

Integrating Coronary Anastomotic Connectors and Robotics Toward a Totally Endoscopic Beating Heart Approach: Review of 120 Cases

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Background. Endoscopic coronary bypass has been a difficult procedure to perform. The recent introduction of the Intuitive EndoWrist stabilizer (Intuitive Surgical, Sunnyvale, CA) has facilitated this procedure robotically on the beating heart. The addition of anastomotic connectors allows a significant improvement in the execution of this technically demanding procedure. We report on our first 120 cases of totally endoscopic, beating heart connector coronary artery bypass grafting integrating these technologies.

Methods. From January 2008 to April 2010, 120 patients (age range 43 to 86 years, 72% male) underwent either single or multivessel all arterial, totally endoscopic coronary artery bypass grafting using the da Vinci robot with the aid of the Flex A distal anastomotic device (Cardica, Redwood City, CA). Patients with multivessel disease involving branches of the right coronary and circumflex arteries underwent hybrid revascularization with stents. Early and midterm clinical outcomes were evaluated for all patients. Eighty-five internal mammary artery grafts in 68 patients were evaluated at a mean of 4 months using

multidetector computed tomography and formal angiography (in 18 hybrid patients).

Results. Mean hospital stay was 3.3 ± 2.4 days. There was 1 postoperative death (the same patient had a stroke secondary to carotid disease), and 1 postoperative myocardial infarction. Two patients were converted to minithoracotomy and 1 patient was converted to sternotomy. One patient required cardiopulmonary bypass support through the femoral cannulation during the procedure. Mean intraoperative transit time flow in all the internal mammary artery grafts was $76 \text{ cc/minute} \pm 43$, and pulsatility index of 1.5 ± 0.5 . Of the 85 grafts evaluated angiographically, 80 were patent at a mean of 4 months (94.1%).

Conclusions. Totally endoscopic beating heart connector coronary bypass using the da Vinci robot with the Flex A anastomotic device is a safe and reproducible procedure. A significant learning curve is involved and experience with anastomotic devices in the open setting is necessary. Long-term follow-up of graft patency and patient outcomes is warranted.

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Endoscopic coronary artery bypass using the da Vinci robot on the beating heart has been enhanced by the recent development of new technologies. Whereas the original application of endoscopic internal mammary artery (IMA) takedown using the robot was relatively easily mastered by many surgeons, the next step of performing the rest of the operation endoscopically has not been realized on a wide scale. The lack of adequate stabilizing techniques and the difficulty with creating the anastomosis on the beating heart contributed to this lack of adaption.

The introduction of the Intuitive EndoWrist stabilizer for the da Vinci S tele-manipulation system (Intuitive Surgical, Sunnyvale, CA) in 2008 was a significant advance over table-mounted stabilizers for ease and accuracy of placement. This provided the ability to make

minor adjustments to improve presentation and stabilization of the target.

Similarly the introduction of the C-Port Flex A distal anastomotic device (Cardica, Redwood City, CA) in 2007 was a major breakthrough in automating the creation of the distal anastomosis. It is uniquely applicable through endoscopic ports.

We report on our surgical approach in detail and early and mid term outcomes of integrating these two technologies to achieve totally endoscopic beating heart single and multivessel coronary artery bypass grafting.

Patients and Methods

This study was approved by our Institutional Review Board during retroactive review. Formal consent was

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waived as it was considered a de-identified retrospective study.

After gaining a significant experience using the Cardica C-Port distal anastomotic connector in open off-pump coronary artery bypass procedures on both saphenous vein and arterial grafts, we began our robotic revascularization experience with IMA take-down and minimally invasive direct coronary artery bypass (MIDCAB). This was followed by beating heart totally endoscopic single, and then multivessel grafting using sequential and bilateral IMA grafts.

We reviewed the technical aspects of the procedure and clinical outcomes of our first 120 patients (from January 2008 to April 2010). This after excluding 10 patients representing the very early learning experience.

