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Port-Access™ Cardiac Surgery: From a Learning Process to the Standard

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ABSTRACT

Background: Port-Access™ surgery has been one of the most innovative and controversial methods in the spectrum of minimally invasive techniques for cardiac operations and has been widely used for the treatment of several cardiac diseases. The technique was introduced in our center to evaluate its efficacy in reproducing standardized results without an additional risk.

Methods: Endovascular cardiopulmonary bypass (CPB) through femoral access and endoluminal aortic occlusion were used in 129 patients for a variety of surgical procedures, all of which were video-assisted. A minimal (4-6 cm) anterior thoracotomy through the fourth intercostal space was used in all cases as the surgical approach.

Results: More than 96% of the planned cases concluded as true Port-Access™ procedures. Mean CBP and cross-clamp times were 87.2 min. ± 51.2 (range of 10-457) and 54.9 min. ± 30.6 (range of 10-190), respectively. Hospital mortality for the overall group was 1.5%, and mitral valve surgery had a 2.2% hospital death rate. The incidence of early neurological events was 0.7%. Mean extubation time, ICU stay, and total length of hospital stay were 5 hours ± 6 hrs. (range of 2-32), 12 hours ± 11.8 hrs. (range of 5-78), and 7 days ± 7.03 days (range of 1-72), respectively.

Conclusions: Our experience indicates that the Port-Access™ technique is safe and permits reproduction of standardized results with the use of a very limited surgical approach. We are convinced that this is a superior procedure for certain types of surgery, including isolated primary or redo mitral surgery, repair of a variety of atrial septal defects (ASDs), and atrial tumors. It is especially useful in high-risk patients, such as elderly patients or those requiring reoperation. Simplification of the procedure is nevertheless desirable in order to further reduce the time of operation and to address other drawbacks.

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INTRODUCTION

A broad spectrum of minimally invasive surgical techniques has been introduced in cardiac surgery in recent years [Vanermen 1998]. The theoretical advantages of these options, such as fewer postoperative complications and more rapid recovery, have not been thoroughly demonstrated, but elimination of cardiopulmonary bypass (CPB) and reduction of surgical trauma are both obvious objectives for improving the overall results of a cardiac operation [Wimmer-Greinecker 1999].

Port-Access™ surgery, which involves approaching the heart through ports of minimal size, has been one of the most original and controversial methods of minimally invasive surgery. Since its introduction in 1996 at Stanford University [Stevens 1996a, Stevens 1996b], it has been used widely for more than 10,000 patients in the treatment of different diseases. The aim of the present study is to describe our initial experience and to discuss some technical aspects and theoretical concerns of this approach.

MATERIALS AND METHODS

Patients

Between September 1997 and May 2001, 129 patients underwent cardiac surgery using the Port-Access™ system at the Hospital Clinic, University of Barcelona. Preoperative diagnoses for these patients were coronary artery disease in seven cases (6%), mitral valve disease, with or without tricuspid valve involvement, in 92 cases (71%), atrial septal defect in 28 cases (21%), and left atrial myxoma in two cases (2%). The mean age of patients was 51.4 ± 15 years (range of 17-84), and 70% of patients were female. Preoperative characteristics of mitral valve patients are listed in Table 1 (). Physical and instrumental evaluation was done on prospective patients to exclude any with contraindications for femoral cannulation or right thoracotomy.

All patients were informed in detail about the features of the technique, the potential advantages over the traditional approach in terms of postoperative recovery, and the possible risks and complications.

Surgical Technique

All patients were operated upon under general anesthesia with orotracheal intubation to allow single-lung ventilation, a Swan-Ganz thermo-dilution catheter, and external thoracic

defibrillating pads (Zoll®). Catheter and cannulae positioning was always done under transesophageal echocardiography (TEE) guidance. The superior vena cava (SVC) was cannulated percutaneously by the anesthesiologist with a 14 Fr. cannula (Medtronic DLP, Minneapolis, MN) through the right jugular vein. Alternatively, an endocoronary sinus catheter and endopulmonary vent catheter (Ethicon, Inc., Somerville, NJ) were inserted in the right jugular vein and advanced to the coronary sinus and pulmonary artery for delivery of retrograde cardioplegia and venting.

