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Reinforced aortic root reconstruction for acute type A aortic dissection involving the aortic root

Reconstrução da raiz da aorta reforçada para dissecção aguda da aorta tipo A envolvendo a raiz da aórtica

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Abstract

Objective: **There are debates regarding the optimal approach for AAAD involving the aortic root. We described a modified reinforced aortic root reconstruction approach for treating AAAD involving the aortic root.**

Methods: **A total of 161 patients with AAAD involving the aortic root were treated by our modified reinforced aortic root reconstruction approach from January 1998 to December 2008. Key features of our modified approach were placement of an autologous pericardial patch in the false lumen, lining of the sinotubular junction lumen with a polyester vascular ring, and wrapping of the vessel with Teflon strips. Outcome measures included post-operative mortality, survival, complications, and level of aortic regurgitation.**

Results: **A total of 161 patients were included in the study (mean age: 43.3 ± 15.5 years). The mean duration of follow-up was 5.1 ± 2.96 years (2-12 years). A total of 10 (6.2%) and 11 (6.8%) patients died during hospitalization and during follow-up, respectively. Thirty-one (19.3%) patients experienced postoperative complications. The 1-, 3-, 5-, and 10-year survival rates were 99.3%, 98%, 93.8%, and 75.5%, respectively. There were no instances of recurrent aortic dissection, aortic aneurysm, or pseudoaneurysm during the entire study period. The severity of aortic regurgitation dramatically decreased immediately after surgery (from 28.6% to 0% grade 3-4) and thereafter slightly increased (from 0% to 7.2% at 5 years and 9.1% at 10 years).**

Conclusion: **This modified reinforced aortic root reconstruction was feasible, safe and durable/effective, as indicated by its low mortality, low postoperative complications and high survival rate.**

Descriptors: **Aneurysm, dissecting. Aortic diseases/surgery. Aorta/surgery.**

Resumo

Objetivo: **Há um debate sobre a melhor abordagem para dissecção aguda da aorta tipo A (DAAA) envolvendo a raiz da aorta. Nós descrevemos abordagem aórtica reforçada modificada de reconstrução de raiz para o tratamento DAAA envolvendo a raiz da aorta.**

Métodos: **Um total de 161 pacientes com DAAA envolvendo a raiz da aorta foram tratados pelo nosso abordagem reforçada modificada da reconstrução da raiz da aorta de janeiro de 1998 a dezembro de 2008. As características-chave da nossa**

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Abbreviations, Acronyms & Symbols	
AAAD	Acute type A aortic dissection
BP	Blood pressure
CIs	Confidence intervals
CT	Computed tomographic scan
HR	Hazard ratios
OR	Odds ratios
PASW	Predictive Analytics SoftWare
SOV	Sinus of Valsalva
STJ	Sinotubular junction

abordagem modificada foram a colocação de um remendo de pericárdio autólogo na falsa luz, forro do lúmen supravalvar com um anel vascular, poliéster e envolvimento dos vasos com tiras de teflon. A avaliação pós-operatória incluiu mortalidade, sobrevivência, complicações, e grau de insuficiência aórtica.

Resultados: **Um total de 161 pacientes foram incluídos no estudo (média de idade: 43,3 ± 15,5 anos). A duração média de acompanhamento foi de 5,1 ± 2,96 anos (2-12 anos). Um total de 10 (6,2%) e 11 (6,8%) pacientes morreram durante a internação e durante o acompanhamento, respectivamente. Trinta e um (19,3%) pacientes apresentaram complicações pós-operatórias. A 1 -, 3 -, 5 -, e as taxas de sobrevivência de 10 anos foram 99,3%, 98%, 93,8% e 75,5%, respectivamente. Não houve casos de dissecção aórtica recorrente, aneurisma ou pseudoaneurisma da aorta durante o período de estudo. A gravidade da regurgitação aórtica diminuiu drasticamente logo após a cirurgia (de 28,6% para grau 0 de 3-4%) e, posteriormente, teve ligeiro aumento (de 0% a 7,2% em 5 anos e de 9,1% aos 10 anos).**

