VALVE REPLACEMENT IN SMALL AORTIC ROOT; A TEN-YEAR EXPERIECE OF AORTIC ROOT RECONSTRUCTION BY MANOUGUIAN'S TECHNIQUE

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Abstract:

Back ground:

Aortic valve replacement (AVR) in patients with a small aortic annulus may represent a surgical challenge. Although new generation heart valves especially stentless bioprosthesis minimize the need for aortic annulus enlargement procedures but there were some conditions that necessitate the aortic root enlarging method to implant a suitable size of prosthesis. We evaluated the midterm results of the Manouguian procedure as a simple method to aortic root enlargement.

Methods & Material:

We performed a retrospective review of 70 patients (38 female, 32 male; mean age 29.3 +/- 19 years) underwent aortic root enlargement during AVR. The Mean follow-up period was 36.7 months. Primary aortic valve disease included rheumatic heart disease (75.7%), congenital aortic valve disease (14.3%) and active endocarditis (10%) The predominant aortic valve pathology was aortic stenosis (AS) in the majority of cases (75.7%). All patients underwent AVR with a prosthetic valve one or more size larger than patients annulus diameter.

Results:

Improvement of functional status was seen in all survivors and all of them were in NYHA class I or II. After use of this procedure the mean indexed effective orifice area of patients' annulus had enhanced from 0.71+/-0.19 to 1.46 +/- 0.38 based on label size of prosthesis. There was 10 operative mortality (14.3%) and two late deaths (2.8%). The rate of surgically induced mitral regurgitation was 4.2% but only one of these patients need for mitral valve replacement. There was no case of other procedure-related morbidities including peri-prosthetic leak, sever hemolysis, prosthetic valve endocarditis or residual patient prosthetic mismatch (PPM).

Conclusion:

This procedure seems a simple and effective method to enlargement of aortic annulus and provide excellent hemodynamic results with a low incidence of operation related morbidities. Although the in-hospital mortality rate of our series was high but we should consider that the primary causes of deaths were not related to the enlarging aortic annulus procedure directly.

Keywords:

prosthetic mismatch, Manouguian procedure, small aortic annulus

Introduction:

Aortic valve replacement (AVR) in patients with small aortic annulus is a challenging procedure and is not an uncommon surgical problem. Sever patient-prosthetic mismatch (PPM) is a predictor of higher long-term mortality and congestive heart failure [1, 2]. For patients undergoing AVR who are at risk of sever mismatch, every effort should be made to use a larger prosthesis or to consider a prosthesis with a larger effective orifice area. Although new generation heart valves especially stentless bioprosthesis minimize the need for aortic annulus enlargement procedures but there were some conditions that necessitate the aortic root enlarging method to implant a suitable size of prosthesis [3, 4].

Various techniques have been proposed to enlarge the aortic annulus, however some of these are complex and have a relatively high mortality and generally

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recommended for complex left ventricular outlet tract obstructions [3, 5]. The Manouguian operation is considered as a simple and effective method to enlarge the aortic annulus. The objective of this study was to assess the midterm outcome of this procedure.

Methods and Materials:

Patient population:

Between March 1994 and August 2005, 70 patients underwent aortic root enlargement during AVR using Manouguian's approach were identified from surgical database. All preoperative, surgical and postoperative data were obtained from medical records. There were 38 female and 32 male patients. The ages ranged from 2 to 77 years (mean 29.3 +/- 19 years) and body surface area (BSA) ranged from 0.70 to 2.20 m2 (mean 1.41 +/- 0.28 m2). Primary aortic valve disease included rheumatic heart disease (75.7%), congenital aortic valve disease (14.3%) and active endocarditis (10%) The predominant aortic valve pathology was aortic stenosis (AS) in the majority of cases (75.7%) and aortic insufficiency (AI) in 7.2% (5/70) and mixed lesions in 17.1% (12/70) of patients were the main aortic valve diseases (Table 1). Twenty four patients (34.3%) had a previous aortic valve (AV) surgery and Manouguian's procedure was done as a re-operation (Table 2).

Table 1: Incidence and types of valves involvement

Underlying Pathology	NO. (%)	%
AS	11	15.7
AI	3	4.3
AS+AI	27	38.6
AS+MR	5	7.1
AS+AI+MS	5	7.1
AS+AI+MR	1	1.4
AS+AI+MS+TR	1	1.4
AS+AI+MR+MS+TS+TR	2	2.9
AS+AI+MS+MR	1	1.4
AI+MR	1	1.4
AV ENDOCARDITIS	7	10.0
AV MALFUNCTION+MS	3	4.3
AS+AI+CAD	1	1.4
AI+MS	2	2.

