intervention on non-LAD targets in patients with multivessel disease to offer to these patients a closed chest option with the long-term benefits of LIMA to LAD.

Patients and Methods

Adult patients with double vessel coronary disease involving the LAD were included. A total of 27 patients from 7 centers were enrolled. Ethics committee approval and appropriate informed consent was obtained in all cases. Mean age was 59.8±8.9 years, range 39 to 77 years. The majority of the patients were male (n=19, 70.4%), and there were 8 females (29.6%). Risk factors and comorbidities are listed in Table 1. Although the original study

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TABLE 1. Comorbidities

Variable	n=27
Preoperative angina	23 (85.2%)
Left Ventricular Ejection Fraction	
Preoperative	57% (±12)
Postoperative (3 months)	59% (±12)
Family history of CAD	16 (59.3%)
Hypercholesterolemia	21 (77.8%)
Diabetes	4 (14.8%)
Hypertension	15 (55.6%)
Smoking	17 (62.9%)

CAD indicates coronary artery disease.

showed a 3% conversion rate to nonrobotic techniques, none of the patients in this subcohort was excluded or converted.

The LAD was bypassed using the LIMA. A second lesion was treated with angioplasty and stenting before surgery, during the same operative session, or after surgery, depending on the severity and type of the coronary lesions.

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

Surgical Technique

The surgical procedure was performed under general anesthesia via three 8- to 12-mm left-sided thoracic ports using the daVinci robotic system (Intuitive Surgical, Sunnyvale, Calif). All aspects of the procedure, including internal mammary artery (IMA) mobilization and preparation, pericardiotomy, coronary artery identification, arteriotomy, and anastomosis were performed endoscopically. Peripherally introduced cardiopulmonary bypass with endoaortic balloon occlusion and cardioplegic arrest was used in all cases. The TECAB procedure on the arrested heart has been described in detail previously[4,9]

Catheter-Based Intervention

Percutaneous interventions were performed using standard techniques and the choice of stent was determined by the individual cardiologist. Previous percutaneous coronary intervention (PCI), unrelated to the current integrated plan, had been performed in 14 patients (51.8%).

Eleven patients (40.7%) underwent PCI on average 38 days (range, 2 to 137) before surgery. In these patients the TECAB procedure was performed under platelet inhibition with aspirin with or without clopidogrel. Twelve patients (44.4%) had PCI on average 16 days (range, 2 to 60) after surgery, and 4 (14.8%) had PCI and surgery during the same operative session (Table 2).

Percutaneous interventions addressed lesions in the right coronary distribution in 20 (74%) patients, circumflex system in 5 (19%), and anterior descending or diagonal distribution in 2 (7%). Bare metal stents were implanted in 10 patients (37%), and drug-eluting stents were placed in 17 (63%) (Table 3). All patents underwent 3-month follow-up angiography, which was reviewed by an independent core laboratory for assessment of graft and vessel patency.

TABLE 2. PCI Timing

Timing	n=27	Mean Interval (days)
Before TECAB	11	37.9
After TECAB	12	15.7
Simultaneous	4	0

TABLE 3. PCI Locations

	n=27	Bare Metal	DES
LAD/diagonal	2 (7%)	0	2
Circumflex	5 (19%)	2	3
Right coronary	20 (74%)	8	12
		10 (37%)	17 (63%)

Statistics

Categorical variables are shown as absolute numbers and percentages. Continuous variables are given as median and range. Continuous variables were compared preoperatively and postoperatively using the Student *t* test for paired samples.

Results

Perioperative Results

There were no perioperative mortalities or neurological events. Further perioperative results are listed in Table 4.

Intermediate Term Results

Three-month survival was 100%. Eight patients (29.6%) required target vessel re-intervention (Table 5). An anastomotic stenosis of the LAD developed in one of the 8 on the 3-month follow-up angiogram (anastomosis was widely patent on postoperative day 2 at time of PCI). This was treated successfully with balloon angioplasty. The remaining 7 required restenting of the previously stented vessel. Three of these initially had bare metal stents placed, whereas 4 had drug-eluting stents (DES). Of the patients requiring reintervention, 2 in the bare metal stent group had developed target lesion restenosis and 1 target vessel restenosis. In the drug eluting stent subgroup, 2 each developed target lesion and target vessel restenosis. (Table 6). All restenoses were diagnosed at the time of the 90-day follow-up angiogram or later. Five noted at 90 days, 1 at 150, 1 at 180, and 1 at 270 days postoperatively. Of these re-interventions 3 experienced stable angina, 1 of those reintervened at 90 days, 1 at 150 days, and 1 at 270 days.

