Preliminary experience and mid-term follow-up of a minimally invasive revascularisation technique

Robotic coronary revascularisation

Aristotelis Panos[a,b], Patrick O. Myers[b]

[a] Cardiac and Vascular Surgery Hirslanden, Clinique La Colline, Geneva
[b] Cardiovascular Surgery, Geneva University Hospitals, Geneva

Summary

Objectives: Robot-assisted coronary revascularisation is a relatively new strategy. By performing a minimally invasive left internal thoracic artery (LITA) to left anterior descending (LAD) artery bypass, we are taking advantage of the survival benefit of the LITA-to-LAD bypass while decreasing the morbidity of the procedure associated with sternal spreading. The objective was to assess clinical outcomes and graft patency at 3 years.
Methods: From March 2011 to July 2014, 17 consecutive patients were operated on, with robotic LITA harvesting and manual anastomosis to the LAD on the beating heart through a small anterior thoracotomy. Patients underwent coronary (n = 6) or computed tomographic angiography (n = 11) 1 year after the operation.
Results: All patients were successfully revascularised as planned. There were no early or late deaths. All patients were fast tracked, with extubation during the first 2 hours in the intensive care unit, or (for six of them) in the operating theatre. The mean hospital stay was 4 ± 1.1 days. No patient required reoperation or re-exploration for bleeding. Follow-up ranged from 18 to 48 months. At 1 year, all patients had a patent LITA-LAD anastomosis. All patients remain symptom-free with a negative stress test at latest follow-up.
Conclusions: Robotic LITA takedown and minimally invasive off-pump LAD revascularisation results in excellent perioperative outcomes, high graft patency and freedom from angina during follow-up.

Key words: coronary artery disease; cardiac surgery; coronary artery bypass graft; off-pump; robotic cardiac surgery

Introduction

Coronary artery bypass grafting (CABG) is an established method of treating patients with coronary artery disease [1, 2]. Despite advances in optimal medical treatment and in stents, no alternative has been able to rival the efficacy and durability of the left internal thoracic artery (LITA) to left anterior descending (LAD) coronary artery bypass graft [2]. Less invasive surgical options for performing this anastomosis have been proposed, one of which is robot-assisted coronary artery bypass (roboCAB), in which the LITA is taken down with robotic assistance, and anastomosed on the beating heart through a mini-thoracotomy [3]. Although more complicated for the surgeon, minimally invasive and robot-assisted cardiac surgery has been shown to be less traumatic for the patient and to provide faster recovery [4]. The aim of this study was to describe our initial experience with roboCAB for minimally invasive off-pump LITA to LAD CABG.

Methods

Study design

This study was a retrospective review of all patients who underwent minimally invasive roboCAB at our institution between 2011 and 2014. Patients with single LAD disease referred for CABG, who had evidence of distal ischaemia on nuclear functional testing or magnetic resonance imaging (MRI), were included. Patients with multivessel disease were excluded from this initial experience. The primary endpoint was angiographic graft patency at 1-year follow-up, and the secondary endpoint was freedom from angina at latest follow-up. Clinical or treatment variables were recorded to determine predictors of the endpoints. All patients were followed up to December 2015.

Surgical techniques

After induction of anaesthesia, a double-lumen endotracheal tube for single-lung ventilation was used. Patients were positioned in the supine position with the left elbow bent and outside the surgical table.
The da Vinci robotic system (Intuitive Surgical, Sunnyvale, CA, USA) was set-up by a dedicated nurse while the surgical tables were set up. The time necessary for this procedure is 15 minutes. The camera port was introduced into the left fifth intercostal space on the anterior axillary line. This incision was extended medially after LITA takedown to create the incision for the LITA-LAD anastomosis. After CO_2 insufflation at a pressure of 7 to 10 mm Hg and deflation of the left lung, the instrument ports were inserted through the third and the sixth intercostal spaces on the midclavicular line under thoracoscopic vision. The LITA was exposed and harvested, pedicled, from its origin to the sixth intercostal space with use of electrocautery. The time for LITA harvesting was 57 minutes (range 45–68 minutes) for the first six patients and continuously decreased to 41 minutes for the last five patients (range 35–47 minutes). After LITA harvesting, heparin was administered at half of the usual on-pump dose

(150 IU/kg), and the graft was clipped and partially divided at its distal end [3, 5]. Before the pericardium was opened, an infusion of 150 mg xylocaine was given to avoid ventricular arrhythmias. A small anterior thoracotomy was made without spreading the ribs and the LAD exposed with a soft tissue retractor (Edwards Lifesciences, Irvine, CA, USA). The LITA was then completely divided and prepared. The LAD was identified and stabilised with the help of the Octopus-NUVO TE stabiliser (Medtronic, Minneapolis, MN, USA). A coronary shunt was always used. The LITA was anastomosed manually to the LAD on a beating heart using running 8/0 polypropylene suture. We aimed for a fast-track postoperative care protocol, with rapid extubation (within 6 hours) and rapid mobilisation on the day after surgery. The additional cost of each procedure due to roboCAB, taking into account the life span of the robotic instruments ("20 lives" with four different instruments), was 723.35 CHF. The cost of the Octopus-NUVO stabiliser is 2700 CHF, which made a total cost of 3423.35 CHF per procedure.