Conclusão: **A reconstrução da raiz da aorta reforçada modificada é viável, segura e durável/eficaz, como indicado pelas baixas mortalidade e complicações pós-operatórias e taxa de sobrevivência elevada.**

Descritores: **Aneurisma dissecante. Doenças da aorta/cirurgia. Aorta/cirurgia.**

INTRODUCTION

Acute type A aortic dissection (AAAD) is associated with a very high mortality rate (1%-2% per hour after the onset of symptoms) if left untreated, and up to 20% of patients die before receiving medical attention [1-3]. The current standard of care in the treatment of AAAD is emergency surgery, which is associated with an approximately 70% chance of survival, and high postoperative mortality and morbidity [1,2,4].

The primary aim of surgery in the treatment of AAAD is to prevent rupture of the dissection and subsequent hemorrhage. For patients with involvement of the aortic root, there are two conventional methods of surgical management. First, if the aortic root has evidence of aortic valve or aortic ring pathologies, or there is an existing aortic aneurysm, a valve sparing [5] or Bentall approach [6] may be used. Second, if the aforementioned pathologies are not apparent, ascending aortic replacement with traditional aortic root reconstruction (supracomissural replacement) may be performed [7,8]. Various modifications of aortic valve sparing approaches have also been described, including remodeling [9], Teflon remodeling [10], gluing dissected layers [11], and supracoronary replacement of the ascending aorta with root reconstruction [12]. Aortic valve-sparing can reduce short- and long-term complications associated with mechanical and biological replacement valves [13,14].

However, the conventional methods of management have limitations, including a long duration of surgery for both the valve sparing and Bentall approaches (a particular concern for patients requiring emergency surgery), the need for long term anticoagulation with the Bentall approach [15], and recurrent aortic dissection, development of aortic aneurysm or pseudoaneurysm, aortic insufficiency, and increased morbidity because of failure at the proximal aorta with the supracomissural replacement [1,16]. Based on the available evidence, none of these approaches appear to be associated with consistently better outcomes than the others [1]. Unsurprisingly, there is a lack of consensus as to the optimal surgical approach for the treatment of AAAD involving the aortic root.

Herein, we describe a modified reinforced aortic root reconstruction approach for treating acute AAAD involving the aortic root and analyzed effects of various perioperative factors on survival, postoperative mortality and complications. The aim of this study is to investigate the feasibility, effectiveness and safety of this modified approach.

METHODS

Patients

All patients were treated from January 1998 to December 2008 at Shanghai Hospital, Second Military Medical University, P. R. China. Patients with AAAD affecting the aortic root (between the sinotubular junction and the aortic annulus) were eligible for the surgery, and thus inclusion in the study. Exclusion criteria were pathologies not suitable for aortic root reconstruction including aortic sinus aneurysm or aortic annulus dilatation; tears at the aortic root or in the coronary artery; coronary artery avulsion; moderate or severe aortic regurgitation caused by disorders other than dissection; and obvious aortic valve lesions. A total of 161 patients were included in the study and their demographic and clinical characteristics are summarized in Table 1.

Table 1. Patient demographic and clinical characteristics (N = 161).

Age, years	43.3 ± 15.5 (16-71)
Sex	
Male	131 (81.4)
Female	30 (18.6)
Smoking	40 (24.8)
Hypertension	106 (65.8)
Pericardial effusion	20 (12.4)
Diabetes mellitus	16 (9.9)
Cardiogenic shock	14 (8.7)
Visceral malperfusion	10 (6.2)
Neurological symptoms	8 (5.0)
Creatinine > 2 mg/dL	5 (3.1)
DeBakey type	
Type I	142 (88.2)
Type II	19 (11.8)
Time from symptom onset to surgery (days)	3.5 ± 2.9 (1-14)

Data are summarized as mean ± standard deviation (range: minimum to maximum) for continuous variables or number (percentage) for categorical variables

The study was approved by the Ethics Committee of Shanghai Hospital, Second Military Medical University. Patients' informed consent was waived due to the retrospective nature of the study.