Table 2 : Incidence of different types of previous surgeries

Underlying Pathology	NO. (%)	%
Aortic Valvotomy	6	10.3
AVR*	3	5.2
Subvalvular Resection	2	3.4
AVR + CO-A **Repair	1	1.7
AVR + MVR***	1	1.7
Aortic Valvoplasty	3	5.2
PDA#	1	1.7
Aortic Valvotomy+PDA+COA repair	1	1.7
Subvalvular resection + COA repair	1	1.7
MVR	1	1.7
Subvalvular Resection + PDA	1	1.7
CMVC##	1	1.7

*Aortic Valve Replacement, ** Coarctation of Aorta
*** Mitral Valve Replacement, # Patent Ductus Arteriosus
Closed Mitral Valve Commissurotomy

Statistical analysis:

Continuous variations were expressed as mean+/- standard deviation. Differences of frequencies were compared using chi-square test and fisher exact test. A p value less than 0.5 was considered statistically significant. The statistical analysis was performed using the SPSS version 12 software package.

Surgical technique:

The heart was exposed through a standard median sternotomy under general anesthesia. Cardiopulmonary. bypass was instituted with the use of ascending aorta and single caval cannulation during moderate hypothermia (32oC). Myocardial protection was performed with cold crystalloid cardioplegic solution every 20 minutes, directly into coronary ostium and retrograde infusion into coronary sinus in few cases as surgeon preference. Aortotomy was done with an oblique incision and native or prosthetic aortic valve was resected. Additional procedure including coronary artery bypass graft, septal myotomy or myomectomy and other valves surgery was carried out when needed (table 3). Then incision of aortotomy directed to commissure between left and non-coronary cusps was extended through the intervalvular fibrosa trigone toward the center of anterior mitral valve leaflet for a distance about 1 cm. The depth of incision and opening of the left atrial (LA) roof depended on the anatomical structure and the surgeon's judgment. In 29 patients (41%) this incision was extended toward mitral valve annulus and left atrium was opened, therefore double patch repair was performed but for the remainders single patch technique repair without incision of mitral annulus or LA was used. The resulting V-shaped defect in aortic wall was closed using an adequately sized diamond shaped Dacron (37/70) or untreated fresh autologous pericardial (33/70) patch with running or interrupted vertical mattress 4-0 polypropylene sutures. Repair of left atrial defect was performed from outside using an elliptical autologous pericardial patch with running sutures. A prosthetic aortic valve that was two sizes larger than the native annulus was sewn into the place using running 2-0 polypropylene sutures or interrupted horizontal mattress 2-0 polyester pledgeted sutures. A stented bioprosthesis was used in on patient and for the others a mechanical aortic valve includes St.jude (64.3%), Carbomedics (27.1%) or Medtronic-Hall (7.1%) valve types were implanted. Re-warming, de-airing and weaning off from CPB were performed as standard way.

Table 3: incidence of Concomitant Procedure during Aortoplasty

Concomitant procedure	*NO. (%)*	*%*
MVR*	7	12.1
MVR+TV** repair	2	3.4
OMVC***	3	5.2
Septal Myomectomy MVR + septal	11	19.0
Myomectmy	2	3.4
MVR+TVR#	1	1.7
MV## Thrombectomy+TVR	2	3.4
MV Repair	1	1.7
CABG###	29	50.0

*Mitral Valve Replacement, ** Tricuspid valve
*** Open Mitral Valve Commissurotomy
# tricuspid valve replacement, ##Mitral Valve
###Coronary artery bypass Graft Surgery

Follow up:

All survivors were considered to visit at 1, 3, 6 and 12 months after operation and every year thereafter. Follow up protocol completed in 96.4% of cases for at least the third month of postoperative period. The mean follow up period was 36.7 months ranged from 3 to 138 months.
The patients were followed up in cardiology and cardiac surgery clinics with clinical examination, serial transthoracic 2D color-Doppler echocardiographic (TTE) assessment and if indicated transesophageal (TEE) echocardiographic study. During each follow up periods the patient's clinical status, hemodynamic performance of prosthetic valve and postoperative complications were assessed.