Results

Demographics and surgical technique

From March 2011 to July 2014, 17 selected, consecutive patients were included. Patient baseline demographics and characteristics are detailed in table 1. They underwent roboCAB for stable angina and LAD disease due to chronic occlusion or stenosis unsuitable for a percutaneous approach. The mean age at operation was 45 ± 15 years. The mean left ventricular ejection fraction (LVEF) was 50 ± 15%. No patient had previously undergone cardiac surgery.

Early outcomes

All procedures were uneventful, and no patient required conversion to sternotomy or cardiopulmonary bypass. There were no re-explorations for bleeding and all had a fast-track extubation. No transfusion was required and all patients were operated on without stopping aspirin. They were discharged from the hospital on the fourth or fifth post-operative day. The mean intensive care unit (ICU) stay was 0.9 ± 0.5 days, and the mean hospital stay was 4 ± 1.1 days. One patient presented a pleural effusion (5.8%).

Late outcomes

Follow-up ranged from 18 to 48 months, during which time none of the patients reported any angina symptoms. No patient required a reoperation during late follow-up. Graft patency was assessed in all patients, six with coronary angiography and the rest with computed tomographic angiography (n = 11) at 1 year after the operation. All LITA to LAD anastomoses were patent and free from stenosis at 1 year. All patients had negative stress testing and were clinically free of angina at latest follow-up in December 2015.

Discussion

Reuthenbuch [6] reported as early as 2003 their experience with robotic LITA take-down, although the rest of the operation was continued through a median sternotomy. We introduced minimally invasive and robot-assisted surgery into our routine practice in 2008 [7] and have expanded from intracardiac repairs such as mitral [7, 8] and tricuspid [10] valve repair, to tumour resection [11] and now CABG. Standardisation of the procedures associated with minimally-invasive and robotic cardiac surgery have played a central role in achieving an easy, fast and reproducible set-up in the operating room, as we have described previously [8].

Although minimally invasive and robotic approaches in cardiac surgery have shown benefits to patients, this has been predominantly in the repair of septal defects or of the mitral and tricuspid valves [4, 12–14], and the

Table 1: Baseline patient characteristics.

Characteristic	Value
Patients	17
Age (years)	45 ± 15
Diabetes	4 (24%)
CAD	17 (100%)
LAD occlusion	15 (88%)
LAD stenosis	2 (12%)
LVEF	50 ± 15%
NYHA functional class (median)	I–II
Prior cardiac surgery	0

All data are presented as mean ± standard deviation or number (percentage), unless otherwise noted. CAD: coronary artery disease; LAD: left anterior descending coronary artery; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association.

Table 2: Patient operative and postoperative characteristics.

Characteristic	Value
Patients	17 (100%)
Robotic LITA harvesting	17 (100%)
LITA to LAD	17 (100%)
Fast track extubation <6 h	17 (100%)
ICU stay (days)	0.9 ± 0.5
Hospital stay (days)	4 ± 1.1

All data are presented as mean±standard deviation or number (percentage), unless otherwise noted. ICU: intensive care unit. LAD: left anterior descending coronary artery. LITA: left internal mammary artery.

penetrance in CABG has been limited. The three most common minimally invasive CABG procedures use a sternal-sparing approach and include minimally invasive direct coronary artery bypass (MIDCAB), robot-assisted coronary artery bypass (roboCAB), and robot-assisted totally endoscopic coronary artery bypass (TECAB) [3, 5]. Each approach has unique advantages and disadvantages. One reason robotic CABG has been slow to catch on in routine practice could be the combined difficulty in conventional LITA harvesting and the difficulty of a LITA-LAD robotic anastomosis. In roboCAB, the LITA harvest, pericardiotomy,and LAD identification are accomplished with robotic assistance, but the anastomosis is performed manually under direct vision, through a non-rib-spreading 3- to 4-cm anterior thoracotomy without cardiopulmonary bypass. This approach leverages the advantages of a minimally-invasive approach, the relatively simple takedown of the LITA with robotic assistance, while avoiding the learning curve associated with a robotic LITA-LAD anastomosis by performing this anastomosis through validated manual, direct-vision techniques through a small thoracotomy. For the LITA harvest and pericardiotomy, robotic techniques provide high-definition intrathoracic exposure, ease of three-dimensional manipulation and a smaller incision giving exposure without rib spreading, when compared with the MIDCAB LITA harvesting. These advantages overcome the difficulties of the exposure for the LITA harvesting in the setting of the MIDCAB, while keeping the major advantage of the MIDCAB, which is the quality of the direct hand-sewn anastomosis of the LITA to the LAD.

