Featured Article

Bilateral internal thoracic artery grafting in robotic beating-heart totally endoscopic coronary artery bypass: 10-year outcomes

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Background: Multi-arterial grafting (MAG) with bilateral internal thoracic arteries (BITAs) is superior to single internal thoracic artery (ITA) and veins, however, sternal wound infection (SWI) is a deterrent to using BITA, especially in diabetic and obese patients. Sternal-sparing approaches, including robotic totally endoscopic coronary artery bypass (TECAB), may mitigate this risk. We reviewed outcomes of robotic TECAB with BITA grafting.

Methods: A total of 871 patients underwent robotic TECAB at our institution from 7/2013 to 4/2024. Of these, 406 patients received BITA grafts and are the subject of this review. Early and mid-term clinical outcomes were reviewed and angiographic patency in those undergoing hybrid revascularization with percutaneous coronary intervention (PCI) after TECAB. All cases were performed via a beating-heart robotic approach, with standard TECAB port placement.

Results: The mean age of the cohort was 67±9 years and 16% were female. The mean Society of Thoracic Surgeons (STS) risk was 1.47%±2.2%. Thirty-nine percent were diabetic (15% insulin-dependent) and 39% had a body mass index (BMI) ≥30 kg/m^2. Twenty percent had an ejection fraction (EF) ≤40%. Ninety-eight percent of cases were completed off-pump and there were no conversions to sternotomy. The mean number of grafts per patient was 2.2±0.4. The mean intensive care unit (ICU) and hospital length of stay (LOS) were 1.22±0.62 and 2.44±0.83 days, respectively. Postoperative complications included atrial fibrillation in 13%, acute kidney injury (AKI) in 3.4%, return to theatre for bleeding in 0.7%, postoperative myocardial infarction (MI) in 0.2%, and stroke in 0.2%. Thirty-day mortality was 1.2% [observed/expected (O/E): 0.89]. Return to full activities and work occurred at mean of 14±8.6 and 17±13 days, respectively. Two hundred and two patients (50%) had 'advanced' hybrid revascularization (with at least two arterial grafts and stents). ITA early graft patency in this cohort of patients was 271/278 (98%) with 100% left ITA to left anterior descending artery (LITA-LAD) patency. Mid-term follow-up was complete in all patients at mean of 51±36 months (longest follow-up at 10 years). All-cause mortality was 13% and cardiac-mortality was 2.5%. Freedom from angina was 96%, and freedom from repeat revascularization was 94%.

Conclusions: Use of the beating-heart robotic TECAB approach facilitates BITA grafting to achieve multi-vessel arterial revascularization of the left coronary system, with excellent 10-year outcomes.

Keywords: Robotic; totally endoscopic coronary artery bypass (TECAB); coronary artery bypass grafting (CABG); minimally invasive; coronary artery disease (CAD)

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Introduction

The use of bilateral internal thoracic artery (BITA) grafts in coronary artery bypass grafting (CABG) surgery has been associated with better outcomes than single ITA grafting in patients with multivessel coronary artery disease (CAD). Robotic off-pump totally endoscopic coronary artery bypass (TECAB) represents the least invasive form of surgical coronary revascularization. In specialized centers it can offer swift recovery and good long-term outcomes and graft patency. The sternal-sparing robotic-assisted approach allows for harvesting of both ITA grafts with no risk of sternal wound complications. In this study, we present the 10-year follow-up on our series of patients undergoing robotic TECAB with bilateral ITA grafts at a single institution in the setting of a multi-spectrum robotic cardiac surgery practice. In addition to demonstrating the safety and feasibility of this approach, we present good mid-term clinical outcomes as well as early graft patency in patients undergoing hybrid revascularization.

Methods

Study population

Eight hundred and seventy-one patients underwent robotic-assisted, beating-heart TECAB between 7/2013 and 4/2024 (single surgeon/institution). Of these, 406 underwent BITA grafting and are the subject of this review. Clinical outcomes were retrospectively reviewed from our prospectively collected database with Institutional Review Board approval (#18-0742; date of approval 4/28/2020). Angiographic data were reviewed in patients undergoing percutaneous coronary intervention (PCI) after TECAB in the setting of hybrid coronary revascularization (HCR). Mid-term clinical data were collected from annual patient contact (phone calls, email, or family/cardiologist contact). Major adverse cardiac and cerebrovascular events (MACCEs) included cardiac-related mortality, myocardial infarction (MI), repeat cardiac surgery, repeat revascularization to the surgical culprit vessel, and/or stroke.