Results:

Improvement of functional status was seen in all survivors. Postoperatively 77.1% of patients were in NYHA functional class I and the remainder were in NYHA class II, while preoperatively only 4.3% of patients were in NYHA class I, 68.6% in class II and 27.1 % of them were in NYHA class III. This changes were statistically significant ($P<0.01$).
Postoperative echocardiographic assessments showed significant reduction in trans-valvular peak gradient (TVPG) after the surgery. The mean TVPG had reduced from 82 +/- 39 mmHg to 28 +/- 16 mmHg postoperatively ($P<.0001$). According to the preoperative evaluations the mean aortic annulus diameter was 15.8+/- 4.6 mm (Ranged from 7 to 21.9 mm) and estimated indexed effective orifice area (IEOA) based on defined geometric orifice area (GOA) of different sizes of St. Jude regent type prosthesis without annulus
enlarging operation was 0.75 +/- 0.21. The range of GOA for implanted different types of aortic prosthesis based on manufactured labeled size was from 1.47 cm2 to 3.84 cm2 (mean 2.15 +/- 0.45 cm2). Postoperatively the mean in-vitro IEOA was 1.46 +/- 0.38 (Ranged from 0.9 to 2.93), indicated that this improvement in IEOA was significant ($P<0.0001$).
We also evaluated the roles of used patch type and two operative methods (one or two patch technique) and found that there were no significant relationship between these factors and operative mortality or morbidities (P=NS).

Mortality:

The in-hospital death rate of our series was 14.3% (10/70). Low cardiac output syndrome was the most common cause of early death (6/10). Septicemia was primary cause of death in a 28 years old man presented with native aortic valve endocarditis. Hypoxic encephalopathy, perioperative myocardial infarction and uncontrolled postoperative mediastinal bleeding due to sever coagulopathy were the other primary causes of early mortalities. Twenty six percent of dead cases had a history of previous aortic operations and 64.3% of them had another concomitant procedure.
We had two cases of late death (2.8%) therefore the overall mortality rate in our series was 17.1%. Non-cardiac events were the leading cause of death in these two cases of late mortality. One of these patients was a 14 years old boy presented with active native aortic valve endocarditis. She died 4 month after operation due to recurrent endocarditis

***Table4:** Characteristics of Dead Patients after Manouguian's Aortoplasty.*

No.	*Age*	*Sex*	*BSA * m2*	*Previous operation*	*underlying disease*	*Pre-op PG** mmHg*	*Valve size*	*Valve type*	*Concomitant procedure*	*CPB*** time min.*	*AOX **** time min.*	*Death*	*Death cause*
1	20	F	1.30	NO	AS###	138	19	C.M*^	septal myomectomy	220	166	in-hospital	Low output syn.
2	67	F	1.45	NO	AS	80	19	SJM**^	NO	136	99	in-hospital	Low output syn.
3	28	M	1.85	MVR#&AVR##	PVE+	61	21	CM	Re-do MVR	187	132	in-hospital	Septicemia
4	45	F	1.50	MVR&AVR	TR+PVM++	110	21	CM	TVR*#	250	110	in-hospital	Perioperative MI
5	75	F	1.60	NO	AS+MS^	90	21	SJM	OMVC*#*	191	161	in-hospital	Bleeding
6	11	M	1.35	Aortic valvotomy	AS+AI^^	54	21	MH*^*	NO	124	95	in-hospital	Low output syn.
7	44	F	2.25	NO	AS+AI	95	23	SJM	NO	382	158	in-hospital	Low output syn.
8	29	M	1.85	NO	AS+AI	136	25	MH	septal myomectomy	215	124	in-hospital	Tachyarrythmia
9	13	M	1.60	Aortic valvotomy	AS+AI	80	21	SJM	NO	297	139	in-hospital	Low output syn.
10	46	F	1.65	AVR	MS+TS+PVM	36	21	CM	MVR + OTVC^#	311	180	in-hospital	Low output syn.
11	47	F	1.75	NO	AS+AI+MS	93	21	SJM	MVR	155	121	Late	Hemorrhagic CVA
12	14	M	1.20	NO	NVE^^^	28	21	SJM	NO	85	70	Late	Brain septic emboli

*Body Surface Area, ** Peak Gradient, ***Cardiopulmonary bypass time, ****aortic Cross Clamping Time,#Mitral valve replacement, ## Aortic Valve replacement, ### Aortic stenosis, +Prosthetic valve endocarditis,++Aortic Prosthetic Valve Malfunction,^mitral stenosis, ^^Aortic Insufficiency, ^^^Native valve endocarditis, *^Carbomedics, **^St.Jude Medical, *^*Medtronic Hall, *#Tricuspid valve replacement, *#*Open mitral valve commissurotomy, ^#Open tricuspid valve commissurotomy

and cerebral septic emboli. The second case was a 29 years old lady underwent mitral valve replacement (MVR) in addition to Manouguian's procedure. She died in 17th month of postoperative period as a result of a hemorrhagic cerebrovascular accident. . Table 4 shows the characteristics of dead patients.