Surgical Technique

The surgical technique was adapted from a previously described method [17]. A midline incision was performed to open the chest cavity, and catheters were placed to monitor central venous and pulmonary artery pressure. Invasive arterial blood pressure (BP) monitoring in the upper bilateral and lower limbs was also initiated via the subclavian and femoral arteries.

Normally, the right subclavian artery was cannulated for arterial inflow. If the subclavian artery was too thin and unable to satisfy the inflow requirement, the femoral artery would be cannulated. If the subclavian artery had plaque or dissection, the femoral artery would be cannulated initially. The aorta was never directly cannulated.

After the right atrium was cannulated, cardiopulmonary bypass was initiated with lowered systemic temperature (nasopharyngeal temperature of 30°C). The aortic arch and its branches were fully exposed during this period. The distal ascending aorta was clamped and the proximal aorta was incised. Subsequently, a cardioplegic solution was directly infused. After cardiac arrest, aortic root reconstruction was performed while systemic temperature continued to be lowered.

Then, the aortic root was carefully explored to ensure that the criteria for aortic root reconstruction were met. The tissue surrounding the aortic root was carefully dissected to ensure that the integrity of the intima and the adventitia was maintained. The ascending aorta was transected 5 mm above the sinotubular junction (STJ), and thrombi and debris in the false lumen were removed. A valve gauge was used to measure the STJ endoluminal diameter, and an 8 mm polyester vascular ring (with an inner diameter 1 to 2 mm smaller than that of the STJ) was used to line the STJ lumen (i.e., the inner surface of the intima). The lower edge of the vascular ring was approximately 1 mm above the STJ plane. The vessel was wrapped (outside the adventitia) in Teflon felt strips for reinforcement. An autologous pericardial patch, which had already been trimmed to match the affected area, was then placed in the false lumen.

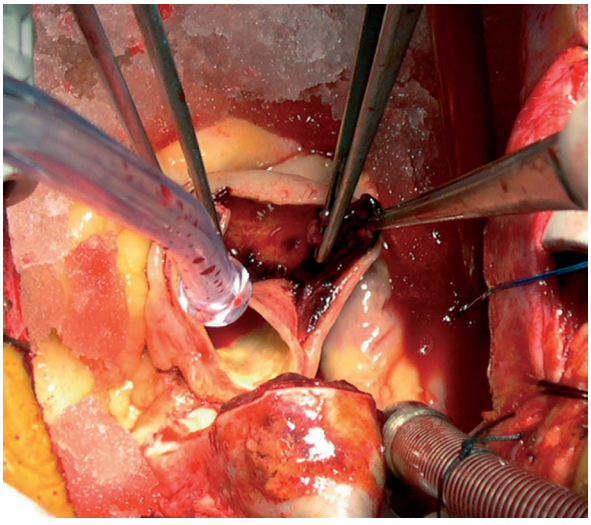
Care was taken to avoid the coronary artery to ameliorate the risk of myocardial ischemia caused by coronary artery compression. Root reconstruction was completed by performing over-and-over suturing using 4-0 propylene. The stitch emerging from the aortic intima was in the same plane as that 2 mm above the STJ plane. A prosthetic Dacron graft was used to replace the ascending aorta. The Dacron graft within the lumen was not everted. After aortic root reconstruction, the reconstructed stump was anastomosed with the artificial vessel directly. There was rarely any difficult-to-control bleeding after the reconstruction; the fragile dissected vascular wall became very robust with firm suturing. If there was bleeding, U-shaped suturing using propylene with a patch was performed and satisfactory hemostasis was obtained.

In the meantime, the systemic temperature was continuously being reduced until the rectal temperature measured approximately 22°C. Then the systemic circulation was stopped and antegrade brain perfusion was initiated after the following conditions were met: if the right subclavian artery was already cannulated, then the origin of the innominate artery would be clamped. At the same time, origin of the left common carotid artery would be cannulated with a 14F perfusion tube and origin of the left subclavian artery would be clamped. Subsequently, antegrade brain perfusion with 25°C perfusion fluid would be initiated at 10 ml/kg/min, and radial artery pressure would be maintained at approximately 50 mmHg; if the right subclavian artery was not cannulated (as described previously), the origin of the innominate artery would be cannulated with an 18F perfusion tube. At the same time, the origin of the left common carotid artery would be cannulated with a 14F perfusion tube and origin of the left subclavian artery was clamped. Subsequently, antegrade brain perfusion would be initiated with the parameters as described earlier. The distal procedure was completed under deep hypothermic circulatory arrest and antegrade cerebral perfusion.