Selection and surgical technique

We have previously described our robotic-assisted, beating-heart TECAB surgical technique in detail (1-3). See *Figure 1* for example of BITA after skeletonized harvesting. We detailed our technique for multi-vessel grafting with BITA, specifically, in two recent publications (4,5). Patients are considered for TECAB on an all-comer basis, according to the recommendations of the heart-team as previously reported. Patients are referred (either by cardiologist or self-referral) typically seeking a sternal-sparing option for coronary revascularization. All are discussed within the heart team, specifically with interventional cardiology in cases of multi-vessel disease to ensure hybrid revascularization can be achieved when needed. The only absolute exclusion criteria for TECAB are a fused left chest, or emergency surgery.

Statistical analysis

Continuous variables were tested for normality using the Shapiro-Wilk test. Those with normal distribution are expressed as mean ± standard deviation, and those without as median (interquartile range). Categorical and sequential variables are expressed as the number and percentage of patients. Kaplan-Meier analysis was applied for mid-term survival rate and freedom from major adverse cardiac events (MACEs). A P value <0.05 was considered statistically significant. The statistical analyses were conducted using IBM SPSS 25 (IBM, Inc., Chicago, IL, USA).

Results

Of a total of 871 patients undergoing TECAB during the study period, 470 patients (54%) had multi-vessel grafting and of these, 406 (86%) received BITA grafts. Demographics are shown in *Table 1*. The mean Society of Thoracic Surgeons (STS) predicted risk of mortality (PROM) score was 1.47%±2.2%. The mean age of the patient cohort was 67±9 years, with 16% female. Comorbidities in the patient cohort included those 87% with hypertension, 26% with prior MI, and 22% with chronic kidney disease. Thirty-nine percent had diabetes and 38% of these (15% overall) had insulin-dependent diabetes mellitus (IDDM). The mean body mass index (BMI) was 29±5 kg/m^2. Thirty-nine percent of patients had a BMI ≥30 kg/m^2, 11% had a BMI ≥35 kg/m^2, and 4% had BMI ≥40 kg/m^2. Three patients had undergone prior heart surgery [one of these prior CABG with vein grafts to obtuse marginal (OM) and right coronary artery (RCA)].

Three hundred and forty-two patients (84%) underwent TECAB grafting (two grafts), 15% had three grafts, and two patients had four grafts. The mean number of grafts per patient was 2.2±0.4 (see *Table 2* regarding graft details). The most common grafting configuration (63%) was LITA-

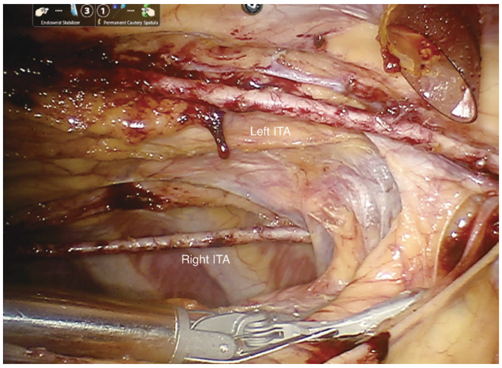

Figure 1 Demonstration of BITAs after robotic-assisted skeletonized harvesting. ITA, internal thoracic artery; BITA, bilateral internal thoracic artery.

Table 1 Preoperative characteristics

Variables	Data (n=406)
Age (years)	67±9
Female gender	66 [16]
STS score (%)	1.47±2.2
BMI >30 kg/m^2	158 [39]
Hypertension	354 [87]
Diabetes mellitus	158 [39]
IDDM	60 [15]
Chronic renal failure	88 [22]
Renal failure on dialysis	10 [2.5]
COPD	20 [4.9]
EF ≤40%	79 [20]
Atrial fibrillation	39 [9.6]
Prior cerebrovascular accident	37 [9.1]
Prior MI	104 [26]
Prior PCI	147 [36]
Previous cardiac surgery	3[†] [0.7]
Angina	202 [50]
Left main disease ≥70%	73 [18]

Data are presented as mean ± SD or n [%]. [†], one previous coronary artery bypass. STS, Society of Thoracic Surgeons; BMI, body mass index; IDDM, insulin-dependent diabetes mellitus; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; MI, myocardial infarction; PCI, percutaneous coronary intervention; SD, standard deviation.