Our patients had excellent results, with no conversions or operative complications, fast-track post-operative care, 100% graft patency at 1 year and freedom from symptoms at 2 years. Given these outcomes, and increasing evidence with similar reported results [3, 5], cardiologists may be more willing to refer patients for this approach, providing patients with the best available treatment option for the LAD – the LITA – through a less invasive approach. Furthermore, patients with multivessel coronary artery disease may be referred for hybrid management, with operative roboCAB leveraging the long-term survival benefit of the LITA-LAD anastomosis while minimising invasiveness and operative risk through the percutaneous approach to other vessels.

The relatively limited additional cost of the robotic procedure may be counterbalanced by the precision of the LITA harvesting and the relatively painless, smaller and more aesthetic incisions.

Finally, although the long-term results of CABG compare favourably with those of percutaneous coronary intervention [2], stroke remains one of the main limitations of CABG. This approach, off-pump and without aortic manipulation, has the potential to decrease this Achilles' heel of CABG [14].

This study was limited by its design: a retrospective study designed to review our results after introducing a novel and standardised approach to robotically assisted minimally invasive CABG, with a relatively limited sample size at this point.

Conclusions

Robotic LITA takedown and minimally invasive off-pump revascularisation results in excellent perioperative outcomes, high graft patency and freedom from angina during follow-up.

Disclosure statement
No financial support and no other potential conflict of interest relevant to this article was reported.

References
The full list of references is included in the online article at www.cardiovascmed.ch

Correspondence:
Aristotelis Panos
Center for Robotic and Minimally Invasive Cardiac Surgery
Av de la Roseraie 76A
CH-1205 Geneva
a.panos[at]bluewin.ch

References

1 Serruys PW, Morice MC, Kappetein AP, et al. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. N Engl J Med. 2009;360:961–72.
2 Head SJ, Davierwala PM, Serruys PW, et al. Coronary artery bypass grafting vs. percutaneous coronary intervention for patients with three-vessel disease: final five-year follow-up of the SYNTAX trial. Eur Heart J. 2014;35:2821–30.
3 Halkos ME, Vassiliades TA, Myung RJ, et al. Sternotomy versus nonsternotomy LIMA-LAD grafting for single-vessel disease. The Ann Thorac Surg. 2012;94:1469–77.
4 Mihaljevic T, Jarrett CM, Gillinov AM, et al. Robotic repair of posterior mitral valve prolapse versus conventional approaches: potential realized. J Thorac Cardiovasc Surg. 2011;141:72–80 e71–74.
5 Halkos ME, Liberman HA, Devireddy C, et al. Early clinical and angiographic outcomes after robotic-assisted coronary artery bypass surgery. J Thorac Cardiovasc Surg. 2014;147:179–85.
6 Reuthebuch O, Comber M, Gruenenfelder J, Zund G, Turina M. Experiences in robotically enhanced IMA preparation as initial step towards totally endoscopic coronary artery bypass grafting. J Cardiovasc Surg. 2003;11:483–7
7 Panos A, Myers PO. Routine robotic and video-assisted mitral valve repair in everyday surgery. Cardiovasc Med. 2011;14:92–4.
8 Panos A, Vlad S, Milas F, Myers PO. Is minimally invasive mitral valve repair with artificial chords reproducible and applicable in routine surgery? Interact Cardiovasc Thorac Surg. 2015;20:707–11.
9 Myers PO, Panos A, Kalangos A. Simplifying robotic mitral valve repair: Minimizing sutures with intra-annular ring implantation. J Thorac Cardiovasc Surg. 2010;140:1441–2.
10 Panos A, Myers PO, Kalangos A. Thoracoscopic and robotic tricuspid valve annuloplasty with a biodegradable ring: an initial experience. J Heart Valve Dis. 2010;19:201–5.
11 Panos A, Myers PO. Video-assisted cardiac myxoma resection: -basket technique for complete and safe removal from the heart. The Ann Thoracic Surg. 2012;93:e109–110.
12 Mihaljevic T, Jarrett CM, Gillinov AM, Blackstone EH. A novel -running annuloplasty suture technique for robotically assisted mitral valve repair. J Thorac Cardiovasc Surg. 2010;139:1343–4.
13 Mihaljevic T, Pattakos G, Gillinov AM, et al. Robotic posterior -mitral leaflet repair: neochordal versus resectional techniques. The Ann Thorac Surg. 2013;95:787–94.
14 Chitwood WR, Jr., Rodriguez E, Chu MW, et al. Robotic mitral valve repairs in 300 patients: a single-center experience. J Thorac Cardiovasc Surg. 2008;136:436–41.
15 El Zayat H, Puskas JD, Hwang S, et al. Avoiding the clamp during off-pump coronary artery bypass reduces cerebral embolic events: results of a prospective randomized trial. Interact Cardiovasc Thorac Surg. 2012;14:12–6.