We analyzed the risk factors for mortality and found that redo operation, concomitant procedure, aortic cross clamping time>100 minute and active endocarditis were more common in dead cases than survivors but the correlation of theses factors and also older or younger age, types of valve or patch, preoperative LVEF and CPB time with early or late mortality were not significant statistically (P>0.05).

Morbidity:

The incidence of Manouguian's procedure-related complication was low in our study. We had three cases of surgically induced mitral valve regurgitation (4.2%). One of these patients underwent mitral valve replacement due to rupture of mitral valve apparatus. Resultant mitral regurgitation was not significant in two other patients to necessitate surgical intervention during follow-up period. There was one case of postoperative transient complete heart block that returned to sinus rhythm after five days. We had no case of other procedure-related morbidities including peri-prosthetic leak, sever hemolysis, prosthetic valve endocarditis or residual patient prosthetic mismatch (PPM). The other postoperative complications were listed in table 5

Table 5: Incidence of Post-operative Complications.

Complication	*Frequency*	*Percent %*
Surgical bleeding	6	10.2
PE*	7	11.9
Long-intubation	2	3.4
CVA**	1	1.7
RBBB***	1	1.7
Hypoxic Encephalopathy	1	1.7
Complete Heart Block	1	1.7
MV^ Rupture	1	1.7

Pericardial Effusion, ** Cerebrovascular Accident, ***Right Bundle Branch Block ^ Mitral Valve

Re-operation:

The mediastinal re-exploration rate for control of surgical postoperative bleeding was 4.2% (3/70) and

Conclusion:

The overall goal of aortic valve replacement is to reduce the pressure and volume overload on the left ventricle (LV) thereby helping the remodeling process of the ventricle. However when the aortic root is small these goals may be difficult to achieve.[3,7] Aortic valve replacement (AVR) in the patients with small aortic annulus is a challenging procedure and is not an uncommon surgical problem.

Sever patient-prosthetic mismatch is a predictor of higher long-term mortality and congestive heart failure.

Prosthetic-patient mismatch affects LV function and therefore patient's original symptoms may not be alleviated, this has adverse effects on the patient's quality of life. For every 1.0 mmHg increase in trans-aortic gradient, the risk of LV dysfunction and heart failure will increase by 1.03 times.[7,8,9]

The effect of PPM on survival is a mater of controversy. In 1997 Pibarot & his colleagues reviewed 72 patients after AVR. Using iEOA of less than 0.85 as PPM he did not find any significant difference in survival of patients with or without PPM. However he showed that patients with PPM were in higher NYHA classification. [7,8,9] In a meta-analysis of 1300 patients comparing patients with and without PPM, those with small aortic valve prosthesis had higher operative risk (1.0%). However there was no difference in mid- and long-term survival. [11,12] The conclusion appears to be; although PPM seems not to affect long-term mortality it certainly increases morbidity of these patients.

It seems that for patients with small aortic root the ideal choice is aortic homograft (or pulmonary autograft) implantation.[9] These have excellent hemodynamics performance and do not reduce the diameter of the aortic root significantly. However for those patients with severely calcified and non-compliant aortic root, and those younger than 20 years of age use of aortic homograft is contraindicated. [7,9] A superior hemodynamic performance may be obtained by the use of the new generation prosthetic valves and stentless bioprostheses even when the aortic annulus is 19 mm in diameter. When using stentless valves it is advisable to use the total root replacement techniques since it has better long-term outcome with no added operative risk over the subcoronary technique.[12,13,14,15,16,] As the occurrence of PPM was rare in total root replacements, and the implantation procedure did not seem to increase the operative risk, the recommendation is made to consider this implantation technique if a small projected IEOA is expected. Unfortunately these prosthesis may not be easily available in some centers and probably some surgeons doesn't popular with implantation techniques. In addition the long term durability of currently manufactured tissue valves whether stented or stentless remains unknown, therefore these valves were used mostly to elderly patients.[17] Patient-prosthesis mismatch with heart valve prostheses as demonstrated by the indexed effective orifice area can be avoided by use of aortic annulus enlarging techniques such as Manouguian or Nick methods. . The hemodynamic performance of these aortic valve prostheses is satisfactory.