Table 2 Graft information

Variables	Data (n=878)
Grafts per patient	2.2±0.4
LITA flow (cc/min)	84±42
LITA PI	1.4±0.4
RITA flow (cc/min)	74±35
RITA PI	1.6±0.5
Anastomosis technique	
Anastomotic device (C-Port Flex A)	397 [45]
Sutured (7-0 Pronova)	466 [53]
U-clips	15 [2]
Redo anastomosis	6 [0.7]

Data are presented as mean ± SD or n [%]. LITA, left internal thoracic artery; PI, pulsatility index; RITA, right internal thoracic artery; SD, standard deviation.

LAD, and right ITA (RITA) to an anterior non-LAD or lateral wall target. The LAD was grafted with LITA in 65% and RITA in 35%. In the first 5 years, the distal anastomosis was performed using the C-Port Flex A anastomotic device for a majority of the grafts (45% overall), and in the latter 5 years, a robotic suture technique was used in the majority of patients due to the device being taken off the market. A total of seven patients required the use of cardiopulmonary bypass (CPB) via peripheral femoral cannulation, with five for hemodynamic support due to difficult target exposure and two for planned concomitant intra-cardiac procedures. The remaining cases were all completed off-pump, on a beating-heart. The intraoperative blood transfusion requirement was 6%. The mean operative time was 313 min. There were no conversions to sternotomy. See *Table 3*.

The mean hospital and intensive care unit (ICU) length of stay (LOS) were 2.44±0.83 and 1.22±0.62 days, respectively. Eight percent of patients required postoperative blood transfusion. Thirteen percent had new-onset atrial fibrillation, 1.2% had pericarditis, and 3.4% had postoperative acute kidney injury (AKI). There were no wound infections. There was one incidence of MI and one stroke, respectively (0.2% each). Three patients (0.7%) required return to theatre for bleeding which necessitated sternotomy in two cases. Mortality occurred in five patients with an observed/expected (O/E) ratio of 0.89 (O/E: postoperative mortality incidence/

Table 3 Intraoperative data

Variables	Data (n=406)
Operative time (min)	313±58
TECAB graft	
Two grafts	342 [84]
Three grafts	62 [15]
Four grafts	2 [0.5]
CPB use	7 [1.7]
Inotrope requirement	5 [1.2]
Intraoperative BTF use	24 [5.9]
Conversion	0
OR extubation	154 [38]

Data are presented as mean ± SD or n [%]. TECAB, totally endoscopic coronary artery bypass surgery; CPB, cardiopulmonary bypass; BTF, blood transfusion; OR, operating room; SD, standard deviation.

Table 4 Early postoperative outcomes

Postoperative variables	Data (n=406)
Extubation within 6 hours	325 [80]
Post-operative BTF use	33 [8.1]
Chest tube drainage total (mL)	651±296
Chest tube drainage 24 hours (mL)	588±244
ICU LOS (days)	1.22±0.62
Hospital LOS (days)	2.44±0.83
Mortality	5 [1.2]
Mortality, O/E	0.89
Readmission	21 [5.2]
Mean time to return to full activities (days)	14±8.6
Mean time to return to work (days)	17±13

Data are presented as n [%], mean ± SD, or ratio. BTF, blood transfusion; CU, intensive care unit; LOS, length of stay; O/E, observed/expected; SD, standard deviation.

Table 5 Early postoperative adverse events

Postoperative variables	Data (n=406)
Reintubation	6 [1.5]
Prolonged ventilation (>24 hours)	5 [1.2]
Wound infection	0
AKI	14 [3.4]
Pericarditis	5 [1.2]
Pleural effusion	12 [3.0]
Clinical MI	1 [0.2]
New atrial fibrillation	54 [13]
Sepsis	1 [0.2]
Stroke or TIA	1 [0.2]
Re-exploration for bleeding	3 [0.7]

Data are presented as n [%]. AKI, acute kidney injury; MI, myocardial infarction; TIA, transient ischemic attack.