The patient was positioned with slight elevation of the right hemi-thorax, and a 2 cm skin incision parallel to the groin groove was made to gain access to the femoral vessels. Approach to the pleural cavity was gained through a limited (4-6 cm) right anterior thoracotomy at the fourth intercostal space (the working port). A soft tissue retractor was then inserted. Two 10 mm ports were created at the fourth and sixth intercostal spaces along the anterior axillary line. A 10 mm/0º Videothoracoscope (Storz®) was introduced in the chest and CO_2 delivery was started at a flow of 2 l/min. through the ports. The pericardium was opened 2 cm anterior to the phrenic nerve with t-reversed incision. Stay sutures were then brought out by means of a suture-snare and an angiocath and fixed outside the chest. Under full heparinization, a 25 Fr. cannula (Ethicon, Inc., Somerville, NJ) was advanced over a guide wire through a 5-0 prolene purse-string suture of the femoral vein and positioned under TEE guidance at the junction of the right atrium and the inferior vena cava (IVC). The femoral artery was then cannulated through a direct transverse arteriotomy using a 21 or 23 Fr. Y-shape cannula (Ethicon, Inc., Somerville, NJ) specifically designed to be used in conjunction with the Endo-Aortic Clamp™. Finally, an assisted venous return by a centrifugal pump (Biomedicus-Medtronic, Minneapolis, MN) achieved a complete CPB. An Endo-Aortic Clamp™ (Ethicon, Inc., Somerville, NJ) was introduced in the arm of the arterial cannula and sited over a guide wire in the ascending aorta, about 4 cm distal to the aortic valve, under careful TEE control. While the heart was completely empty, the balloon was inflated with saline in an amount proportional to the intra-aortic diameter, and cool blood antegrade cardioplegia was then delivered through the tip of the endoclamp. The left or right atrium was then opened and an appropriate sized atrial retractor (Ethicon, Inc., Somerville, NJ) was positioned and fixed out through the anterior thoracic wall. Direct atrial aspiration was achieved by venting with a Cardiac Sump (Medtronics, Minneapolis, MN) device through the lower thoracic port. The video-thoracoscope was pushed forward into the atrium to allow an adequate view of the valve and subvalvular apparatus.

The valve was explored and repaired or replaced with the assistance of videoscopy and direct view. For atrial septal defects (ASDs), in the case of ASD II, closure was performed by direct suture or with a patch. Knots were usually downplaced with a knot-pusher device.

At the end of the procedure, a 14G soft Foley catheter was inserted through the valve or prosthesis into the left ventricle to facilitate de-airing of the heart. The atrium was closed and a proper de-airing procedure was started. CO_2 was always delivered until the atrium was completely closed and venting through the ventricle stopped. Aortic venting through the distal tip of the endoclamp was initiated at the time the balloon was deflated to re-establish normal coronary perfusion. Cardiac activity was restored spontaneously in most cases, and for the others an external defibrillation of 200/260 joules was applied. Weaning from CPB was started as soon as a normal and stable rhythm was achieved.

Femoral vessels were decannulated after reversal of heparin, and both inguinal and thoracic incisions were then repaired.

Table 1. Preoperative Characteristics of Mitral Valve Series.