Patients were selected for endoscopic coronary artery bypass grafting (CABG) based on their anatomy. Sixty-one (50.8%) had single-vessel disease, 31 (25.8%) had double-vessel disease, and 28 (23.3%) had triple vessel disease. Patients undergoing hybrid revascularization had non-left anterior descending (LAD) lesions amenable to percutaneous intervention (PCI), as determined by the referring cardiologist. Patients were stented either preoperatively or postoperatively depending on the clinical presentation. Patients were entered into a database and offered a follow-up multidetector computed tomographic angiogram.

All grafts were subjected to intraoperative patency evaluation using transit time flowmetry with a flexible probe (MediStim, Oslo, Norway). Criteria for graft revision were a flow less than 15 cc/minute and pulsatility index (PI) greater than 5. Patency evaluation was performed using postoperative angiograms (in the hybrid patients) or multidetector computed tomography angiogram at 126 ± 90 days.

Patient Preparation and Anesthesia Considerations

The patient is positioned supine on the operating room table with a roll under the left chest. The legs are prepped as for normal CABG surgery with adequate groin exposure for possible femoral cannulation. Intubation is performed with a double lumen tube or a single lumen tube and left endobronchial blocker to allow for split lung ventilation.

Port Placement

Standard ports are placed in the second, fourth, and sixth interspace, respectively, midway between the midaxillary and midclavicular lines (Fig 1). Access to the marginal branches of the circumflex artery requires ports to be placed slightly more posterior. Carbon dioxide insufflation is required to maintain space in the chest. Two extra ports are a 12-mm robotic port in the left subcostal plane medial to the midclavicular line for the fourth robotic arm (and EndoWrist stabilizer), and a 15-mm port (Ethicon Surgical, Somerville, NJ) in the second interspace midclavicular line for insertion of the Flex A device (Fig 2). The robot cart is docked with the center column at the level of the right arm port in a slightly angled orientation

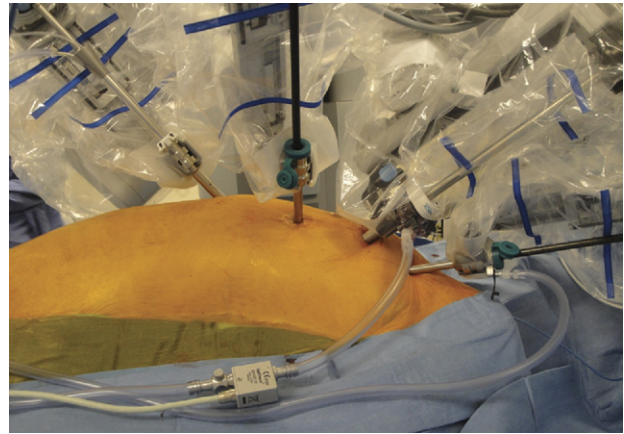


Fig 1. Robotic port position during multivessel beating heart totally endoscopic coronary artery bypass.

(toward the foot of the patient), to allow better maneuvering of the fourth arm.

Target and Conduit Preparation

The extrapericardial fat pad is dissected and reflected. The pericardium is opened anterior to the phrenic nerve (for LAD-diagonal targets) and posterior to the phrenic nerve for circumflex marginal targets. After the pericardium is opened careful re-review of the angiogram is helpful in identifying the coronary targets. Once the targets are identified the IMA(s) are harvested. If the right IMA is to be used this should be harvested first. A skeletonized technique is preferred to increase conduit length and aid in its handling inside the chest.

Once the IMA(s) are harvested, the 2 extra ports are placed and the EndoWrist stabilizer is introduced as the fourth robotic arm. Of note, docking the fourth arm (subcostal port) requires adjusting the left robotic arm and camera arm cephalad at the setup joint.