A different technique was used for the distal portion of the anastomosis. If the dissection was DeBakey type I, a stented elephant trunk implantation to the proximal end of descending aorta was performed and the distal reconstruction was completed using the suturing ring of the stented

elephant trunk with the Teflon felts of the outermost layer (without placing an autologous pericardial patch in the false lumen). Then anastomosis with artificial vessels was then performed. If the dissection was DeBakey type II, Teflon felts were used on the inner and outer layers (again without placing autologous pericardial patch in the false lumen) to complete distal reconstruction before anastomosis with the artificial vessels.

Representative intraoperative and postoperative follow-up images are shown in Figures 1 to 3.



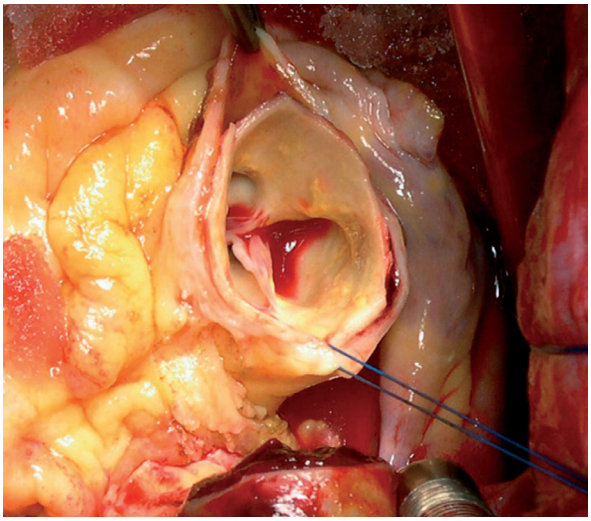
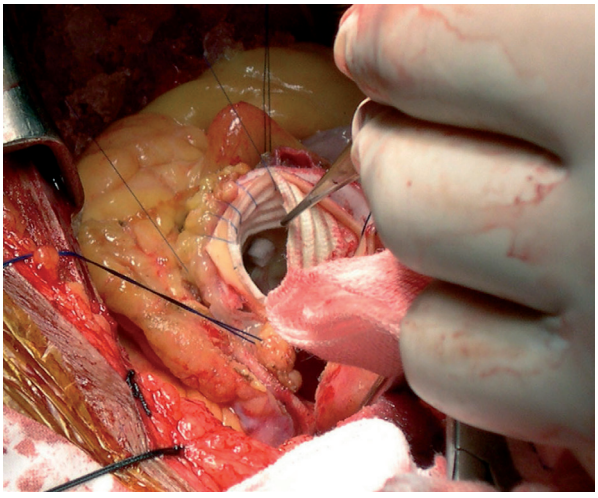
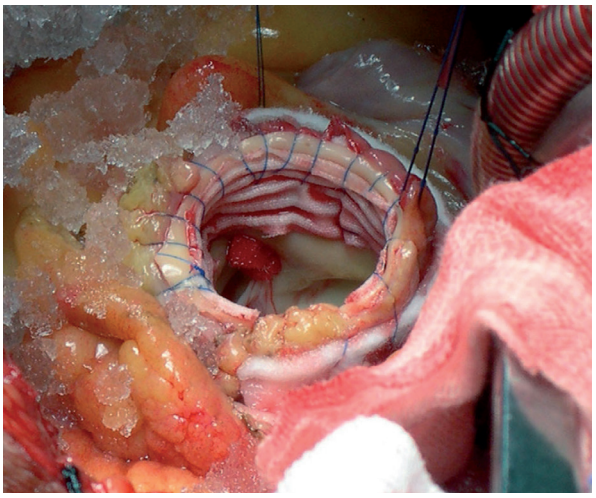