Characteristic	Number of Patients (%)
Mitral stenosis	37 (40%)
Mitral regurgitation	30 (33%)
Mixed lesion	20 (22%)
Peri-prosthetic leakage	4 (5%)
Rheumatic	60 (66%)
Degenerative	22 (23%)
Endocarditic	9 (10%)
Pulmonary hypertension	30 (32%)
Previous embolism	17 (19%)
Atrial fibrillation	42 (45%)
Anti-phospholipid syndrome	5 (6%)
Mean EF	55%
NYHA III/IV	53 (57%)
COPD	11 (12%)
Redo	19 (20%)

RESULTS

In 96% of cases (all but five), the Port-Access™ surgical approach was performed "from skin to skin" and proved to be feasible. The remaining five patients required a conversion to standard sternotomy. Surgical procedures are listed in Table 2 ( ).

Mean CBP and cross-clamp times were 87.2 min. ± 51.2 (range of 10-457) and 54.9 min. ± 30.6 (range of 10-190), respectively. TEE was used in all patients and fluoroscopy was also employed in the first 25 cases. The "Fast-Track" technique was used in 45% of cases. An intra-operative or postoperative intra-aortic balloon pump (IABP) was never needed.

One patient undergoing a mitral valve replacement required conversion to midline sternotomy due to an uncontrollable localized atrial hemorrhage. This patient, despite surgical control of bleeding, died on post-op day 1 due to cardiogenic shock. Additional procedure-related complications during surgery requiring conversion to sternotomy were: aortic dissection (one patient) and iliac venous laceration (one patient). The remaining conversions took place during our initial experience and were secondary to very poor visualization of the target lesions (two cases). Rupture of the endoclamp occurred in three cases, with substitution required in one of these cases. In two patients a bilateral femoral artery cannula-

Table 2. Surgical Procedures.

ASD I closure	2
ASD II and PAVR correction	1
ASD II closure	25
Direct closure	24
Patch closure	4
Mitral valve replacement	58
with tricuspid plasty/replacement	5
Mitral valve repair	25
Peri-prosthetic leak repair	4
Myxoma removal	2
LIMA to LAD	5
LIMA to LAD plus SVGs	2

tion was necessary due to high pressure in the arterial line. Mechanical ventilation for longer than 24 hours was necessary in two patients (1.5%). Reoperation for postoperative bleeding was required in five patients (3.8%), with an immediate reoperation for cardiac reasons in one case and for groin revision in another. A 77-year-old woman in cachectic nutritional condition was extubated in the OR and given dinner; after food inhalation during the night, she died of intractable chronic respiratory failure after 72 days in the hospital.

Postoperative course was completely uneventful in 61% of the patients.

Overall hospital mortality consisted of two patients (1.5% for the global series; 2.2% for the mitral valve surgery cohort). Inotropic support was used in 15% of the patients. There was no observed perioperative myocardial infarction, acute renal failure, or wound infection. Permanent heart pacing was never required.

Median postoperative extubation time and ICU stay were 5 hrs. ± 6 hrs. (range of 2-32) and 18 hrs. ± 11.8 hrs. (range of 5-78), respectively. Median postoperative bleeding was 500 ± 814 ml (range of 55-4000), and 48% of patients did not receive any blood transfusion after surgery. Postoperative complications are listed in Table 3 (). Overall mean and median hospital stay was 7.57 ± 7.03 days and 7 ± 7.03 days (range of 1-72).

Follow-up at 50 months (mean 13.7 mos. ± 11.8, range 1-50) was 97% complete and included routine physical examination and postoperative echocardiography investigations. More than 91% of the patients were in NYHA class I/II. Postoperative echocardiography showed entirely normal findings in 82% of the patients. 73.2% of patients returned to work and/or normal physical activity within the first postoperative month.

Three patients were successfully reoperated upon after two months, three months, and three years, respectively, due to a perivalvular leak (one patient) and mitral regurgitation after previous repair (two patients). Three patients underwent noncardiac operations due to peripheral embolism (two patients) and peripheral atherosclerotic vascular disease. Late mortality accounted for three patients. Two of these patients developed acute mitral thrombosis and underwent emergency reoperation after two and three months, respectively. The remaining late mortality patient died of a cerebral tumor.

