First Italian robot-enhanced coronary bypass

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This case report presents the first totally endoscopic coronary artery bypass performed with a robotic system in Italy at the Department of Cardiovascular Surgery of Padua University in December 2001. A 66-year-old male, with an indication to a single bypass of the left anterior descending coronary artery using the left mammary artery, was considered eligible for a robot-assisted myocardial revascularization using the da Vinci robotic system. The left internal mammary artery takedown was performed through three 1 cm ports on the thoracic wall. The "end-to-side" anastomosis between the mammary artery and the target coronary artery was totally performed endoscopically on a beating heart by means of a stabilizing device introduced through an additional subxiphoid port. Angiographic follow-up at 1 year showed patency of the graft. Since September 2001, robot-enhanced left mammary artery harvesting has been performed in another 18 patients without complications.

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Introduction

In the past few years we have been facing a tendency toward a progressive reduction in the size of surgical incisions in cardiac surgery, with the aim of achieving early mobilization and discharge together with better cosmetic results.

The request to perform cardiac surgery interventions with minimal trauma and maximal patient benefit has led to the development of alternative techniques directed at the avoidance of both sternotomy and cardiopulmonary bypass.

Current options for limited access myocardial revascularization procedures range from minimally invasive direct coronary artery bypass graft (CABG) via a minithoracotomy (MIDCAB) to the ultimate goal of totally endoscopic robot-assisted coronary artery bypass (TECAB).

In September 2001, the da Vinci robotic surgical system was introduced at the Department of Cardiovascular Surgery of Padua University as a part of the minimally invasive surgery program. Since then, the robotic system has been applied successfully for endoscopic computer-enhanced left internal mammary artery (LIMA) harvesting in 19 patients candidates to a single coronary artery bypass on the left anterior descending coronary artery (LAD). The CABG procedure was performed on a beating heart through a median sternotomy in 14 patients, a minithoracotomy in 4 patients, and a totally endoscopic procedure in 1 patient. Accurate selection of the patients, with the exclusion of those with an unfavorable chest wall anatomy (i.e. obese patients) was mandatory. Other exclusion criteria were: angiographic evidence of an intramyocardial course or widespread calcifications of the target vessel, left ventricular dilation, anterior wall aneurysms, and impaired lung function. Unlike other groups we have not encountered any complication related to the robot-enhanced LIMA harvesting procedure[1].

In this case report, we present the first Italian TECAB, performed on the beating heart, with a robot-assisted technique in December 2001 and a review of our experience with the da Vinci robotic system.

The da Vinci robotic system

The da Vinci intuitive robotic microsurgical system is an endo-wrist enhanced three-dimensional visual robotic system, consisting of a master console, a computer control system and a three-arm surgical manipulator.

The surgeon is seated at a console and manipulates two master handles representing the surgical instruments. The central arm with the three-dimensional videoscope and the two instrument arms with the surgical instruments, are placed in the patient's chest through three 1 cm incisions. The telemanipulated instruments are articulated, so as to enable reproduction of the movements of the surgeon's hands.

The video image is projected by two continuous tone monitors at a three-dimensional binocular display in the console, giving the operator the illusion of holding the instruments' tips in his own hands, within the thorax. The image can be magnified up to 10 times the real size.

All the movements of the master handles are translated by the slave manipulators into the instruments, via a computer processor.

The system permits a totally free motion in the three-dimensional space: the manipulators allow three degrees of freedom (pitch, jaw and insertion); moreover, at the tips of the tools three more degrees of freedom, together with the instrument's actuation, are guaranteed by a cable-driven mechanical wrist.

The movements of the instruments are subjected to motion scaling and 6 Hz tremor filtering, that cancel the effects of unintended movements related to intrinsic human tremor, further enhancing the precision of the system[2,3] (Fig. 1).

Case report

A 66-year-old male patient with a history of hypertension, peripheral vascular disease and chronic gastritis, presented with acute antero-septal subendocardial infarction. Coronary angiography revealed single-vessel coronary artery disease, with a significant stenosis of the proximal LAD (type B1 lesion) (Fig. 2). The patient was symptomatic for recurrent angina pectoris at rest.

The patient, who had a surgical indication of single bypass of the LAD using the internal mammary artery, did not have any contraindication to a robot-assisted procedure.