preoperative STS PROM). See *Tables 4,5*. At 30-day follow-up, the readmission rate was 5%, and 3% of patients had a pleural effusion requiring thoracentesis. The mean time to return to full activities and work was 14 and 17 days, respectively. All patients were reached for mid-term clinical follow-up (mean follow-up 51±36 months). The longest follow-up was 10.4 years. All-cause mortality was 13%, and cardiac-related mortality was 2.5%. See *Figures 2,3*. Repeat cardiac surgery occurred in six patients. Two patients underwent redo-CABG, one occurred 3.5 years after TECAB (despite having a patent LITA-LAD at the time of hybrid RCA stenting), and one 3.5 years after TECAB due to high-grade left main disease. One patient required aortic valve replacement (AVR) 2 years postoperatively. Three patients with pre-operative ischemic cardiomyopathy went on to advanced surgical therapy [two patients had a heart transplant, and one required left ventricular assist device (LVAD) placement]. All had patent grafts. The incidence of MI and unplanned PCI was 1.7% and 5.9%, respectively. Of the 18 patients undergoing repeat percutaneous intervention, only one was for a failed surgical graft. Freedom from angina was 96%, and freedom from MACE was 92% (*Table 6*). See *Figures 2-4* for Kaplan-Meier survival curves demonstrating key mid-term outcomes.

Two hundred and two patients (50%) were selected for an advanced hybrid coronary revascularization (AHCR) strategy (BITA grafting plus PCI). Of these, 94% had surgery first, followed by staged PCI. The mean time to catheterization for these patients undergoing PCI after TECAB was 2.3±5.3 months. Overall, graft patency was 98% (271/278 grafts). Overall, RITA patency was 96%

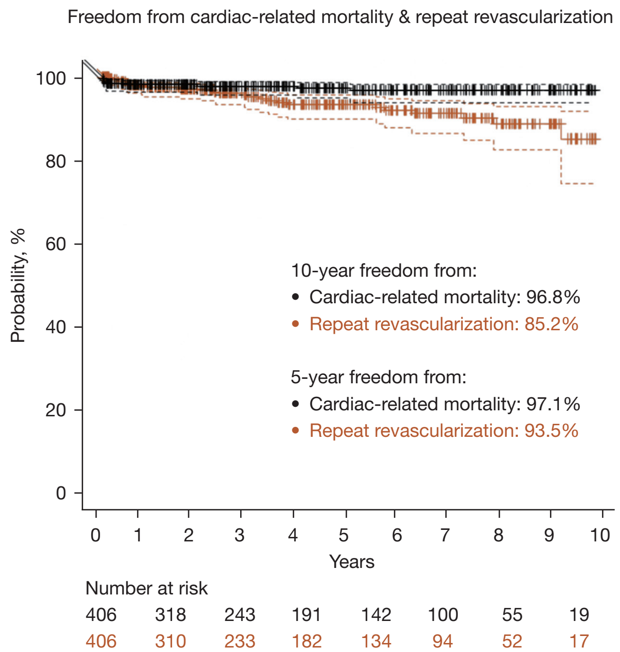

Figure 2 Kaplan-Meier survival curve: freedom from cardiac-related mortality and repeat revascularization.

Table 6 Mid-term follow-up

Mid-term variables	Data (n=406)
Average time to follow-up (months)	51±36
All-cause mortality	54 [13]
Cardiac-related mortality	10 [2.5]
Repeat cardiac surgery	5 [1.2]
MI	7 [1.7]
Repeat angiography	56 [14]
Unplanned PCI	24 [5.9]
Unplanned PCI in culprit (surgical) vessel	11 [2.7]
Unplanned PCI in culprit (PCI) vessel	4 [1.0]
PCI for failed graft	1 [0.2]
Freedom from angina	391 [96]
Freedom from MACCEs	375 [92]

Data are presented as mean ± SD or n [%]. MI, myocardial infarction; PCI, percutaneous coronary intervention; MACCE, major adverse cardiac and cerebrovascular event; SD, standard deviation.

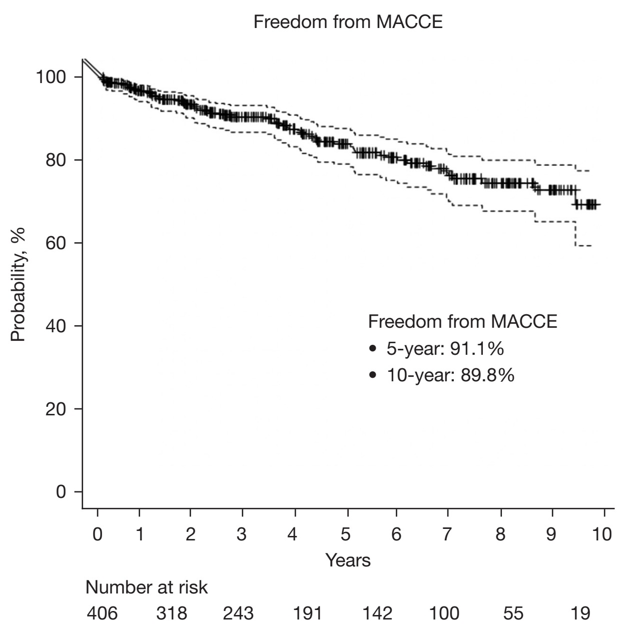

Figure 3 Kaplan-Meier survival curve: MACCE. MACCE, major adverse cardiac and cerebrovascular event.