The survival rate four years after the operation was 96% for the overall group of Port-Access patients. Figures 1a () and 1b () show survival curves for the overall group and the mitral cohort of patients. Figures 2a () and 2b () show freedom from reoperation curves for the overall group and the mitral cohort of patients. Cosmetic results were excellent in 97% of the cases and good in the remaining late survivors.

DISCUSSION

This study shows that despite the initial difficulties of adapting to a new technique, Port-Access™ surgery is a very useful tool for reducing surgical invasiveness in a subset of patients for whom sternotomy is avoidable or undesirable. Although a necessary selection of patients was evident in the early period of our study, our results, as reflected in mortality and morbidity, are encouraging.

Since the introduction of Port-Access™ surgery in late 1996 [Stevens 1996a, Stevens 1996b], the supposed advantages of using a less invasive approach to treating cardiac pathologies has been contrasted with the theoretical risks associated with a new technique and with the difficulty initially encountered in operating without standard vision and through a very limited incision. The need for femoral cannulation and difficulties with de-airing associated with these procedures were objects of theoretical concern since the beginning of their use. The early negative experiences reported by some groups [Mohr 1998] relating to risk of arterial injuries were probably a result of insufficient experience of cardiac surgeons with the Seldinger approach and of the stiffness of the first generation cannulae and endoclamp. Also, it is more likely that groups pioneering a new technology will encounter more negative experiences. The overall incidence of major arterial injuries reported by the PAIR (Port Access International Registry) [Galloway 1999, Glower 2000] is 0.75% of 1063 operations included on the registry (0.18% in the second half of the series concerning 532 patients), and no specific group during that time has reported results as negative as those that occurred in the early series.

Table 3. Postoperative Complications.

Pleural effusion	9.8%
New onset atrial fibrillation	14.9%
Deep venous thrombosis	2.3%
Re-operation for bleeding	3.9%
Pneumonia	3.9%
Pneumothorax	1.5%
Wound infection	None
Acute renal failure	None
Pacemaker	None
Perioperative AMI	None
Stroke	0.7%
Acute lung failure	0.7%
Pericardial effusion	0.7%
No early complications	61%

Our only case of serious arterial injury, an acute type A aortic dissection, occurred in the first half of the experience and was most likely linked to an improper advancement of the guide wire in the ascending aorta together with an inadequate visualization by TEE. The patient was promptly converted to a standard mid-sternotomy and the ascending aorta was successfully replaced with a Dacron prosthesis. Twenty months later, the patient is asymptomatic and has returned to normal life activities, except for the addition of a permanent pacemaker. A careful clinical and, if necessary, instrumental preoperative evaluation of the patient should be undertaken to exclude patients at unusually high risk for peripheral vascular disease, even though valve disease patients seldom have this accompanying risk factor. Optimal visualization of the aorta by TEE [Siegel 1997] during guide-wire and endoclamp work-up is mandatory not only for correct positioning but also to minimize the risk of other complications [Falk 1996].

It is also possible to completely eliminate femoral manipulation by use of an Endodirect® aortic cannula [Glower 1999] for direct cannulation of the ascending aorta through an additional port in the first intercostal space. Femoral cannulation is safe if done properly and is, in fact, our first choice for cannulation. Endodirect® aortic cannulation requires very careful control of the aorta, sometimes requiring that the third intercostal space be included in the incision, which reduces the advantages of a minimal access approach. We do not have wide experience with the transthoracic clamp of the aorta described by Chitwood [Chitwood 1997]. However, it appears to be a useful alternative in cases of difficult or incomplete endoaortic occlusion (aortic dilatation). Although it may be difficult to use in redo operations, where dissection of the aorta from the pulmonary artery to cross-clamp the aorta may not be feasible without risk of injuries, we feel that it is a valuable addition to the surgeon's armamentarium. In our opinion, limited aortic manipulation through use of endoluminal occlusion offers a great advantage in minimizing the risk of embolism and may explain the low overall incidence of neurological complication (less than 1%) in our series.