Prior to heparinization, the coronary targets are stabilized and prepared. This entails dissecting off the epicardial tissue, placing a silastic snare, and pre-placing an adventitial stitch (Gore-Tex CV8; W. L. Gore & Assoc, Flagstaff, AZ) to close the insertion site of the anvil of the Flex A after the anastomosis is complete.

The patient is heparinized to an activated clotting time of 300 to 350 seconds, and the IMA conduits are prepared with intraluminal papaverine using a 20-Ga epidural catheter (Braun Medical, Bethlehem, PA). The catheter has a blunt nonperforated tip and side holes for perfusion. It is introduced through the subcostal port, inserted gently into the tip of the IMA, and advanced very slowly. The tableside assistant draws back on the syringe prior to infusing to confirm a clean intraluminal position. Alternatively, extraluminal papaverine may be infused on the outside of the IMA.

The grafting strategy dictates the next step at this point. It is recommended to graft the back of the heart first if this is hemodynamically appropriate. If the right (R)IMA is to be used as a free T graft, it is now detached. The T graft is performed with the Flex A device, attaching

the proximal end of the free RIMA to the left (L)IMA in end to side fashion. We prefer to load the proximal RIMA onto the device inside the chest, insert the anvil at the site of a branch on the LIMA, and control this with 2 or 3 U clips (Medtronic, Minneapolis, MN). In this configuration the free RIMA is used to graft the circumflex branch and the LIMA is used for the LAD. Alternatively, the RIMA can be left as an attached conduit and brought across the midline to graft the LAD if the stenosis is fairly proximal and the RIMA can reach. Care should be taken to use some of the endothoracic fascia to cover the RIMA in the midline if this configuration is used.

Insertion and Loading of the Flex A

The Flex A device is introduced through the 15-mm port. The device is held by an instrument in the subcostal port (needle driver or DeBakey forceps). Once its cables are aligned and the device anvil is facing the heart, it is rotated 180 degrees counterclockwise so that the anvil is now facing the sternum. A 30-degree up scope is used with 2 black diamond forceps. The IMA is then aligned and rotated in a similar manner to the device; the end of the conduit is placed through the jaws of the cartridge and spatulated. The adventitia is now grasped on either side of the heel and the conduit is gently elevated onto the heel clip, while the tableside assistant activates the lever to bring the piercer down onto the heel clip. The shield guard is then brought down and tucked into the hood of the conduit. This ensures an adequate hood of the graft. The tableside assistant then brings down the right and then the left wing guard (after the piercer is removed). It should be noted that the part of the conduit that is draped over the top of the cartridge is not part of the anastomosis (Fig 3). The Flex A is then brought back to the neutral position, with the anvil facing the heart, and placed gently on the pericardium.

Creation of the Anastomosis

The stabilizer is now reintroduced and the target is stabilized. The snare is tightened and hemodynamics are observed briefly. ST segment elevation can be tolerated as long as there is no hemodynamic compromise, ventricular arrhythmia, or wall motion abnormality. If this happens we have found ischemic preconditioning to be useful. A 3 to 4 minute test occlusion is performed; if

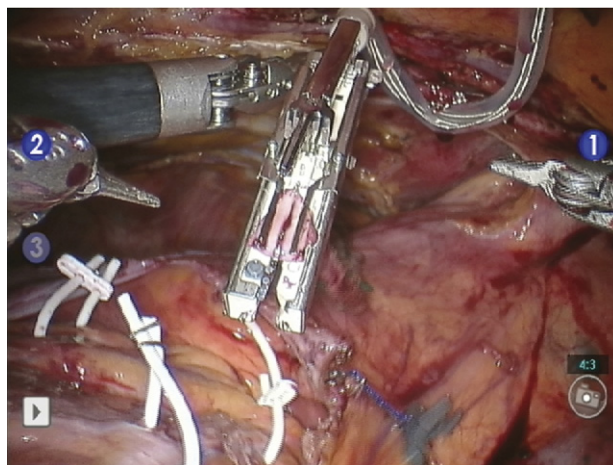


Fig 3. Internal mammary artery loaded into cartridge of the Flex A.

ischemic changes are seen, flow is restored for several minutes allowing another test occlusion. An arteriotomy is then created in the middle of the preplaced suture. The anvil of the device is then gently inserted at a 45-degree angle until the tip is in the lumen. Once this is assured it is brought back to a parallel orientation and then advanced slowly (Fig 4). Confirmation of intraluminal position is the most important step of the whole process. If this is uncertain, the device should be removed and reinserted with a slightly different angle or after making the arteriotomy slightly larger.

