

The Comparison between Minimally Invasive Coronary Bypass Grafting Surgery and Conventional Bypass Grafting Surgery in Proximal LAD Lesion

Mehmet Ezelsoy, MD,¹ Baris Caynak, MD,² Muhammed Bayram, MD,¹ Kerem Oral, MD,¹
Zehra Bayramoglu, MD,¹ Ertan Sagbas, MD,² Vedat Aytekin, MD,³ Belhan Akpinar, MD¹

¹Cardiovascular Surgery Department and ³Cardiology Department, Istanbul Florence Nightingale Hospital; and ²Cardiovascular Surgery Department, Istanbul Bilim University, Istanbul, Turkey

ABSTRACT

Background: Minimally invasive bypass grafting surgery has entered the clinical routine in several centers around the world, with an increasing popularity in the last decade. In our study, we aimed to make a comparison between minimally invasive coronary artery bypass grafting surgery and conventional bypass grafting surgery in isolated proximal left anterior descending artery (LAD) lesions.

Methods: Between January 2004 and December 2011, patients with proximal LAD lesions, who were treated with robotically assisted minimally invasive coronary artery bypass surgery and conventional bypass surgery, were included in the study. In Group 1, coronary bypass with cardiopulmonary bypass and complete sternotomy were applied to 35 patients and in Group 2, robotically assisted minimally invasive bypass surgery was applied to 35 patients. The demographic, preoperative, perioperative, and postoperative data were collected retrospectively.

Results: The mean follow-up time of the conventional bypass group was 5.7 ± 1.7 years, whereas this ratio was 7.3 ± 1.3 in the robotic group. There was no postoperative transient ischemic attack (TIA), wound infection, mortality, or need for intra-aortic balloon pump (IABP) in any of the patients. In the conventional bypass group, blood transfusion and ventilation time were significantly higher ($P < .05$) than in the robotic group. The intensive care unit (ICU) stay and hospital stay were remarkably shorter in the robotic group ($P < .01$). The postoperative pneumonia rate was significantly higher (20%) in the conventional bypass group ($P < .01$). Postoperative day 1 pain score was higher in the robotic group ($P < .05$), however, postoperative day 3 pain score in the conventional bypass group was higher ($P < .05$). Graft patency rate was 88.6% in the conventional bypass group whereas this ratio was 91.4% in the robotic bypass group, which was not clinically significant ($P > .05$).

Conclusion: In isolated proximal LAD stenosis, robotic assisted minimally invasive coronary artery bypass grafting surgery requires less blood products, is associated with

shorter ICU and hospital stay, and lesser pain in the early postoperative period in contrast to conventional surgery. The result of our studies, which showed similarities to the past studies, lead us to recognize the importance of minimally invasive interventions and the need to perform them more frequently in the future.

INTRODUCTION

Myocardial revascularization with coronary artery bypass grafting surgery (CABG) has been performed for more than 40 years. It is one of the most commonly applied surgical interventions. Conventional bypass surgery is performed with the use of median sternotomy and cardiopulmonary bypass (CPB) techniques. The anastomosis of left internal mammary artery (LIMA) to left anterior descending artery (LAD) for revascularization is primarily preferred due to long-term patency rates and the advantages in patient survival [Loop 1986; Cameron 1996]. With the success of current technical advances, there is increased capability in performing operations on the beating heart, with minimally invasive techniques more commonly used. Even though minimally invasive direct coronary artery bypass surgery (MIDCAB) is a technically challenging method, there are studies that show it can be used in select patient groups [Detter 2002].

Minimally invasive bypass surgery has become the routine method in many centers around the World, with increasing popularity in the last 10 years. Beating heart bypass surgeries to proximal LAD stenosis are performed with the help of surgical robotic systems, in direct vision from left anterior minithoracotomy, and have an important place in clinical practice. There are clinical report publications about robotic bypass surgeries from various clinics, including ours [Çaynak 2011; Diegeler 1999]. However, in the literature, there is rarely information that compares coronary angiographic results of minimally invasive bypass with conventional bypass. In this study, we aimed to compare the clinical and angiographic results of minimally invasive surgery with those of conventional surgery.

METHODS

This retrospective study included patients with proximal LAD lesions who had undergone robotically assisted minimal invasive coronary bypass surgery and conventional bypass surgery between January 2004 and December 2011 in Istanbul

Received December 10, 2014; received in revised form February 11, 2015; accepted March 6, 2015.