Technical problems with the endoclamp, such as displacement or rupture, are very unusual if it is correctly used. Puncture of the balloon is especially likely to occur during stitching of the left upper quarter of the mitral annulus. If problems with the endoclamp occur, it can be replaced without major difficulty, as it is completely independent of the arterial cannula. The use of the Chitwood clamp at this stage may also be a good solution when the left heart is opened and rhythm is recovered. Alternatively, the procedure may continue under moderate hypothermic fibrillation of the heart without major risk. Displacement of the endoclamp during surgery is unusual if the catheter is firmly locked and the pressure of the balloon is carefully checked. However, some concerns may arise if heart activity resumes during the procedure and there is not complete evidence of an adequate aortic occlusion. TEE under an arrested heart is sometimes not an accurate tool for disclosing the exact balloon position.

De-airing after opening of the atrium was considered to be a problem due to the difficulty of gently shaking the ventricle through a very small incision. In practice, a thin, soft Foley catheter is introduced through the valve or prosthesis until deflation of the endoclamp and is gently used as a left vent. Aspiration through the tip of the endoclamp still located at the aortic root also assists with de-airing. However, the use of CO_2 since the beginning of the thoracotomy, allowing for a permanent intra-thoracic atmosphere of this gas, is the most significant tool in reducing the risk of air embolism. In our series, we have only recorded one case of a transient neurological event in a multi-redo mitral valve surgery, most likely related to the bad quality of the mitral annulus and to debris rather than air embolism. From the time we started using CO_2 routinely during these procedures, we noticed (as already described by others) a notable reduction in the amount of air detected by TEE. In fact, temporary early ECG changes after aortic declamping, suggesting coronary embolism by air, have become very unusual. Furthermore, the hypothesized difficulties of CO_2 washout during CPB were never observed.

From the very beginning, our intention was to simplify the procedure as much as possible and to reduce the time of operation and the risk of possible complications. After the first 25 patients, we were able to eliminate completely the need for fluoroscopy, using TEE for both cannulae and endoclamp positioning. We began to use a percutaneous 14 Fr. cannula through a neck access to the jugular vein to improve venous drainage of the superior vena cava, even in procedures for which there was no plan to open the right atrium. This change dramatically reduced the need for active drainage. Since the early part of the series, we have limited the use of the Endopulmonary vent and the EndoCoronary sinus catheter to only selected situations.

Port-Access™ surgery is considered especially appropriate for redo operations [Verrier 1998] to reduce the risk associated with a re-entry sternotomy and to limit the amount of bleeding. Our experience with Port-Access™ for redos was satisfactory. We used the technique in 19 patients (close to one-fifth of the mitral patients in our series) with encouraging results even for high risk patients like multi-redo patients (four), patent CABG patients (one), and octogenarians (two), as well as for mitral procedures in the presence of a prosthetic aortic valve (four patients).

A limited approach is also useful in elderly patients and patients with poor lung function or severe nutritional problems for whom sternotomy and a more extensive approach may affect postoperative recovery. In our series, in a group of 18 patients (20%) older than 70 years who were operated upon for mitral valve disease, the 30-day mortality rate was 5.5% (one patient). The postoperative course was also favorable, with 94% of patients discharged from ICU within 24 hours and a median hospital stay of 7 days ± 16.6 days. At the present time, only severe pulmonary hypertension or obesity would constitute a formal contraindication to the use of the Port-Access™ technique for mitral valve surgery.

Two of our patients had a quite early thrombosis of the mechanical bileaflet mitral prosthesis. One patient was a young north-African immigrant who experienced inadequate control of anticoagulation and required emergency surgery. The patient died due to cardiogenic shock. The second patient was a 30-year-old woman affected by an antiphospholipid syndrome who underwent mitral valve replacement and

was readmitted two months later for valve thrombosis. The bileaflet valve was replaced by a monodisc mechanical device uneventfully, but on the day of discharge the patient died suddenly upon leaving the hospital. The relatives did not authorize a post-mortem examination.