The choice of aortic root enlargement for the implantation of a valve with a larger effective orifice area is preferred by most of the surgeons over the implantation of a valve with a smaller effective orifice area. The late postoperative functional capacity of the patient is significantly improved with root enlargement. Surgeons should be encouraged to perform root enlargement in patients with a small effective orifice area, and such surgery may even be performed routinely in these patients when new generation mechanical or stentless bioprosthesis are not available.[3]

Although the in-hospital mortality rate of our series was higher than the previous studies but we emphasize that the primary causes of deaths were not related to the enlarging aortic annulus procedure directly. Low cardiac output syndrome solely was the main death cause in 60% of our patients and most of mortalities occurred in the early years of our experience therefore it seems that poor myocardial management during operation was the most important technical problem. In the other hand we had a heterogeneous group of patients and also 64% of patient had a major concomitant procedure and 26% of operations were done as a redo surgery, however, statistical analysis did not show the correlation of these factors and early mortality($P=0.07$). Meanwhile the aortic cross clamping time more than 100 minute and replacement of a smaller prosthetic aortic valve size (19 & 21 mm) were more common in dead cases than survivors, but statistically these factors were not predictive factors of mortality($P>0.05$).

In contrast to mortality rate, improvement of clinical status and hemodynamic profiles was excellent in our series. All survivors were in NYHA class I (77.1%) or II (22.9%) postoperatively. The mean IEOA increased from 0.75 +/- 0.21 to 1.46 +/- 0.38 using aortic root enlarging procedure ($P<0.0001$).In addition the procedure related complications in our patients were rare. The surgically induced mitral regurgitation was occurred in 3 patients but only one of them needed to mitral valve replacement. We had no case of other procedure-related morbidities including peri-prosthetic leak, sever hemolysis, prosthetic valve endocarditis or dysfunction and residual patient prosthetic mismatch (PPM). It may indicate that we can get a good result from the Manouguian procedure with a good myocardial management during the operation and better peri-operative cares.

Residual mild to moderate trans-prosthetic valve gradient (peak gradient 20-40 mmHg) was seen in 9 patients. The primary cause of this residual gradient was complex left ventricle outlet obstruction (aortic & subaortic stenosis) and ineffective septal myomectomy in 2 patients, double valve replacement (AVR & MVR) in 3 cases, systolic anterior motion (SAM) phenomena following mitral valve repair in one patient inherent stenotic property of stented bioprosthesis in one case and incomplete annular enlargement in two patients with BSA more than 1.80 m2. Despite of the residual stenosis in LVOT, these entire patients remained physically active individual during follow up period and none of needed for re-intervention. Foster and associates found no correlation of aortic transvalvular gradient with clinical status during long-term period [18].

We used the fresh non-treated autologous pericardium or Dacron patch in either one or two patch surgical techniques as surgeons' preference and found no patch-related surgical complications. Some studies have shown that the autologous pericardium of adults is so durable that it does not become aneurysmal not only in left ventricle but also in aortic root [19,20]. Ease of handling, accurate hemostasis, low infectious risk and non-hemolytic nature are the other advantages of pericardial patch, therefore it seems that this type of patch is better choice for reconstruction of aortic root and left atrial roof during Manouguian operation.

In summary for patients undergoing AVR who are at risk of sever mismatch, every effort should be made to use a larger prosthesis or to consider prosthesis with a larger effective orifice area. Valve selection for the small aortic root is a multi-factorial process. These factors include patient age, lifestyle, pregnancy status, drug compliance, EOA of prosthetic valve, availability of prosthesis, experience & skill of surgeon

Although the new generation prosthetic aortic valves especially stentless bioprosthesis have reduced the risk of PPM and need for aortic root enlarging surgeries but there are some conditions that necessitate these types of operations yet. These situations include of AVR in adult patients with small aortic root (annulus size <21mm) and large BSA or significant PPM (IEOA<= 0.85) or patients with endocarditis and aortic root abscess formation that destroyed aorto-mitral fibrosa in centers that new generation aortic valves are not available or the surgeons have not enough experience to performing aortic root replacement or

subcoronary implantation of a stentless bioprosthesis. The other indication of Manouguian operation is children with congenital aortic stenosis who valve repair techniques are not effective and Ross operation can not performed due to medical or technical problems.

We prefer the AVR with a suitable size prosthetic valve using a more complex and more time consuming annulus enlarging procedure to AVR with remaining PPM because we got good clinical and hemodynamic results but to achievement of acceptable mortality rate we need a better myocardial management strategy and more experience to doing this operation

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