Disengagement of the cartridge should be done under control and very gently to avoid pulling on the anastomosis. The anvil stitch is then tied and the bulldog is released. Minimal bleeding from the toe usually stops on its own. An extra stitch at the toe is needed in less than 20% of cases.

The flow in the graft is then checked. We prefer to use transit time flowmetry with the Medistim device (MediStim, Oslo, Norway). This device provides multiple parameters

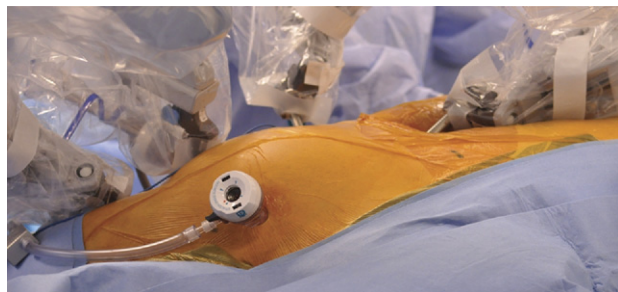


Fig 2. A 15-mm working port for introduction of the Flex A anastomotic device.

Fig 4. Anvil of the Flex A fully inserted into left anterior descending artery.

of graft patency including flow, pulsatility index, and percent diastolic flow.

If sequential grafts are needed, the side-to-side anastomosis can be performed after the connector end-to-side anastomosis is completed. We prefer an interrupted technique with anastomotic U clips, as described by Srivastava and colleagues [1].

Results

From July 2007 to April 2010 we performed 130 beating heart robotic-assisted CABG procedures. The first 10 patients were excluded from this analysis as they were considered part of the early learning experience, and included our very first 5 robotic cases (all done with the aid of a MIDCAB incision). Totally endoscopic coronary artery bypass (TECAB) off-pump beating heart procedures were performed in 120 patients (86 males; age range, 43 to 86 years) using all arterial grafts and are the subject of this review (Table 1). Twenty-one patients were operated on as part of a staged hybrid revascularization (18 with postoperative PCI and 3 with preoperative PCI). During this time frame in the lead authors' practice, a total of 248 isolated coronary revascularization procedures were performed; 120 (48.4%) were TECABS. Sixteen procedures (12.5%) were redos and 245 (98.8%) were off-pump. A total of 211 total robotic cardiac procedures were performed during this time frame.

Of 120 TECABs, 78 (65%) were single-vessel, 37 (31%) were double-vessel, and 5 (4%) were triple-vessel bypass procedures. Of the 37 double-vessel procedures, 20 were with bilateral IMA grafts, 12 were sequential LIMA grafts, and 5 were using IMA-only T grafts. All of the triple-vessel procedures were with bilateral IMA and sequential LIMA grafts. A total of 167 arterial grafts were

Table 1. Demographics of 120 Totally Endoscopic Coronary Artery Bypass Patients

Demographic	Percentage
Mean age (years)	66.3 ± 10.4 (46-83)
Male	72%
Family history of coronary artery disease	38.9%
History of smoking	30.6%
Diabetes	19.4%
Obesity (body mass index > 30)	19.4%
Hyperlipidemia	55.6%
Prior myocardial infarction	6.9%
Angina	30.6%
Arrhythmia	8.3%
Renal dysfunction (HD or SCr > 2.0)	2.8%
Hypertension	61.1%
Chronic obstructive pulmonary disease	12.5%
History of cerebrovascular accidents	8.3%
Peripheral vascular disease	5.6%
Congestive heart failure	5.6%
Alcohol abuse	8.3%

HD = hemodialysis; SCr = serum creatinine.