CONCLUSION

Our experience with the Port-Access™ technique was similar to that reported by other groups [Galloway 1999, Glower 2000] in that it was found to be safe in terms of mortality and morbidity. Early in our series, because we were at the bottom of the learning curve, the procedure was more time-consuming than the standard technique, and we encountered some technical problems due to inexperience that gave rise to a few procedural concerns. At present, despite constraints on using the technique due to certain infrastructural limitations of our unit, the Port-Access™ approach is our first choice for patients with surgical atrial septal defect and all mitral valve disease patients. With the exception of patients with peripheral vascular contraindications, we strongly encourage the use of this technique for patients who would be exposed to higher risk from a standard mid-sternotomy approach or for other extreme clinical situations.

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Figure Legends

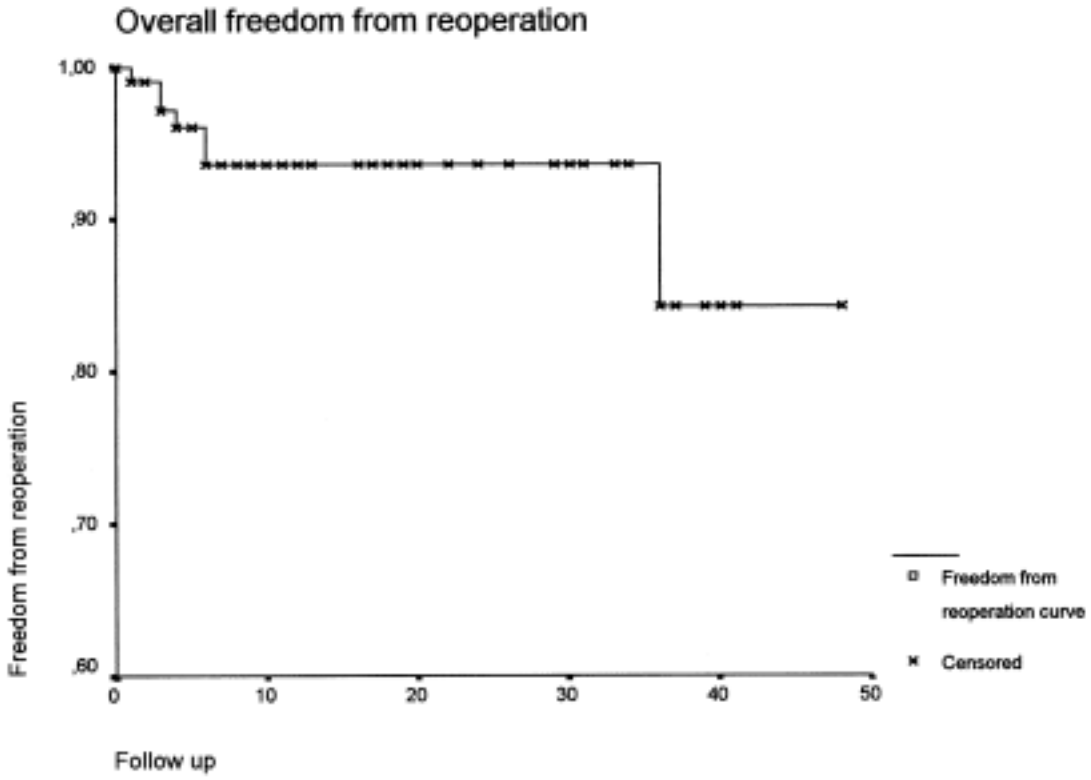

Figure 1a: Overall Kaplan Meier Survival Curve.