Fig. 1 – A) Dissection involved posterior, right, and left coronary cusps of the aortic valve. Partial thrombus formation can be seen within the false lumen. B) Thrombus removed. No formation of aortic root aneurysm and expansion of aortic valvular ring were visualized. No dissection tear was seen at the aortic root, and the coronary arteries were uninvolved with good aortic valvular function





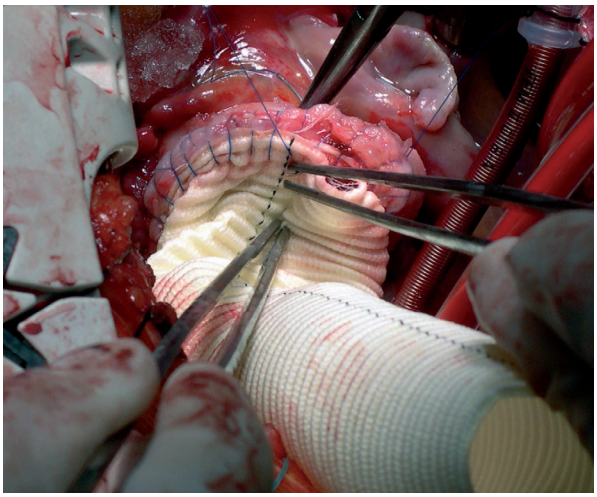


Fig. 2 – A, B) The vascular lumen was lined with an artificial polyester vascular ring, and the false lumen was lined with an autologous pericardial patch, and a Teflon felt strip was wrapped around the vessel. Finally, 4-0 propylene suture was used to complete reconstruction. C) Reconstructed aortic root was anastomosed with the artificial vessel

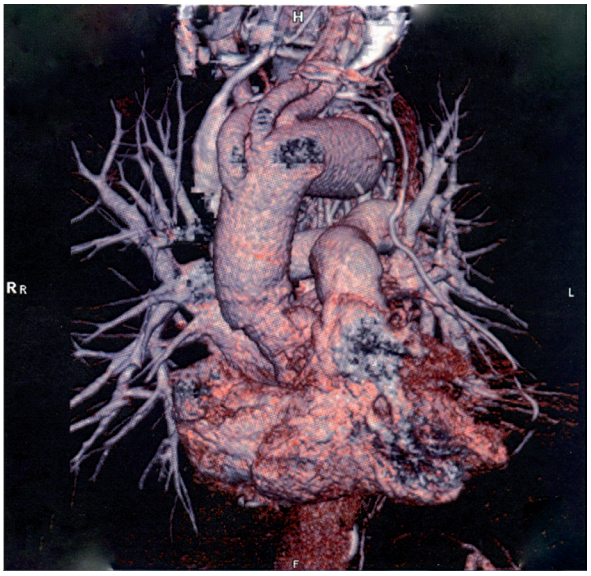


Fig. 3 – CT angiography 1 year post-operatively showed that the morphology of the reconstructed aortic root appeared normal without sign of aneurysm or dissection recurrence

Follow-up

All patients were followed up after discharge. Patients were contacted by a combination of outpatient and phone interviews. Physical examinations were performed to check for the development of heart murmurs. Echocardiography and contrast-enhanced computed tomographic (CT) scans were performed before discharge, 3 and 6 months after surgery, and annually thereafter to evaluate the degree of aortic valve function and cardiac function, observe whether any recurrent dissection, aneurysm, or pseudoaneurysm had developed, and measure the annulus, sinus of Valsalva (SOV), and STJ lumen diameter. Aortic regurgitation was classified as follows: 0 = none; 1 = trivial; 2 = mild; 3 = moderate; 4 = severe [12].

Outcomes

Our measured outcomes included postoperative mortality, survival, complications, and the extent of aortic regurgitation after surgery.