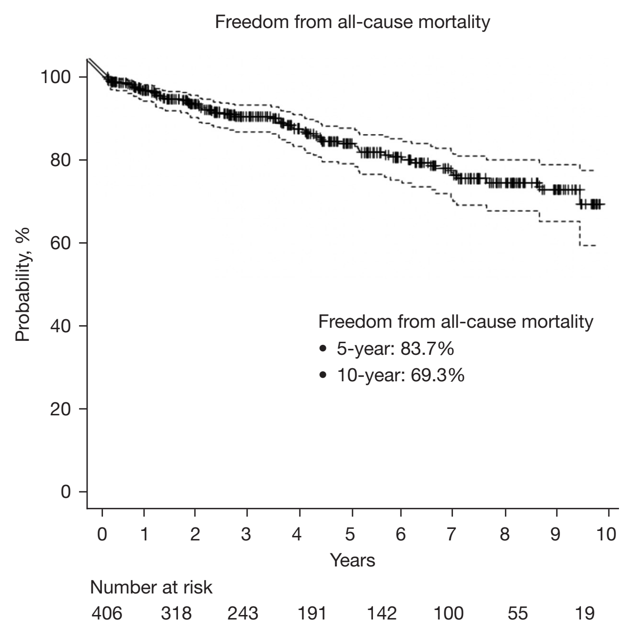

Figure 4 Kaplan-Meier survival curve: freedom from all-cause mortality.

Table 7 Early graft patency (patients undergoing PCI after TECAB)

Early graft patency	Data (n=135)
Time to catheterization (months)	2.3±5.3
Total IMA grafts imaged	278
Graft patency (n=278)	271 [98]
LITA patency (n=142)	141 [99]
RITA patency (n=136)	130 [96]
LITA-LAD patency (n=85)	85 [100]

Data are presented as mean ± SD, n, or n [%]. PCI, percutaneous coronary intervention; TECAB, totally endoscopic coronary artery bypass; IMA, internal mammary artery; LITA, left internal thoracic artery; RITA, right internal thoracic artery; LAD, left anterior descending; SD, standard deviation.

(130/136 grafts). Overall, LITA patency was 99% (141/142 grafts), with 100% LITA-LAD patency (*Table 7*).

Discussion

We present a series of 406 patients undergoing robotic-assisted beating-heart TECAB with BITA grafting over a 10-year period, with good early and mid-term outcomes. This is part of a multi-arterial grafting (MAG) strategy, where we employ an exclusive ITA conduit strategy in all patients undergoing multi-vessel TECAB. To our knowledge, this is the largest reported series of BITA grafting via a totally-endoscopic, off-pump robotic approach. The notable benefits of this sternal-sparing technique in coronary revascularization as it relates to BITA use are: maintaining an all-arterial grafting strategy, achieving complete revascularization (using a hybrid revascularization strategy in half the patients), and eliminating the risk of sternal wound infection (SWI).

MAG and total arterial grafting (TAG) in surgical revascularization has been shown to have superior outcomes compared to single arterial grafting (SAG) (6). Multiple studies have demonstrated improved long-term survival and lower rates of repeat revascularization/other MACE with MAG compared to SAG (7-11). Rocha *et al.* in a multi-center, propensity-matched study comparing CABG patients who received TAG (~5% overall) to those who did not demonstrate better survival and lower MACCEs/MI at 8 years in the TAG group (12). In another recent meta-analysis of 44 studies comparing MAG to SAG, median survival (at 17.5 and 11.6 years, respectively), both overall and event-free, were higher in the MAG group (13).