Table 2. Conduits and Targets in 167 Totally Endoscopic Coronary Artery Bypass Grafts in 120 Patients

Conduit and Target	Frequency
LIMA-LAD	106 (63.5%)
LIMA-Cx marginal	18 (10.8%)
LIMA-Diagonal/Ramus (sequential or T)	17 (10.2%)
RIMA-LAD	14 (8.4%)
RIMA-Cx (T graft)	10 (6.0%)
RIMA-RCA (right ports)	2 (1.2%)

Cx = circumflex; LAD = left anterior descending; LIMA = left internal mammary artery; RCA = right coronary artery; RIMA = right internal mammary artery.

performed; 146 with the Flex A device and 21 with anastomotic U clips. Conduits and distribution of grafts are summarized in Table 2.

Mean operative time in the first 20 single-vessel patients was 384 ± 92 minutes. This improved to 189 ± 38 minutes in the last 20 single-vessel patients. Mean robotic time (dock to undock) in the first 20 single-vessel patients since we began recording this (January 2009) was 192 ± 56 minutes, and in the last 20 single-vessel patients was 145 ± 37 minutes.

The mean intraoperative transit time flowmetry graft flow was 76 ± 43 cc/minute, with a pulsatility index of 1.5 ± 0.5. There were 5 grafts that needed intraoperative revision due to poor flow. These were all performed with anastomotic U clips with or without an intracoronary shunt. Of the 5 grafts that required revision, 2 were felt to be related to poor target preparation and failure to place the anvil correctly into the lumen. One was felt to be secondary to platelet thrombus in the distal LIMA, one was thought to be secondary to twisting in a T graft to OM1, and one was a RIMA graft that was under too much tension to the distal LAD and was revised to a T graft. All transit time flowmetry flows improved after revision.

There was 1 conversion to a sternotomy in a patient who had a totally occluded right coronary artery (RCA) collateralized by a stenotic LAD, and developed inferior wall ischemia during LAD grafting requiring sternotomy off-pump coronary artery bypass and an additional vein graft to the posterior descending branch. Two patients were converted to MIDCAB early in the experience secondary to body habitus and poor exposure. One patient was converted to on-pump beating heart TECAB. He was destined to have a hybrid revascularization to the RCA and developed increased pulmonary artery pressure and hypoxia secondary to single lung ventilation.

Concomitant procedures were performed in 4 patients. One patient underwent left atrial appendage ligation for atrial fibrillation and 3 underwent additional epicardial left atrial ablation through right-sided ports (one of these was a right-sided TECAB RIMA-RCA). These 3 patients had paroxysmal atrial fibrillation and underwent pulmonary vein isolation (Box lesion) through right-sided thoracoscopic (or robotic) ports, using the Cobra XL unipolar radiofrequency ablation device from Estech (San Ramon, CA). We check for both entrance and exit conduction

Table 3. Perioperative Complications in 120 Totally Endoscopic Coronary Artery Bypass Patients

Complication	Frequency	Percentage
30-day mortality	1	0.8%
Perioperative myocardial infarction	1	0.8%
Perioperative cerebrovascular accident	1	0.8%
Return for bleeding	2	1.6 %
Wound infection	0	0.0%
Phrenic nerve palsy	1	0.8%
Prolonged hospitalization	2	1.6%
Brachial artery embolism	1	0.8%
Pericardial effusion	1	0.8%
Pleural effusion requiring intervention	2	1.6%

block and ligate the left atrial appendage using an endoloop technique under transesophageal echo guidance.