Statistical Analysis

Demographic and clinical characteristics are presented as mean ± standard deviation (range) for continuous variables and number (percentage) for categorical variables. Kaplan-Meier curves summarizing survival over time were constructed. Univariate and subsequent multivariate binary logistic regression analyses were performed to identify demographic and clinical variables associated with mortality and complications. These data are presented as odds ratios (OR) with 95% confidence intervals (95% CIs). Variables with $P<0.2$ in the univariate logistic regression analysis were entered into multivariate logistic regression analysis using backward selection. Cox regression analysis was performed to determine the relationship between survival time and demographic and clinical variables. These data are presented as hazard ratios (HR) with 95% CIs. All statistical assessments were two-tailed and the level of statistical significance was determined at $P<0.05$. Statistical analyses were performed using Predictive Analytics SoftWare (PASW) 18.0, a statistics software (SPSS Inc, Chicago, IL).

RESULTS

Patients were followed up with a mean time of 5.1 ± 2.96 years (2-12 years). Details of surgical methods and perioperative data are presented in Table 2. A total of 21 patients died during hospitalization (n=10, 6.2%) or follow-up (n=11, 6.8%). Causes of death during hospitalization were gastrointestinal tract necrosis (n=3), gastrointestinal hemorrhage (n=2), sepsis (n=2), acute renal failure (n=1), pulmonary failure (n=1), and stroke (n=1). Causes of death during follow-up were stroke (n=2), ruptured abdominal aortic aneurysm (n=1), pneumonia (n=1), lung cancer (n=1), acute myocardial infarction (n=1), chronic renal failure (n=1), undefined accident (n=1), surgical repair of acute aortic dissection (n=1), car accident (n=1), and pancreatic cancer (n=1).

Approximately 20% of patients (n=31) experienced postoperative complications, including acute renal failure (requiring bedside hemodialysis), stroke, poor pulmonary function requiring prolonged ventilatory support (> 72h), transient neurological deficits, mild paraplegia, and local infection. All patients recovered from these complications.

Univariate regression analysis revealed that visceral malperfusion, creatinine concentration > 2 mg/dL, operation time, cardiopulmonary bypass time, aortic occlusion time, and deep hypothermic circulatory arrest time were associated with postoperative complications (all, $P<0.05$, Table 3). Subsequent multivariate regression analysis revealed that visceral malperfusion, operation time, and cardiopulmonary bypass time were associated with postoperative complications (all, $P<0.05$, Table 3). Univariate logistic regression analysis also revealed that age, visceral malperfusion, creatinine concentration > 2 mg/dL, operation time, cardiopulmonary bypass time, aortic occlusion time, and deep hypothermic circulatory arrest time were associated with mortality during hospitalization (all, $P<0.05$, Table 4). However, multivariate regression analysis did not reveal any association between the demographic and clinical variables with mortality during hospital stay.

Table 2. Surgical methods and perioperative details (N=161).

Surgical methods	
Modified ARR + ascending aorta replacement	14 (8.7)
Modified ARR + ascending aorta and semi-arch replacement	12 (7.4)
Modified ARR + ascending aorta and total arch replacement	25 (15.5)
Modified ARR + ascending aorta and total arch replacement + elephant trunk implantation	45 (28.0)
Modified ARR + ascending aorta and total arch replacement + stented elephant trunk implantation	65 (40.3)
Degree of aortic valve implication	
Posterior cusp	161 (100.0)
Right cusp	106 (65.8)
Left cusp	9 (5.6)
Operation time, minutes	463.4 ± 129.5 (226-822)
Cardiopulmonary bypass time, minutes	239.0 ± 63.0 (122-463)
Aortic occlusion time, minutes	149.4 ± 48.1 (56-287)
Deep hypothermic circulatory arrest time, minutes	49.3 ± 22.3 (17-118)
Death during hospitalization	10 (6.2)
Death during follow-up	11 (6.8)
Complications	31 (19.3)
Survival, years	5.1 ± 2.9 (0-10)

ARR = aortic root reconstruction. Data are summarized as mean ± standard deviation (range: minimum to maximum) for continuous variables or number (percentage) for categorical variables

Table 3. Associations between demographic and clinical variables and postoperative complications (N=161).