Specifically with regard to BITA grafting, several studies have demonstrated long-term survival benefits compared to single vessel ITA (SITA). This includes in overall CABG populations (14-17), elderly patients (18,19), low ejection fraction (EF) (20), reported "high-risk" patients (21), and importantly, those with diabetes (9,22,23). Despite this well-documented evidence, the use of both TAG (5% overall in the aforementioned Rocha *et al.* study) and BITA remain remarkably low across the US (6,8,21). When considering conduit choice for a second arterial graft in addition to the LITA, several studies have demonstrated a long-term survival benefit with use of RITA as a 2nd arterial conduit, even when compared to the radial artery (RA) (13,24,25).

As is known, the only randomized trial of BITA *vs.* SITA in CABG (ART trial) failed to show superiority of BITA over SITA grafting in the 'intent-to-treat' analysis, however, this can be attributed to multiple factors including a significant crossover rate, as well as the inclusion of RA grafts in the SITA group. In the as-treated analysis, BITA grafting was indeed shown to be superior to SITA in this trial (26). Because of this, the ROMA trial is currently underway. It is a prospective, randomized multicenter study evaluating MAG using RITA or RA as a second arterial conduit. The results of this trial, as well as the equivalent study with female participants only (ROMA women), will provide more information on best practices in total and MAG (7).

Frequently cited reasons for hesitancy in using BITA grafting include concern for SWI and longer operative time required for BITA harvesting, in addition to those specifically related to the technical aspects of using the RITA such as: lack of familiarity, concern over the length of RITA, or grafting configuration (6,9,23). Sternal wound complications/infections remain the primary concern with BITA. Although several studies have shown no difference in SWI rates between SITA and BITA, including in diabetic patients (22,23,27), there have been studies with contradictory findings and therefore this debate is ongoing. Given these potential difficulties of RITA harvesting and use in traditional CABG surgery, utilization of this conduit received only a class IIB indication in both the European Society of Cardiology/European Association for Cardiothoracic Surgery (ESC/EACTS) as well as the STS current guidelines, whereas the use of a RA graft received a class I indication in targets with high-grade stenosis (28).

However, we believe that the potential drawbacks of routine BITA harvesting are "easily" mitigated using a robotic endoscopic surgical approach, or indeed any approach in which the sternum is left intact. Given this, the inclusion/exclusion criteria in this series were not limited by the concern for SWIs. In our practice, patients are considered on a nearly all-comer basis for TECAB, including those with obesity, diabetes (including insulin-dependent), women, elderly, etc. In this series, diabetics and patients with a BMI above 35 constituted 39% and 11% of patients, respectively. The link between complete revascularization and improved long-term outcomes is well-documented (29,30). Glineur *et al.* evaluated patients with >2-vessel CAD undergoing multivessel grafting with BITA plus either additional arterial Y grafts or vein grafts. In comparison, they found at 14 years the BITA + Y arterial grafting group had better survival compared to the BITA + vein group (31). Bakaeen *et al.* importantly found that in BITA grafting, placing a second ITA to another major left coronary target was associated with higher long-term survival, whereas use of vein grafts did not have this survival benefit (32). In our TECAB practice, we ensure complete revascularization in patients with multi-vessel disease through either a third (or rarely, fourth) arterial graft via a sequential or Y technique with BITA; and/or through an AHCR strategy. AHCR achieves sternal-sparing complete revascularization in patients with multi-vessel CAD through the integration of two ITA grafts with PCI (the latter typically to right-sided targets). We recently described a series of 156 patients undergoing AHCR with good early and mid-term clinical outcomes, and an overall early graft patency of 98%. In that study, the mean residual SYNTAX score after AHCR was 2.6±3.0. In another previous report looking at our AHCR TECAB experience, we found that 86% of patients had complete/near-complete revascularization (defined by a residual SYNTAX score <8), which was associated with improved survival and lower MACCEs (5). In the present study, 202 patients (50%) were assigned to an AHCR strategy.