Correspondence: Mehmet Ezelsoy, Istanbul Florence Nightingale Hospital, Cardiovascular Surgery Department, Sisli, Istanbul, Turkey; +902122244950 (e-mail: mehmet_ezelsoy@hotmail.com).

Florence Nightingale Hospital. Thirty-five patients from Group 1 had on-pump coronary bypass with full sternotomy, whereas 35 patients from Group 2 had robotic assisted minimally invasive coronary bypass surgery. Demographic, preoperative, perioperative, and postoperative data of patients were collected retrospectively. Both groups were operated on by the same surgical team.

The inclusion criteria was as follows: patients with isolated proximal LAD stenosis; age between 18-75 years; ejection fraction between 30-60%; anatomically fit for robotic surgery.

The exclusion criteria was as follows: age >75 years; chronic renal disease; advanced chronic obstructive pulmonary disease (COPD); severe peripheral arterial disease (PAD); EF <30%; advanced stage congestive heart disease (CHD); patients who are unfit anatomically for endoscopic imaging.

In the intensive care unit (ICU), the verbal rating scale (VRS) was used as a postoperative pain scale, 0 equaling no pain, and 10 equaling very intense pain. Patients described their pain in numbers and the data were recorded every 4 hours. Paracetamol 10 mg/kg IV was applied to patients with a pain score of 4 or more. Further lasting pain was treated with 0.5 mg/kg tramadol IV.

Intercostal nerve blockage for pain control was applied to patients who underwent robotic surgery. The pulmonary artery cannula, which was placed before the closure of the thoracotomy incision, was directed out of the skin. From this cannula, local anesthetic (bupivacaine hydrochloride 5 mg/mL) was continuously injected in the postoperative stage. Catheter was removed in the postoperative day 3.

OPERATION TECHNIQUE

Group 1: Conventional Bypass

The patients were anticoagulated preoperatively with heparin and followed with activated clotting time (ACT). LIMA-LAD anastomosis was performed on-pump and tepid antegrade blood cardioplegia at 32-34°C.

Internal Mammary Artery Anastomosis: LIMA was removed, with pedicles, from its origin on the subclavian artery to the immediate proximal section of the bifurcation. With the opening of a tunnel on the pericardium for LIMA to pass, LIMA-LAD anastomosis was performed with 8-0 prolene sutures.

Group 2: Robotic Assisted Coronary Bypass Surgery

After general anesthesia, the patients were intubated with a double lumen tube for single lung ventilation. External defibrillator pads were placed on the chest wall. Transesophageal echocardiography (TEE) was performed throughout the procedure. Diltiazem perfusion commenced following anesthesia induction as an adjunct for myocardial protection and to reduce heart rate and facilitate coronary anastomosis.

Technique of Endoscopic Robotic Internal Mammary Artery Harvesting: The patient was placed on the operating table in a supine position with the left side of the chest elevated at about 30° with the aid of an inflatable bag behind the left hemithorax. After deflation of the left lung, the camera port was introduced bluntly in the fourth or fifth intercostal

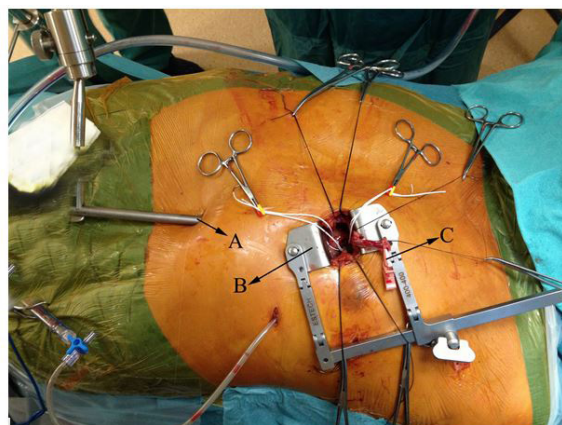


Figure 1. The surgical view of robotically assisted minimally invasive direct coronary bypass. A, Octopus NS stabilizer system; B, Tissue retractor; C, Left IMA.