Discussion

Our study demonstrates that completely endoscopic LIMA to LAD placement using robotic technology can be combined with catheter based intervention to non-LAD targets

Feasibility

The hybrid concept was first introduced when cardiac surgery developed methods for LIMA to LAD placement through small thoracotomies. Angelini et al published the first small series on hybrid coronary artery revascularization in 1996.[10] He used the classic minimally invasive direct coronary artery bypass (MIDCAB) procedure, in which the LIMA is har-

TABLE 4. Results

MACE	TECAB n=27	Stent:BM n=10	Stents:DES n=17
Mortality	0	0	0
CVA	0	0	0
MI	1	0	0
Target vessel reintervention	1 (3.7%)	3 (30%)	4 (23.5%)

TABLE 5. Reinterventions

	TECAB, n=27	Bare Metal, n=10	DES, n=17
PCI of LIMA anastomosis	1		
Target lesion restent		2	2
Target vessel restent		1	2

vested by direct vision through a fourth interspace left mini-thoracotomy. In MIDCAB, the LIMA is sutured to the LAD on the beating heart using special retractors and stabilizers. Over the past 10 years the majority of the few series on integrated coronary revascularization that have been published applied a combination of MIDCAB and placement of bare metal stents.[11–14] Didier de Canniere of our group has demonstrated advantages of this concept versus conventional coronary artery bypass grafting in a prospective randomized trial.[15] Mostly for logistic reasons, but also because the MIDCAB operation is technically challenging, hybrid procedures were never implemented on a broad basis, only slightly >200 operations have been published so far. The MIDCAB operation has been proven superior to bare metal stenting of the proximal LAD in a prospective randomized study reported by Diegeler et al.[16] Nevertheless, according to this study, re-intervention rates on the LIMA to LAD graft were still considerable. The MIDCAB procedure has the drawback of difficult IMA harvest and intercostal pain during the immediate postoperative period.[15] For these and other reasons, MIDCAB has been abandoned by many groups.

The feasibility of completely endoscopic coronary artery bypass grafting and especially of endoscopic LIMA to LAD placement has renewed interest in integrated coronary procedures. Our current series is the largest which combines totally endoscopic LIMA to LAD placement with PCI on other targets.

Collaboration between cardiac surgeons and cardiologists integrating surgical and percutaneous options can provide patients with minimally invasive possibilities for multivessel coronary artery disease. Logistic issues with regard to the timing and sequence of the 2 procedures remain.[17] If PCI is performed first, it is performed with an unprotected anterior wall, and then surgery must be performed after aggressive antiplatelet inhibition. Additionally, stent thrombosis is a risk after reversal of surgical anticoagulation. The opportunity for angiographic checking of the LIMA anastomosis is also lost. If the surgery is performed first antiplatelet therapy is routinely started postoperatively and is therefore present at the time of PCI. The stent is placed with a revascularized LAD distribution and the LIMA anastomosis can be investigated. However should complications of the PCI develop, it could require a second operative intervention. Simultaneous procedures are intriguing; however, questions remain as to the response of DES to anticoagulation reversal at the end of surgery and immediate postoperative antiplatelet management. We have shown that the hybrid concept works for the staged approach in which either the TECAB part of the concept or the PCI part is performed first. Additionally staged hybrid procedures offer the advantage of having each aspect of the procedure performed in the environment (operating room or cardiac catherization laboratory) specific to that procedure. Members of our group have recently shown that hybrid interventions using TECAB on the arrested heart can also be performed simultaneously[4,18] and the current larger series confirms this fact. Catheterization laboratories outfitted to also accommodate cardiac surgery and hybrid operating rooms with permanent fluoroscopic equipment are currently available at only a few centers. Proliferation of percutaneous procedures such as those involving the aorta and valvular disease may also help make these multipurpose rooms more common in the future.

TABLE 6. PCI Patency

Stenosis	n=27	Bare Metal, n=10	DES, n=17
<50%	17 (66.7%)	7 (70%)	10 (58.8%)
≥50%	10 (33.3%)	3 (30%)	7 (41.2%)

Major surgical complications in TECAB did not occur. Safety of TECAB has also been demonstrated by a recently presented multicenter study on this operation.[9]

Target Vessel Reintervention

Our study confirms previous reports that demonstrated low reintervention rates for the internal mammary artery grafts to the LAD.[11,14,15,19] Reports have noted an overall PCI reintervention rate of 12%, which was lower that our observed PCI reintervention rate. Drug-eluting stents have so far shown promising results[1] and are definitely an intriguing stimulus for a revival of the hybrid concept. It was interesting for us to see that stent restenosis rates in our patients who received drug-eluting stents was not much different from restenosis rates in patients in whom bare metal stents were implanted. The restenosis rates were higher than expected. This population was not selected specifically for angiographically descrete lesions, especially in the non-LAD regions. Additionally, the patients in this study had a 14% incidence of diabetes. Many of the index studies involving drug-eluting stents involved select populations. Our overall patient number, however, is too small to draw conclusions from this finding. Additional long-term follow-up of the current patient series will be necessary to further evaluate the potential benefits of the hybrid approach.

Conclusion

From this multicenter experience we conclude that robotic totally endoscopic LIMA to LAD placement can be combined with catheter-based intervention on non-LAD targets in patients with double vessel disease. Reintervention rates on the endoscopically placed internal mammary artery grafts are low but stent reintervention rates were higher than anticipated. Hybrid coronary revascularization is an example for functioning direct cooperation between minimally invasive heart surgeons and interventional cardiologists.

Disclosures

Drs Murphy and Srivastava are consultants for Intuitive Surgical. Ms Kreaden is an employee of Intuitive Surgical.

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