Original articles

The use of robotic technology in the LAST operation

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Key words:
Computer-enhanced LAST; Minimally invasive direct coronary artery bypass.

Background. **The LAST operation represents a good option for single left anterior descending artery (LAD) revascularization. We report our preliminary experience with the LAST operation performed with the aid of the "da Vinci" Intuitive robotic system.**

Methods. **From January 2000 to May 2001, 12 patients (11 males and 1 female, mean age 62 ± 8 years) underwent the LAST operation. All patients had a proximal LAD lesion either not suitable for coronary angioplasty or unsuccessfully treated at coronary angioplasty previously. The mean preoperative ejection fraction was 55 ± 5%. In all patients, left internal mammary artery (LIMA) harvesting was carried out endoscopically using robotic technology. After heparin administration the LIMA was distally divided to check the adequacy of the blood flow. An incision of about 6 cm was then made in the appropriate intercostal space and the LAD was exposed using a special costal retractor. Following the insertion of a temporary intracoronary shunt, the LIMA was anastomosed to the LAD.**

Results. **No hospital or delayed death occurred. Uneventful conversion to midline sternotomy was necessary in one patient who developed ischemic changes and hemodynamic instability. One patient had a revision for postoperative bleeding. All patients were discharged within the first postoperative week and in 4 of them optimal patency of the LIMA graft was angiographically documented.**

Conclusions. **The use of robotic technology seems to overcome all the drawbacks associated with the LAST operation and enhances the role of minimally invasive surgery in coronary artery revascularization.**

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Surgical revascularization of the left anterior descending coronary artery (LAD) with the left internal mammary artery (LIMA) can be carried out through a left anterior small thoracotomy without cardiopulmonary bypass and on a beating heart (LAST operation). This approach is quite appealing to the patients due to its minimal invasiveness and to the short hospital stay and quick recovery.

The LAST operation, introduced and popularized by Calafiore et al.[1] can be considered nowadays as a good option for patients with an isolated proximal LAD lesion not suitable for coronary angioplasty (total obstruction or type C lesion) or in case of recurrent stenosis following coronary angioplasty. However, there are few drawbacks related to the LAST operation. First of all, harvesting of the LIMA is technically demanding when it is performed through a small anterior thoracotomy and the arterial conduit can occasionally be traumatized and/or irreversibly damaged. Furthermore, due to a difficult exposure, the branches of the upper portion of the LIMA are usually not divided and this might result in a steal phenomenon with recurrent angina in spite of a patent LIMA graft[2].

Finally, the LAST operation has to be occasionally converted into a midline sternotomy procedure if the LAD is not appropriately identified or exposed through a small thoracotomy or if it runs intramurally or is diffusely diseased and necessitates an endarterectomy. The application of robotic technology for LIMA harvesting and LAD evaluation before thoracotomy overcomes the above-mentioned potential problems associated with the conventional LAST operation. Furthermore, successful total endoscopic LIMA to LAD anastomosis with or without cardiopulmonary bypass has been previously described[3-6].

In this paper, we report our experience with the LAST operation performed with the aid of the "da Vinci" Intuitive robotic system (Intuitive Surgical Inc., Mountain View, CA, USA).

The robotic system. The "da Vinci" surgical system consists of two main components: the surgeon's viewing and control console

(master) and the surgical arms that hold and move the surgical instruments (slave).

The surgeon sits at the console and views a high-resolution three-dimensional binocular display of the operative field whilst manipulating instrument controllers positioned under the display. The telemanipulated instruments supported by two mechanical arms are articulated at their distal extremities so as to reproduce the surgeon's hands. The mechanical wrist of the instruments has a 7 degrees of freedom motion and is able to mimic the flexibility of the human wrist. Instrument tips in the display are electronically aligned with the instrument controllers to ensure the hand-eye orientation and the natural operative feeling characteristic of conventional surgery.

The system provides motion scaling, tremor filtering and the possibility to disconnect the slave from the master thus enhancing the precision and providing optimal hand-eye alignment and favorable ergonomics. At present, the lack of tactile feedback is a limitation of the robotic system. A detailed description of the system is provided elsewhere[7,8].

Methods

The patients. From January 2000 to May 2001, 12 patients (11 males and 1 female, mean age 62 ± 8 years) underwent the LAST operation for isolated LAD revascularization. In all of them, LIMA harvesting was carried out endoscopically using robotic technology (Fig. 1). All patients had a proximal LAD lesion either not suitable for coronary angioplasty (9 patients) or unsuccessfully treated at coronary angioplasty previously (3 patients). In the other coronary vessels there were no significant lesions.