space (ICS) in the anterior axillary line, and the chest was then insufflated with carbon dioxide (CO₂) gas. After the insertion of the endoscope, two ports were placed in line of sight to accommodate two robotic arms, usually in the third (right arm), and the seventh ICS (left arm) in the mid-clavicular line. The full length of the LIMA was marked as a pedicle from the subclavian artery to the distal bifurcation. The dissection started laterally to the left internal thoracic artery (ITA) which created the flap; it continued medially, detaching the vessel from the chest by means of cautery. Following endoscopic ITA takedown, the distal end was clipped and cut. With the pericardium opened, the LAD artery course was identified and the robotic system was removed. Access to the chest was achieved through a 4-6 cm incision in the left 4th ICS using a soft tissue retractor (Cardioversions, Ethicon, Somerville, NJ, USA) for single vessel small thoracotomy (SVST) cases where the LAD was to be bypassed. Left ITA to LAD artery anastomosis was performed on the beating heart under direct vision, with the help of the Octopus NS stabilizer system (Medtronic Inc, Minneapolis, MN, USA), which was inserted through the 6th-7th intercostal space anterior axillary line (Figure 1).

Statistical Analysis

While the findings of the study were evaluated, SPSS software (SPSS Inc, Chicago, IL, USA) was used for statistics. While data were processed beside descriptive statistical methods such as frequency, percentage, mean values, and standard deviation, Kolmogorov-Smirnov test was used to evaluate the data distribution. In the comparison of qualitative data Pearson χ^2 and Fisher Exact test were used. For the comparison of quantitative data in two groups, independent sample *t* test was used. In the comparison of the parameters in specific groups, paired sample *t* test was used. The ICU and hospital stay duration was obtained with Kaplan-Meier method. The effect of the operation type on these times was evaluated with log-rank test. The results were evaluated by their significance ($P < .05$) and advanced significance ($P < .01$ and $P < .001$).

Table 1. Preoperative Risk Factors*

	Conventional Bypass	Robotic Bypass	P
Age, y	61.26 ± 8.94	58.57 ± 10.29	.248
Body mass index	28.26 ± 3.59	27.10 ± 3.35	.167
Ejection fraction, %	54.91 ± 6.19	62.66 ± 5.95	.000***
Female, n (%)	19 (54)	10 (29)	.029**
Male, n (%)	16 (46)	25 (71)	.029**
COPD, n (%)	8 (23)	1 (3)	.012**
Hypertension, n (%)	28 (80)	19 (54)	.022**
Diabetes mellitus, n (%)	15 (43)	10 (29)	.212
Hyperlipidemia, n (%)	20 (57)	21 (60)	.808
MI, n (%)	5 (14)	6 (17)	.743
Cerebrovascular accident, n (%)	35 (100)	35 (100)	–
Renal failure, n (%)	35 (100)	35 (100)	–
Peripheral vascular disease, n (%)	1 (3)	2 (6)	.555

*Data are presented as the mean ± SD where indicated. COPD indicates chronic obstructive pulmonary disease; MI, myocardial infarction.

** $P < .05$; *** $P < .01$; **** $P < .001$.

Table 2. Intraoperative Results*

	Conventional Bypass	Robotic Bypass	P
LAD stenosis, %	86.00 ± 12.24	90.57 ± 10.49	.098
Operation time, min	–	186.93	–
LIMA take down, min	–	48.17	–
CPB, min	31.49 ± 6.32	–	–
Cross Clamp, min	15.74 ± 4.83	–	–

*Data are presented as the mean ± SD where indicated. LAD indicates left anterior descending artery; LIMA, left internal mammary artery; CPB, cardiopulmonary bypass.

RESULTS

Table 1 shows the demographic data from Group 1 (conventional bypass) and Group 2 (robotic bypass). The conventional bypass group had 19 females (54%) and 16 males (46%) and the robotic bypass group had 10 females (29%) and 25 males (71%). The sum of the included patients was 70. There was no significant difference between the groups in terms of diabetes, hyperlipidemia, chronic renal disease, myocardial infarction (MI), and peripheral arterial disease.