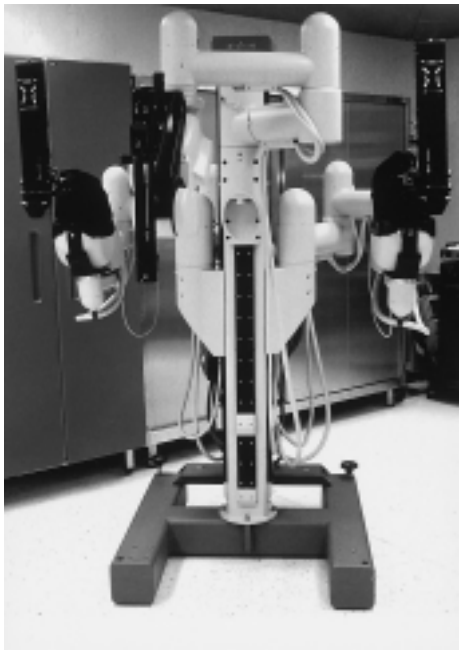

Figure 1. *The da Vinci robotic system's slave unit.*

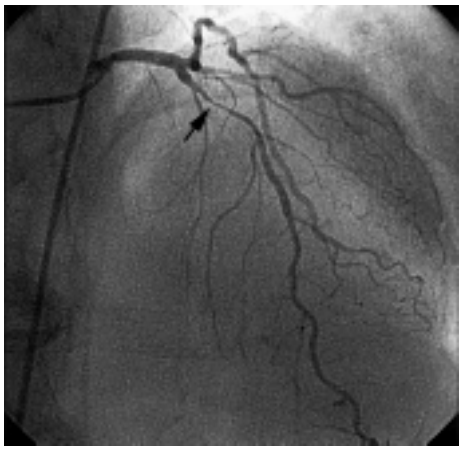

Figure 2. *Left anterior descending coronary artery target lesion.*

After induction of anesthesia, the patient was intubated with a double-lumen endotracheal tube to allow single-lung ventilation, excluding the left lung. A transesophageal probe was inserted to allow echocardiographic evaluation during the procedure.

The patient was placed in the supine position. Following skin disinfection and sterile draping and after collapse of the left lung, the camera port was introduced in the fourth intercostal space on the frontal axillary line, so that the camera could visualize both the target coronary artery and the LIMA course. In order to optimize the exposure of the left pleural cavity, by displacing the intrathoracic structures and increasing the space between the anterior heart surface and the internal chest wall above it, warm carbon-dioxide was insufflated in the port up to an intrapleural pressure of 10 mmHg. This was done whilst closely monitoring the patient's systemic blood pressure. The chest cavity was then explored to identify the LIMA course.

The arm ports were placed in the third and the seventh intercostal spaces on the midaxillary line, so that the instruments could reach the LIMA course from the right and the left axis of the endoscope respectively.

The endoscopic computer-enhanced LIMA takedown was performed: the LIMA was proximally dissected as a pedicle up to the first rib, with division of all branches including the first intercostal branch, and distally down to its bifurcation, by means of electrocautery and clipping.

The patient was fully heparinized (activated clotting time > 400 s) and the LIMA, temporarily occluded with an endoscopic bulldog clamp, prepared for the anastomosis. The pericardium was incised longitudinally above the LAD and the coronary artery course identified.

A stabilizing device was introduced through an additional port (1 cm) in the subxiphoid position, in order to stabilize the LAD and perform the bypass on a beat-

ing heart. The target artery was surrounded and occluded proximally to the anastomotic site by a silastic stitch without any electrocardiographic or echocardiographic sign of myocardial ischemia.

After the application of the stabilizer and the incision of the LAD, the "end to side" anastomosis with the LIMA was totally performed endoscopically by means of robotic da Vinci telemanipulation and using a 7-0 prolene (Ethicon Inc., Somerville, NJ, USA) running suture.

After completion of the anastomosis, the bulldog clamp on the LIMA and the snare on the LAD were removed and the flow released. The anastomosis was checked for leakage and no additional suture placement was necessary. After protamine administration, the chest tubes were inserted and the port incisions sutured.

During the whole procedure there was no evidence of myocardial ischemia or hemodynamic deterioration. The patient left the operating room in stable conditions without inotropic support and in sinus rhythm.

The patient was extubated on the same day and moved to the floor the day later. The postoperative course was uneventful and the patient was discharged home in excellent conditions (Fig. 3). Angiographic evaluation performed on day 5 postoperatively (Fig. 4) showed a patent anastomosis.

The patient was followed up systematically and found to be free from angina pectoris and in NYHA functional class I. He returned to his usual activities, showing normal exercise capacity (Fig. 4). Angiography, performed at 1 year of follow-up (16 months), confirmed the patency of the graft.

Discussion

In the past few years, the tendency toward a reduction in operative trauma has been influencing the evolution of cardiac surgery procedures. The techniques initially developed to perform endoscopic CABG did not yield encouraging results. This was due to the intrinsic limitations of conventional endoscopic instrumentation such as the rigid design, the excessive length, the fixed pivot at the entry sites in the thoracic wall, and the restricted degrees of freedom[4].

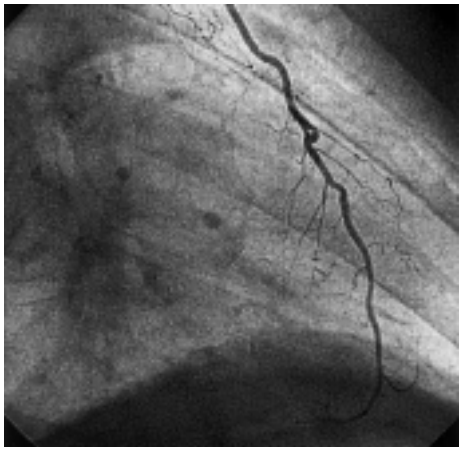

Figure 4. *Angiographic control on day 5 postoperatively.*

The drawbacks of conventional endoscopy stimulated the search for new devices, leading to the development of robotic telemanipulators able to translate traditional open surgery techniques into endosurgery movements[5].