All patients invariably presented with angina pectoris as the predominant preoperative symptom.

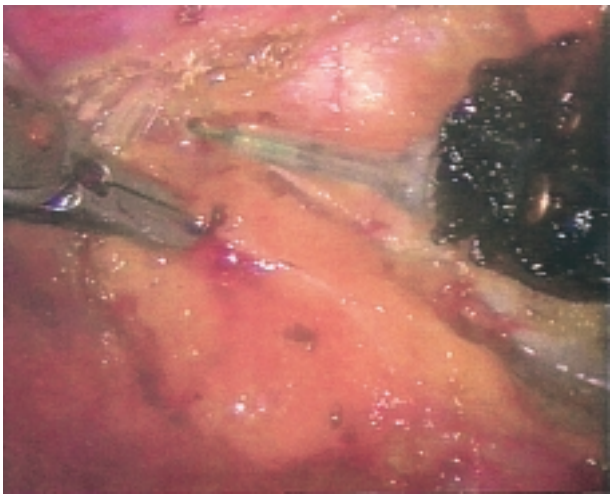

Figure 1. *Endoscopic view of left internal mammary artery harvesting with robotic instruments.*

Although 3 patients had a previous myocardial infarction involving part of the anterior ventricular wall and the septum, in no case was significant ventricular dysfunction present. The mean preoperative ejection fraction in the study group was 55 ± 5%. Three patients had insulin-dependent diabetes mellitus. However, the quality of the LAD distal to the obstructing lesion was considered acceptable at angiography in all patients.

The technique. After induction of anesthesia the patient was intubated with a double-lumen endotracheal tube to allow exclusion of the left lung when necessary during the procedure. The central lines were inserted as usual and the right radial artery was cannulated for arterial pressure monitoring. External defibrillation pads were appropriately placed on the chest wall. The patients were placed in a supine position with the left hemithorax elevated by approximately 30 degrees and were draped so as to expose the entire chest and the groins.

Following exclusion of the left lung, a first port was created in the fourth left intercostal space on the anterior axillary line in order to introduce the robotic camera for the three-dimensional display of the operative field and for carbon dioxide insufflation. Two additional ports were created (one in the third and one in the fifth intercostal space) on the mid-axillary line for the introduction of the robotic instruments.

The LIMA was harvested along its entire course, and all the collateral branches from the origin to the distal bifurcation were interrupted. After heparin administration (150 IU/kg) the LIMA was distally clipped and divided to check the adequacy of the blood flow. Temporary occlusion of the LIMA was then achieved with a small bulldog clamp inserted through one of the ports. At this point, the pericardium was opened to identify the LAD, to evaluate the quality of the vessel and to optimize the site of the small left anterior thoracotomy.

An incision of about 6 cm was then made in the appropriate intercostal space (usually the fourth) and the LAD was exposed using a special costal retractor. No rib or cartilage had to be removed to facilitate the exposure of the surgical field.

The distal end of the previously harvested LIMA was appropriately tailored and prepared for the anastomosis. The portion of the LAD which had been chosen for the anastomosis was stabilized and the artery was incised. Following the insertion of a temporary intracoronary shunt, to provide blood flow in the distal LAD, the LIMA to LAD anastomosis was carried out with a continuous 8-0 polypropylene suture.

Having carefully excluded any bleeding, a drainage was inserted into the left pleural space through one of the ports and the thoracotomy was closed.

Results

No hospital or delayed death occurred.

The entire procedure was always completed within 3 hours. All the endoscopically harvested mammary arteries were adequate in terms of quality, caliber, blood flow and length. The time required for harvesting was initially rather long but progressively decreased, reflecting a learning curve (Fig. 2). Conversion to midline sternotomy was deemed necessary in one patient who developed pronounced ST-segment ischemic changes and hemodynamic instability following LIMA take-down. This patient had an uneventful postoperative course. Surgical revision for postoperative bleeding was required in another patient who also had an otherwise uneventful hospital stay. In all the other patients the average postoperative bleeding was less than that expected for the conventional operation (210 ± 50 ml). No patient required transfusion of blood or blood derivatives.