Mean length of hospital stay was 3.3 ± 2.4 days. There was 1 postoperative death and one perioperative stroke in the same patient (an 85-year-old vasculopathic patient, who underwent carotid endarterectomy 2 days prior to an uneventful single vessel TECAB and suffered a large ipsilateral stroke 5 days postoperatively, just prior to being discharged); 1 perioperative myocardial infarction and 2 patients returned for bleeding (performed through the robotic ports.) Other complications included 1 phrenic nerve palsy, 1 pericardial effusion, 2 prolonged hospitalization (>10 days for respiratory failure), and 1 brachial artery embolism (in a patient with postoperative atrial fibrillation) (Table 3).

Three patients underwent preoperative PCI to the RCA as management for an acute coronary syndrome and returned for interval TECAB for LAD disease. There were 18 patients who underwent TECAB and then subsequent hybrid revascularization with PCI to the RCA (12) or circumflex branches (6) at 4 to 6 weeks. Graft patency was evaluated in these patients (Fig 5) plus an additional group of 50 patients who agreed to return for postoper-

Table 4. Patency Outcomes

Outcome	No. (%)
Grafts	85
Patients	68
Coronary angiogram (hybrid with postoperative PCI)	18
MDCT angiogram	50
Mean patency follow-up	126 ± 90 days
Overall patency	80/85 (94.1%)
Patency in 56 LIMA LAD grafts	55/56 (98.2%)

LAD = left anterior descending; LIMA = left internal mammary artery; MDCT = multidetector computed tomography; PCI = percutaneous coronary intervention.

ative multidetector computed tomographic angiogram, for a total of 85 grafts in 68 patients. Overall graft patency was 94.1% (80 of 85 grafts studied) at a mean follow-up of 126 ± 90 days (Table 4). The patency in 56 LIMA-LAD grafts was 98.2%.

Of the 5 occluded grafts, all had acceptable intraoperative transit time flow. One patient had an occluded sequential LIMA graft to a small LAD with patency in the first part of the graft to a large diagonal branch, 1 patient had an occluded LIMA-LAD at 8 months after it was shown to be patent at 4 weeks (on computed tomographic angiogram obtained for vague chest pain), 1 patient had an occluded RIMA LAD graft possibly secondary to steal from a large first intercostal branch, 1 patient had an occluded T graft segment to the Ramus branch with patent LIMA-LAD, and 1 patient had a failed LIMA graft to a totally occluded OM1. This was the only patient to undergo redo coronary bypass; 3 of the other 4 occluded grafts required percutaneous revascularization and 1 was treated medically.

Clinical follow-up at 6 to 10 months (mean 7.2 ± 2.2) on all the patients (including the 52 who did not undergo computed tomographic angiography or angiography) was obtained by contacting the patients or their referring

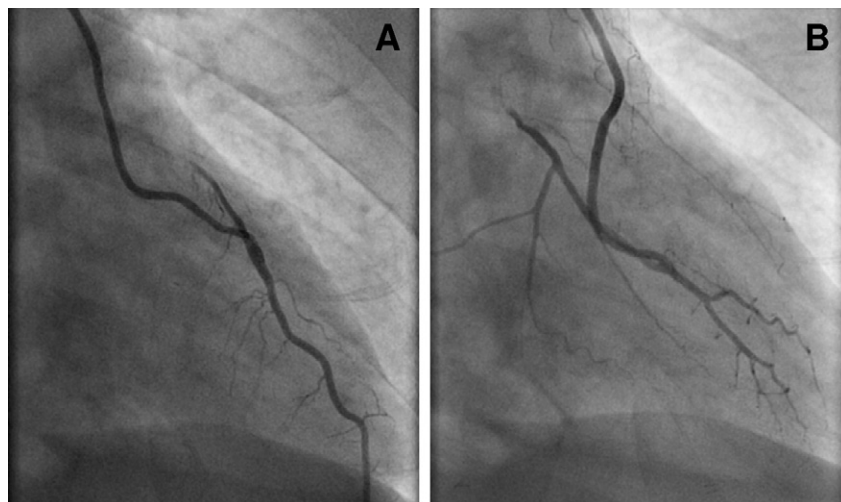


Fig 5. Postoperative angiogram in multivessel totally endoscopic coronary artery bypass. (A) right internal mammary artery-left anterior descending and (B) left internal mammary artery-OM1.

physician's office. Of the 52 patients without angiographic follow-up, all were alive; there were no surgical or catheter reinterventions, and no myocardial infarctions. All patients were free of angina except 1 patient who complained of recurrent stable angina but refused catheterization and was managed medically.