In Group 1, there were more female patients (54%) than male patients and in Group 2 there were more male patients (71%) than female patients ($P < .05$). In Group 1, COPD

Table 3. Postoperative Results*

	Conventional Bypass	Robotic Bypass	P
Transfusion	0.60 ± 0.91	0.23 ± 0.55	.044**
Ventilation, h	5.23 ± 0.97	4.69 ± 1.2	.042**
ICU stay, d	1.66 ± 0.97	1.09 ± 0.28	.002***
Hospital stay, d	7.80 ± 2.29	6.63 ± 1.03	.008***
Postoperative pneumonia, n (%)	7 (20)	0 (0)	.005***
Postoperative ARF, n (%)	2 (6)	0 (0)	.151
Postoperative arrhythmia, n (%)	6 (17)	5 (14)	.743

*Data are presented as the mean ± SD where indicated. ICU indicates intensive care unit; ARF, acute renal failure.

** $P < .05$; *** $P < .01$; **** $P < .001$.

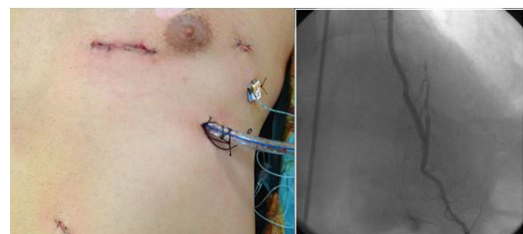


Figure 2. Left: Surgical incision view of robotically assisted MIDCAB procedure on postoperative day 1. Right: Control angiography of the same patient after operation (patent LIMA-LAD graft).

(23%) and hypertension (80%) were significantly more frequent ($P < .05$). The mean follow-up time of Group 1 was 5.7 years (± 1.7) and for Group 2 was 7.3 years (± 1.3). None of the cases had perioperative MI. In the robotic bypass group, mean LIMA preparation time was 48.17 minutes and mean operation time was 186.93 minutes. Furthermore, none of the robotic cases needed sternotomy. In the conventional bypass group, mean CPB time was 31.49 minutes and cross-clamp time was 15.74 minutes (Table 2).

There were no postoperative transient ischemic attacks (TIA), wound infections, or mortality, and there was no need for intra-aortic balloon pump (IABP). Mean ejection fraction in the robotic group (62.657%) was higher than in the conventional group whereas the average use of transfusion in the conventional group was significantly higher than in the robotic group ($P < .05$).

Group 1 had a significantly higher ventilation time ($P < .05$). Similarly, postoperative pneumonia frequency of Group 1 was significantly higher ($P < .01$) than Group 2. However, ICU stay of Group 2 was shorter ($P < .01$) than Group 1 (Table 3).

The robotic group had a higher mean pain score on postoperative day 1 ($P < .05$). The conventional bypass

group had a higher mean pain score on postoperative day 3 ($P < .05$). The decrease of pain score between the 1st and 3rd days of the postoperative period was significantly higher in the robotic group ($P = .000 < .001$).

In the conventional bypass group, the rate of bypass graft patency was 88.6% whereas the rate in the robotic bypass group was 91.4%. This was not clinically significant ($P > .05$) (Table 3) (Figure 2).

According to Kaplan-Meier analysis, ICU and hospital stay of the conventional bypass group were significantly higher than for the robotic bypass group (Log-rank = 11.905; $P = .001 < .01$).

Similarly, the hospital stay of the conventional bypass group was significantly higher than in the robotic bypass group (Log-rank = 8.355; $P = .004 < .01$) (Table 3).

DISCUSSION

On pump coronary artery bypass surgery with median sternotomy is one of the most frequently used surgical interventions in clinical practice. The anastomosis of the left internal mammary artery (LIMA) to left anterior descending artery (LAD) is the primarily preferred revascularization due to long-term patency rates and the advantages in patient survival [Niinami 2005; Şener 2001]. With the success of current technical advances, operations on the beating heart have gained importance and become more common, and the use of minimally invasive techniques has increased.

Robotic surgery systems are presented as a potential facilitative factor for minimally invasive coronary artery revascularization procedures. The beating heart LIMA-LAD anastomosis in isolated LAD lesions from left anterior minithoracotomy is the most commonly known minimal invasive bypass surgery [Detter 2002].

Minimally invasive procedures are preferred due to their better cosmetic results, smaller incision size providing less wound infections, and less postoperative bleeding, thus less need for blood and blood products and less hospital/ICU stays [Diegeler 2000]. Even though minimally invasive coronary artery bypass grafting surgery is a technically challenging method, there are studies that show it can be used safely in specific patient groups [Cisowski 2002].