After an experimental study that proved the possibility of remotely performing endoscopic coronary anastomoses (by means of the da Vinci robotic system) with the same results as those of open-heart standard techniques[6], Carpentier and colleagues[3] reported the first clinical application of TECAB in 2 patients, on an arrested heart[3]. The next step was the demonstration that TECAB revascularization on a beating heart was feasible[7].

The TECAB on a beating heart, avoiding both sternotomy and thoracotomy, is associated with obvious advantages in terms of wound healing. The da Vinci system enables safe endoscopic LIMA harvesting, minimizing injuries to intercostal nerves and costal periosteum and surgical trauma (less rib retraction), with significantly less postoperative pain[8]. The three-dimensional magnified visualization, the motion scaling and the tremor filtering enhance precision even when performing the anastomoses. The introduction of stabilizing devices allows a beating heart procedure, avoiding the undesirable effects of cardiopulmonary bypass.

Figure 3. *Minimal surgical incisions on the thoracic wall.*

The adequate training curve necessary to perform a robot-assisted procedure within acceptable time limits is counterbalanced by the gain in terms of precision and ambidexterity guaranteed by the robotic telemanipulation[9].

This paper reports the first TECAB performed in Italy with a robotic system. It proves the feasibility of TECAB on a beating heart, qualifying it as a repeatable and possibly reproducible technique. On the other hand, we believe because of the many technical limitations due to the chest wall and coronary artery anatomic variations that might necessitate conversion to an open-chest procedure, that TECAB is far from becoming a standard procedure. At the same time the combination of an endoscopic computer-enhanced LIMA takedown with a CABG procedure on a beating heart through a minithoracotomy offers many advantages. During MIDCAB, the application of the da Vinci system for LIMA harvesting avoids the traumatic rib retraction required by LIMA takedown under direct vision. Rib retraction is often associated with postoperative pain levels higher than conventional sternotomy. Completion of the procedure via a minithoracotomy allows the performance of CABG off-pump with a truly minimally invasive approach.

Whilst awaiting confirmation of the validity of this new option at long-term follow-up, a prospective randomized clinical trial comparing endoscopic computer-enhanced LIMA harvesting plus CABG on a beating heart, via minithoracotomy, versus drug-eluting stenting in patients with single-vessel disease will be conducted at our Institution.

Furthermore, it is attractive to treat patients with multivessel disease combining a MIDCAB LIMA to LAD with a catheter-based procedure by means of drug-eluting stents for non-LAD vessels. This approach will allow for complete revascularization as well as for minimal invasiveness. Hybrid coronary revascularization could be the gold standard treatment for patients with multivessel disease, combining the best of the current most attractive proposals of the cardiac surgery and cardiology worlds.

Additionally, we believe that the benefits gained in terms of a faster recovery and earlier discharge, the reduced need of repeated procedures related to the long-term patency of arterial grafts together with a lower rate of rehospitalization, will justify and counterbalance the added expenses of the robotic procedure.

References

1. Reuthebuch O, Comber M, Grunenfelder J, Zund G, Turina M. Experiences in robotically enhanced IMA-preparation as initial step towards totally endoscopic coronary artery bypass grafting. Cardiovasc Surg 2003; 11: 483-7.
2. Falk V, Diegeler A, Walther T, et al. Total endoscopic computer enhanced coronary artery bypass grafting. Eur J Cardiothorac Surg 2000; 17: 38-45.
3. Loulmet D, Carpentier A, d'Attellis N, et al. Endoscopic coronary artery bypass grafting with the aid of robotic assisted instruments. J Thorac Cardiovasc Surg 1999; 118: 4-10.
4. Mack M, Acuff T, Yong P, Jett GK, Carter D. Minimally invasive thoracoscopically assisted coronary artery bypass surgery. Eur J Cardiothorac Surg 1997; 12: 20-4.
5. Kappert U, Schneider J, Cichon R, et al. Wrist-enhanced instrumentation: moving toward totally endoscopic coronary artery bypass grafting. Ann Thorac Surg 2000; 70: 1105-8.
6. Falk V, Gummert JF, Walther T, Hayase M, Berry GJ, Mohr FW. Quality of computer enhanced totally endoscopic coronary bypass graft anastomosis - comparison to conventional technique. Eur J Cardiothorac Surg 1999; 15: 260-5.
7. Reichenspurner H, Boehm DH, Gulbins H, et al. Robotically assisted endoscopic coronary artery bypass procedures without cardiopulmonary bypass. J Thorac Cardiovasc Surg 1999; 118: 960-1.
8. Bucerius J, Metz S, Walther T, et al. Endoscopic internal thoracic artery dissection leads to significant reduction of pain after minimally invasive direct coronary artery bypass graft surgery. Ann Thorac Surg 2002; 73: 1180-3.
9. Boyd WD, Desai ND, Kiaii B, et al. A comparison of robot-assisted versus manually constructed endoscopic coronary anastomosis. Ann Thorac Surg 2000; 70: 839-43.