Comment

The da Vinci robot was cleared for clinical use in cardiac revascularization in July 2004. A multicenter trial for endoscopic on-pump coronary bypass using peripheral cannulation showed excellent patency of LIMA-LAD grafts [2]. Since that time, multiple centers have published experiences with various approaches to coronary bypass using robotic technology, ranging from single and double IMA takedown followed by MIDCAB [3], to on-pump arrested heart totally endoscopic CABG [4, 5], to off-pump beating heart endoscopic CABG [6]. The latter procedure has not been implemented widely because of multiple factors, including the inability of older 3-arm systems to allow for adequate dexterity inside the chest, difficulty with creating the anastomosis endoscopically on the beating heart, and lack of sufficient referrals to help get through a learning curve.

Recent enhancements in robotic technology have improved upon this situation. Notably with the availability of a fourth telemanipulator arm, better visualization in three-dimensional HD vision, improved finger-tip control, and more robotic instruments, particularly the EndoWrist stabilizer.

The C-Port distal anastomotic connector was cleared for use in the US in November 2005 based on a multicenter European trial that showed greater than 95% vein graft patency at 6 months [7]. We showed a 97% early patency of IMA grafts using later generations of the device in off-pump coronary bypass grafting [8].

The C-Port device creates an end to side anastomosis using multiple interrupted stainless-steel clips (Fig 6). The flexible shaft of the Flex A allows its introduction

through a port and facilitates a truly endoscopic approach to coronary bypass. This technology has been an integral part of our robotic endoscopic program. It is a clear improvement on previous attempts at totally endoscopic grafting as it simplifies the creation of the anastomosis with very little ischemia time and a consistently reproducible result. We have become comfortable with using the C Port device in all open coronary revascularization procedures since 2006, including saphenous vein and arterial grafts. Midterm and longer-term patency results are proving to be as good, or better, than hand-sewn anastomoses [9, 10].

Our first 10 patients (not included in the overall analysis) constituted the early experience with robotic-assisted CABG and were performed with the table-mounted Medtronic TE Endo-stabilizer prior to the availability of the Intuitive EndoWrist stabilizer. All of these procedures were off-pump single-vessel LIMA LAD cases. The greatest difficulty was related to the stabilizer. All patients were discharged home in stable condition with an average hospital stay of 4.8 days. Nine of 10 grafts were patent at 3 months by computed tomographic angiography. The biggest lesson learned was that the table-mounted stabilizer was not going to be the solution to performing TECAB.

Suitable patients for robotic endoscopic bypass grafting are patients who have LAD, diagonal branch or high circumflex marginal targets. Right coronary targets are not easily accessed unless it is in the setting of isolated proximal RCA stenosis, where right-sided ports can be used. Patients who present emergently have poor cardiac function and redo patients are not good candidates for TECAB. Finally, the most common reason for exclusion is patients who cannot tolerate single lung ventilation or have extensive left chest adhesions.

It is very important to gain an extensive experience with the C-Port anastomotic device in open chest coronary procedures and to be in one's comfort zone prior to embarking on using it in the closed chest setting. This cannot be overemphasized and will help surgeons understand the nuances of loading and firing, as well as bailout solutions and repair options when needed.