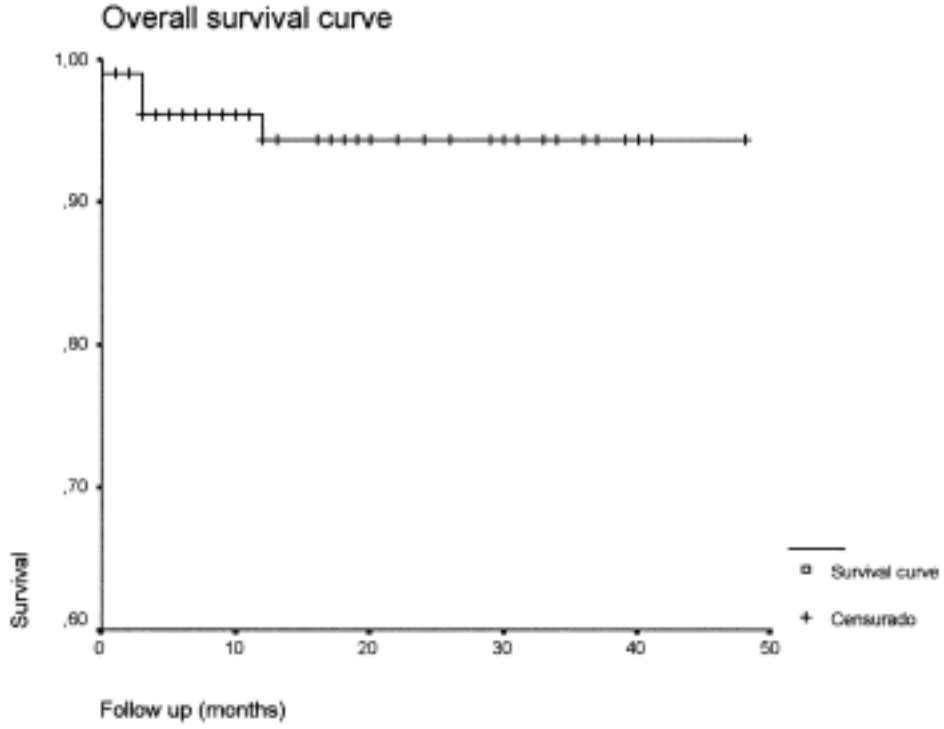

Figure 1b: Mitral Sub-Group Kaplan Meier Survival Curve.