Advantages of the DaVinci robotic system are its visual properties due to 3D and enlarged vision, enough space in the narrow intrathoracic area for surgeons with the help of its arms that move in 7 directions, and its ability to filter tremor and movement without control. Furthermore, the most important disadvantage of endoscopic surgery — the obligation of performing the surgery in the mirror image — has been overcome with this system. Despite these features, the usage of robotic surgical systems in cardiac surgery needs a long and hard learning curve [Bonatti 2004].

Preoperative usage of multidetector CT provides great advantages by finding the target vessel (epidural or intramural) and evaluating the vessel wall quality in the anastomosis area [Herzog 2003]. It has great importance in identifying large diagonal branches, and it is possible for these branches to be confused with LAD in endoscopic images. To minimize

these risks in the operations, we evaluated our patients with multidetector CT preoperatively.

Robotically assisted minimally invasive bypass surgery for proximal LAD stenosis under direct vision has an important place in clinical applications. There are clinical report publications regarding robotic bypass surgery from various clinics, including our studies [Bayramoglu 2014; Calafiore 1996; Cremer 1997; Subramanian 1997; Diegeler 1999]. DaVinci robotically assisted bypass surgeries have been performed successfully since 2004 in Istanbul Florence Nightingale Hospital.

In a study that included 98 patients from 12 centers with single LAD revascularization in 2006, Argenziano et al found that 91% of reinterventions were avoided in control angiographies 3 months later. This study has been effective in DaVinci's approval in coronary revascularization by the FDA [Argenziano 2006].

271 patients with LIMA-LAD bypass with MIDCAB were evaluated with coronary angiography by Diegeler et al. After six months, graft patency rates were 91.5% [Diegeler 1999]. In May 2012, Currie et al published their results on the long-term outcomes of robotic coronary revascularization. 82 out of 160 patients who had undergone robotic coronary revascularization were evaluated with a mean time of 95.8 months and a patency rate of 92.7% [Currie 2012].

Both robotic bypass patients and conventional bypass patients were evaluated with coronary angiography and there were no statistical differences in our study. The mean follow-up time of the conventional bypass group was 5.7 years (± 1.7) and of the robotic group was 7.3 years (± 1.3).

Bonatti et al compared conventional bypass with minimally invasive methods in single vessel disease. The minimally invasive group had less blood product usage and less in hospital stay [Bonatti 1998]. In our study, in the robotic bypass group, blood transfusion amount was less, and ventilation time, ICU, and hospital stays were shorter and statistically significant.

Diegeler et al compared postoperative pain of MIDCAB and conventional bypass patients. They detected a pain that is thought to be due to thoracotomy and could last up to 3 days postoperatively among MIDCAB patients. This patient group showed decrease of the pain level after day 3 and better physical activity, which is thought to be related to the absence of sternotomy and cardiopulmonary bypass [Diegeler 1999]. In our study, we found that the robotic group had more pain during postoperative day 1 and the conventional bypass group had more pain after postoperative day 3.

Conclusion

Robotic surgery systems are presented as a potential facilitative factor for minimal invasive coronary artery revascularization procedures. Minimal invasive bypass surgery has become the routine method in many centers around the world with its popularity increasing in the last 10 years. The beating heart bypass surgery to proximal LAD stenosis with the help of surgical robotic systems under direct vision from left anterior minithoracotomy has an important place in clinical practice. As a result of our retrospective study; the mean follow-up time of the conventional bypass group was 5.7 years (± 1.7)

and of the robotic group was 7.3 years (± 1.3). There were no postoperative transient ischemic attacks, wound infections, or mortality, and there was no need for IABP. The mean transfusion amount and ventilation times were higher in the conventional bypass group.

The ICU and the mean hospital stay of the robotic bypass group was shorter. The postoperative day 1 pain score of the robotic group was significantly higher. The postoperative day 3 pain score was significantly higher in the conventional group. The graft patency rates were 88.6% for the conventional group and 91.4% for the robotic group, but this difference was not clinically significant. As a result, in the isolated proximal LAD stenoses, robotic MIDCAB surgery necessitates less blood transfusion and has less ICU and in-hospital stays.

Our results are consistent with the literature and lead us to assume the future importance and prevalence of minimally invasive interventions. The results regarding the early period of robotic surgery are promising. We think that robotic surgery will take its place as routine as a result of technical advances in the anastomosis instruments and endoscopic stabilizers.