Another cited reason for low use of BITA is lack of familiarity in harvesting RITA/BITA conduits. This potentially could be even more true in a minimally invasive/endoscopic setting if one is not comfortable with these techniques. We recommend mastering RITA/BITA harvesting in the open setting prior to transitioning to a robotic-assisted endoscopic approach. In addition, we believe that the use of the robot as frequently as possible for multiple different types of procedures can be important in the success of a robotic multi-vessel TECAB program (33). In our practice, this strategy has allowed the robot to become simply another instrument/tool that all theatre staff are very familiar and comfortable with. The learning curve for robotic BITA harvesting can differ based on the surgeon's experience, however, once LITA harvesting is mastered it should not be difficult to cross the midline and harvest the RITA as the technique is near identical. The epicardial Endowrist Stabilizer™ (Intuitive Surgical, Sunnyvale, CA, USA), which is an essential tool for robotic endoscopic grafting, is also useful for aiding in RITA harvesting by gently depressing anterior mediastinal structures when crossing the midline. While our ITA harvesting technique has not changed significantly over time, our anastomotic technique has. We transitioned from a coronary stapler device, which was available until about 2018, to a robotic-assisted sutured technique for all anastomoses once the stapler device was removed from the market. We use a 7-0 double-armed Pronova suture and routinely shunt all anastomoses (34). Again, the importance of the stabilizer in the overall performance of robotic beating-heart TECAB cannot be understated or over-emphasized.

In addition to robotic-assisted CABG, minimally invasive approaches are being increasingly used for multi-vessel grafting and include mini-thoracotomy BITA grafting with or without thoracoscopic assistance to increase visualization (35). BITA use in this realm has been reported with good outcomes, although its widespread use (like in traditional CABG) remains low (36-38). These approaches, similar to TECAB, offer the significant advantages of reduced recovery time while still being able to employ bilateral ITAs in the context of sternal-sparing complete revascularization (± AHCR). We believe, however, that the totally endoscopic off-pump approach described here with robotic assistance remains the least invasive form of surgical coronary revascularization. Some of the advantages of adding the robotic approach include the enhanced visualization and ergonomics for the surgeon as well as the potential for offering the procedure to patients with less than ideal anatomy (e.g., morbidly obese).

We prefer to skeletonize ITA conduits. In the open setting, skeletonization has been shown to have equivalent or even lower rates of SWIs, increase length of the conduit, and increase anastomotic flow rate (39-41). There have also been studies comparing patency between skeletonized *vs.* pedicled ITA grafts, with some studies finding no difference in patency between the two techniques, and others finding higher patency in pedicled grafts. However, the advantage of the superior visualization from the robotic approach cannot be understated in this regard, as it lends itself to high precision and careful maneuvering around the conduit, and thus facilitates skeletonization.

Our approach to graft configuration when using BITA in robotic multi-vessel TECAB is that we aim to maintain a LITA-LAD configuration as much as possible and most commonly use the *in-situ* RITA for a second important left coronary target. If the lateral wall cannot be reached with *in-situ* RITA, then we use LITA for this and place the RITA on the LAD. If the *in-situ* RITA will reach neither, it is configured as a Y graft off of the LITA to a lateral wall target. There have been multiple studies comparing between RITA-LAD *vs.* LITA-LAD patency, revealing no difference in mid/long-term patency or clinical outcomes (42-45). We looked at this in our robotic TECAB population in a recent study comparing between these two groups and found no difference in early clinical outcomes or graft patency between RITA *vs.* LITA-LAD. In a propensity-matched sub-analysis of only patients with multi-vessel disease undergoing BITA grafting in each group, we found no differences in patency or midterm clinical outcomes (46).

Finally, a word about the future. Robotics in cardiac surgery is growing overall as patients increasingly request sternal-sparing options and as surgeons are introduced to robotics early in their surgical training. Increased adoption and utilization of this technology by our specialty will not only allow us to respond to the desires of our patients, but also be competitive in this era of rapidly growing transcatheter options in the treatment of heart diseases. One potential and increasingly discussed direction forward is designating coronary revascularization as a sub-specialty within cardiac surgery. In this realm, TAG with more common use of BITA and use of the least invasive approaches and technologies, i.e., off-pump bypass and robotics, could be offered on a routine basis. It would also allow for the re-engagement of our partners in the surgical device industry so that technology, such as the epicardial stabilizer (necessary for TECAB or any off-pump robotic procedure) or automated anastomotic devices (something we believe facilitates TECAB), can be available again, and new technologies in coronary revascularization can once more be developed.

Conclusions

We conclude that in the setting of a dedicated robotic cardiac program, patients with multi-vessel CAD can undergo bilateral ITA grafting using the least invasive surgical approach: robotic beating-heart TECAB. In addition to excellent early clinical outcomes and swift recovery, we demonstrate good midterm outcomes at 10 years and good graft patency comparable to traditional CABG, with the added benefit of no sternal wound complications using this sternal-sparing approach.

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Footnote

Conflicts of Interest: H.H.B. is a proctor for Intuitive Surgical. The other authors have no conflicts of interest to declare.

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