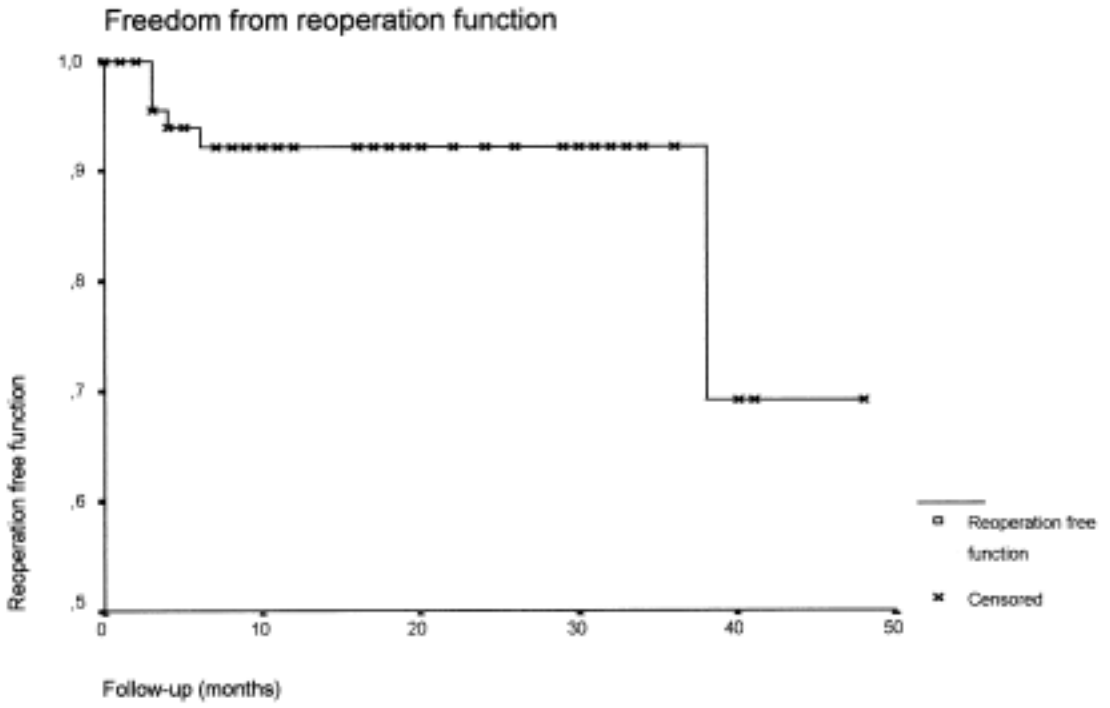

Figure 2a: Overall Freedom From Reoperation Curve.

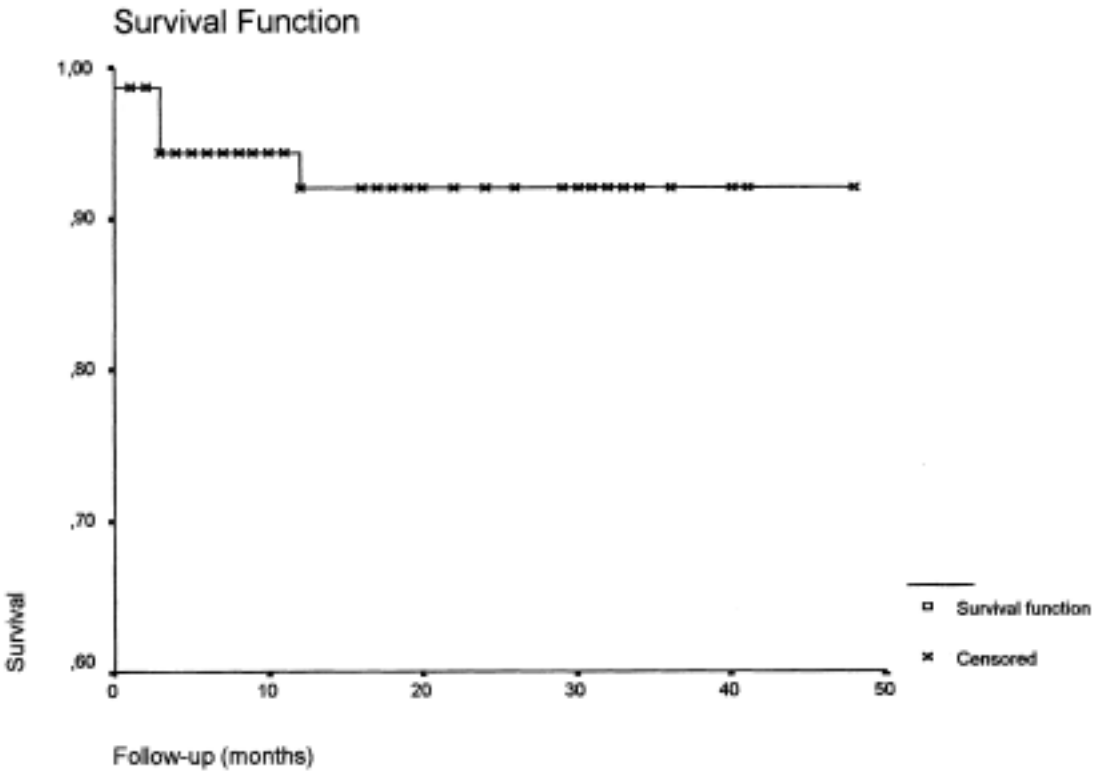

Figure 2b: Mitral Sub-Group Freedom From Reoperation Curve.