REFERENCES

- Argenziano M, Katz M, Bonatti J, et al. 2006. Results of prospective multicenter trial of robotically assisted totally endoscopic coronary artery bypass grafting. *Ann Thorac Surg* 81:1666-74. Discussion 1674-75.
- Bayramoglu Z, Caynak B, Ezelsoy M, et al. 2014. Angiographic evaluation of graft patency in robotic-assisted coronary artery bypass surgery: 8 year follow-up. *Int J Med Robot* 10:121-7.
- Bonatti J, Ladurner R, Antretter H, et al. 1998. Single coronary artery bypass grafting: a comparison between minimally invasive off-pump techniques and conventional procedures. *Eur J Cardiothorac Surg* 14 (Suppl 1):S7-S12.
- Bonatti J, Schachner T, Bernecker O, et al. 2004. Robotic totally endoscopic coronary artery bypass: program development and learning curve issues. *J Thorac Cardiovasc Surg* 127:504-10.
- Calafiore AM, Giammarco GD, Teodori G, et al. 1996. Left anterior descending coronary artery bypass grafting via left anterior small thoracotomy without cardiopulmonary bypass. *Ann Thorac Surg* 61:1658-63.
- Cameron A, Davis KB, Green G, Schaff HV. 1996. Coronary bypass surgery with internal-thoracic-artery grafts — effects on survival over a 15-year period. *N Engl J Med* 334:216-9.
- Çaynak B, Türkiye Klinikleri J. 2011. *Cardiovasc Surg-Special Topics* 3:36-43.
- Cisowski M, Morawski W, Drzewiecki J, et al. 2002. Primary stenting versus MIDCAB: preliminary report—comparison of two methods of revascularization in single left anterior descending coronary artery stenosis. *Ann Thorac Surg* 74:1334-9.
- Cremer J, Strüder M, Wittwer T, et al. 1997. Off-bypass coronary bypass grafting via minithoracotomy using mechanical epicardial stabilization. *Ann Thorac Surg* 63 (6 Suppl):S79-83.
- Currie ME, Romsa J, Fox SA, et al. 2012. Long-term angiography follow-up of robotic –assisted coronary artery revascularization. *Ann Thorac Surg* 93:1426-31.
- Detter C, Reichenspurner H, Boehm DH, et al. 2002. Minimally invasive direct coronary artery bypass grafting (MIDCAB) and off-pump coronary artery bypass grafting (OPCAB): two techniques for beating heart surgery. *Heart Surg Forum* 5:157-62.
- Diegeler A, Matin M, Kayser S, et al. 1999. Angiographic results after minimally invasive coronary bypass grafting using the minimally invasive direct coronary bypass grafting (MIDCAB) Approach. *Eur J Cardiothorac Surg* 15:680-4.
- Diegeler A, Walther T, Metz S, et al. 1999. Comparison of MIDAB versus conventional CABG surgery regarding pain and quality of life. *Heart Surg Forum* 2:290-6.
- Diegeler A, Spyrtantis N, Matin M, et al. 2000. The revival of surgical treatment for isolated proximal high grade LAD lesions by minimally invasive coronary artery bypass grafting. *Eur J Cardiothorac Surg* 17:501-4.
- Herzog C, Dogan S, Diebold T, et al. 2003. Multi-detector row CT versus coronary angiography: preoperative evaluation before totally endoscopic coronary artery bypass grafting. *Radiology* 229:200-8.
- Loop FD, Lytle BW, Cosgrove DM, et al. 1986. Influence of the internal-mammary-artery graft on 10-year survival and other cardiac events. *N Engl J Med* 314:1-6.
- Niinami H, Ogasawara H, Suda Y, Takeuchi Y. 2005. Single-vessel revascularization with minimally invasive direct coronary artery bypass: minithoracotomy or ministernotomy? *Chest* 127:47-52.
- Şener T, Gerçekoğlu H, Evrenkaya S, et al. 2001. Comparison of minithoracotomy with conventional sternotomy methods in valve surgery. *Heart Surg Forum* 4:26-30.
- Subramanian VA, McCabe JC, Geller CM. 1997. Minimally invasive direct coronary artery bypass grafting: Two-year clinical experience. *Ann Thorac Surg* 64:1648-53.