We feel that our midterm patency rate of 94.1% in all grafts evaluated is acceptable but can definitely be improved upon with added experience. Our patency of 98.2% in the 56 LIMA-LAD grafts evaluated is consistent with studies in the literature using traditional techniques [11]. The lack of angiographic follow-up in 52 patients is certainly a weakness of this study; however, midterm clinical follow-up revealed all but 1 patient to be free from angina or major adverse cardiovascular events.

Adapting robotics in a variety of procedures is very helpful in speeding up the learning curve. Not many patients are referred for single-vessel coronary disease; therefore, in patients with multivessel disease who may not seem candidates for an endoscopic approach, the possibility of hybrid revascularization can be explored to avoid sternotomy. Multiple groups have reported on the

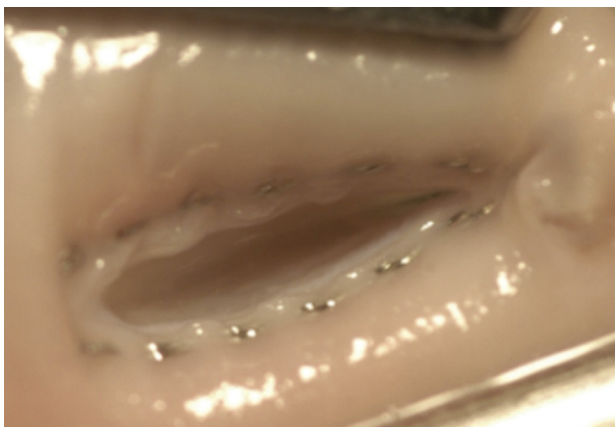


Fig 6. Intraluminal view of C-Port anastomosis.

success of this approach in multivessel revascularization in appropriate patients either as a staged procedure or simultaneously in a hybrid operating suite [12]. Conventional CABG procedures would still be the only option in patients who have diffuse and complex multivessel lesions (high Syntax score).

It is important to measure the outcomes of these minimally invasive approaches to treating multivessel CAD very carefully and include not only intraoperative and in-hospital measures but also other important measures such as return to full function and return to work. This is the only way to appreciate the full impact of less invasive strategies [13].

In conclusion, robotic endoscopic single and multivessel connector beating heart coronary bypass is a safe and reproducible procedure, with excellent short-term and midterm outcomes using new advances in robotic and anastomotic technology. An extensive experience with off-pump coronary bypass, anastomotic connectors, and da Vinci revascularization approaches is necessary before adapting this technique. Surgeons should begin with single-vessel cases before moving on to multivessel procedures. Long-term follow-up is clearly warranted to evaluate graft patency and the effect of this minimally invasive approach on postoperative recovery and return to function.

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INVITED COMMENTARY

The article by Balkhy and colleagues [1] refocuses the therapeutic options for coronary revascularization in a landscape of expanding opportunities for robotic cardiac surgery. The impact of robotic technology is unmistakable with the evident explosion of robotic applications in urologic, gynecologic, gastrointestinal, cardiac, and thoracic surgery. Many major medical centers are experiencing increasing demand and competition for “robot time,” with the advent of “robot committees” to adjudicate the allocation of robotic operating room slots to various surgeons and subspecialties.

Most robotic surgeons have become proficient at harvesting the left internal mammary artery (LIMA) followed by direct revascularization of the left anterior descending artery through a small anterior thoracotomy. While robotic harvesting of the LIMA has been a stan-

dard part of the training progression for many robotic surgeons, only a small subset of this emerging breed has expanded the robotic applications to completely robotic multivessel revascularization.

Balkhy and his colleagues [1] report a remarkable series of patients who underwent completely robotic revascularization of the left anterior descending, diagonal and high circumflex (Cfx) marginal branches. The use of sophisticated stapling devices has facilitated these operations, and the 94% LIMA patency rate at 4 months is certainly respectable. Juxtaposed against this reported experience is the concern of many cardiac surgeons experienced in robotic surgery that current robotic suture techniques and anastomotic stapling devices may not yet be refined enough to compete with the accuracy of direct surgical suturing techniques. Additional analyses of ex-