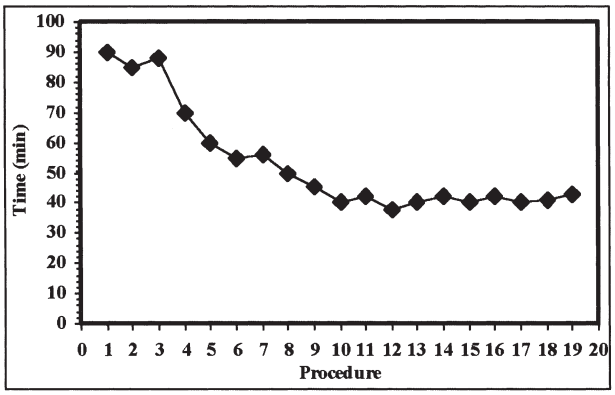

Figure 2. *Learning curve for left internal mammary artery harvesting.*

No perioperative myocardial infarction or other major complications were observed and no abnormal enzyme level elevation was recorded.

Temporary atrial fibrillation occurred in 2 cases and resolved following pharmacological treatment.

The occurrence of chest pain during hospitalization was less than in patients who had a sternotomy. Postoperative chest pain evaluation on the basis of a "pain score test" has not been performed, but the need for analgesic drugs (ketoralac) in patients who had undergone the LAST operation (45 ± 15 mg daily) was significantly less than in conventional surgery patients (60 ± 15 mg daily) ($p < 0.001$).

All patients were discharged within the first postoperative week and resumed their normal activities within the second postoperative week.

All patients remained asymptomatic during follow-up. Four patients gave their consent to a postoperative angiographic check-up. In all of them optimal patency of the LIMA graft was documented.

Discussion

Due to the present state of the art in interventional cardiology, isolated LAD lesions are rarely submitted to surgical revascularization[9,10].

Only those patients presenting with total LAD obstruction or lesions which are not suitable for coronary angioplasty and those who had already been submitted to one or more coronary angioplasty procedures and have experienced recurrence of stenosis are commonly considered as surgical candidates. This general attitude may explain the relatively small number of patients included in this series and operated over a period of 15 months.

For single LAD revascularization, the LAST operation undoubtedly represents a good option. Excellent results have been repeatedly reported by different groups[11-13] and a patency rate of the LIMA to LAD anastomosis > 95% has been documented[14].

Furthermore, the LAST operation offers the advantages associated with a minimally invasive approach, namely a short hospital stay and a fast recovery. In the last years successfully closed chest LIMA to LAD anastomosis, with or without cardiopulmonary bypass, were performed in only a few centers[3-6].

Nevertheless, many surgeons are reluctant to perform the LAST operation because of the difficult LIMA harvesting through the small thoracotomy. In addition, the inappropriate identification or exposure of the LAD, as well as the finding of a diffusely diseased or intramural vessel, may occasionally lead the surgeon to perform midline sternotomy following thoracotomy.

Robotic technology greatly facilitates the LIMA take-down which, in the conventional LAST operation, is technically demanding. After insertion of the robotic instruments through ports in the chest wall, the arterial conduit is perfectly visualized along its entire course and can be easily isolated from its origin to its bifurcation. All the collateral branches are interrupted and the risk of a steal phenomenon resulting in recurrence of angina is prevented. The quality of the LIMA graft and the blood flow through it can be endoscopically evaluated before opening the chest. In all our 12 cases, harvesting of the LIMA using robotic instruments was completely uneventful. The length of the conduit was always adequate and the site of the anastomosis on the LAD was easily accessible.

Using the robot, the pericardium can be incised and the LAD can be endoscopically evaluated. In this series, all patients had a LAD of acceptable quality and never running intramurally. In case of an intramural course or of a bad-quality vessel, midline sternotomy could have been carried out as a first choice, prior to any thoracic incision.

In one patient of this series we elected to perform midline sternotomy only because of pronounced ST-segment ischemic changes and hemodynamic instability occurring following the LIMA take-down.

Endoscopic identification of the LAD allows optimal selection of the site of the thoracotomy and the construction of the LIMA to LAD anastomosis is therefore facilitated.

The use of robotic instruments for this hybrid approach is certainly expensive and operating times still exceed those needed for a conventional procedure. Besides, a substantial learning curve has to be overcome.

In this series, optimal exposure of the operative field was uniformly obtained with minimal costal retraction. It is well recognized that excessive costal retraction results in postoperative chest pain and discomfort.

In conclusion, the use of robotic technology seems to overcome all the drawbacks associated with the LAST operation and enhances the role of minimally invasive surgery in coronary artery revascularization.

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