	Univariate		Multivariate	
Variable	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Age, years	1.01 (0.99-1.04)	0.283		
Gender (male vs. female)	3.98 (0.80-17.71)	0.070		
Smoking	1.31 (0.55-3.13)	0.549		
Hypertension	1.11 (0.48-2.56)	0.804		
Pericardial effusion	1.47 (0.49-4.42)	0.488		
Diabetes mellitus	0.96 (0.26-3.62)	0.957		
Cardiogenic shock	1.16 (0.30-4.43)	0.829		
Visceral malperfusion	22.26 (4.44-111.57)	<0.001*	21.97 (2.31-208.66)	0.007*
Neurological symptoms	0.59 (0.07-4.94)	0.623		
Creatinine > 2 mg/dL	19.11 (2.06-177.77)	0.010*		
DeBakey type (type II vs. type I)	NA			
Time from symptom onset to surgery, days	1.04 (0.92-1.19)	0.513		
Operation time, minutes	1.01 (1.01-1.02)	<0.001*	1.008 (1.001-1.014)	0.028*
Cardiopulmonary bypass time, minutes	1.03 (1.01-1.04)	<0.001*	1.020 (1.005-1.035)	0.010*
Aortic occlusion time, minutes	1.03 (1.02-1.05)	<0.001*		
Deep hypothermic circulatory arrest time, minutes	1.03 (1.02-1.05)	<0.001*		

Data are presented as odds ratios (OR) with 95% confidence intervals (95% CI). NA = not applicable because of limited numbers. Variables with P<0.05 as determined by univariate logistic regression analysis were entered into multivariate logistic regression analysis using a backward conditional method. Indicates a significant association between the variable and mortality (P<0.05)*

The mean duration of survival after surgery was 5.1 years (Table 2). A Kaplan-Meier curve showing cumulative survival during the study period is presented in Figure 4. Cox regression analysis revealed that none of the demographic or clinical variables were associated with survival (Table 4). Of note, the 10 patients who died during hospitalization were not included in this analysis. The 1-, 3-, 5-, and 10-year survival rates were 99.3%, 98.0%, 93.8%, and 75.5%, respectively.

The severity of aortic regurgitation was dramatically decreased immediately after surgery, and thereafter increased only slightly (Figure 5). Preoperatively, 47.8% of patients had trivial to mild (grade 0 to 1) and 28.6% of patients had moderate to severe (grade 3 to 4) aortic regurgitation. At postoperative discharge, 89.4% patients (135 of 151) had no aortic regurgitation, and only 10.6% of patients (16 of 151) had trivial and mild aortic regurgitation. At 5 years after surgery, 29.9% of patients (29 of 97) had trivial to mild, and 7.2% of patients (7 of 97) had moderate to severe aortic re-

gurgitation. At 10 years after surgery, 45.4% of patients (10 of 22) had trivial to mild, and 9.1% of patients (2 of 22) had moderate to severe aortic regurgitation.

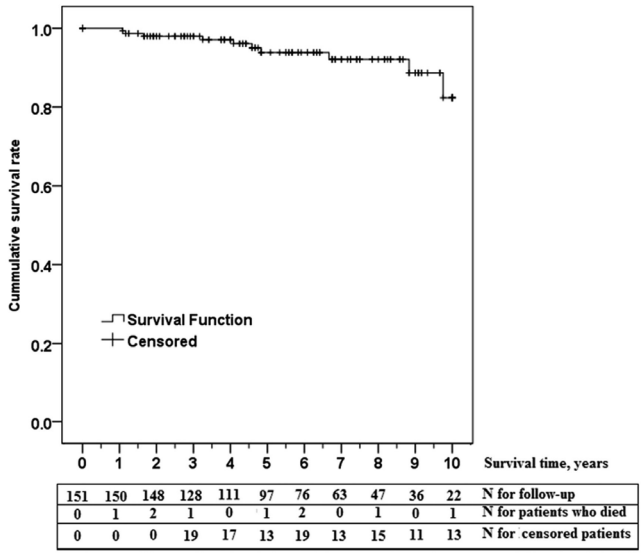


Fig. 4 – Kaplan-Meier curve showing cumulative survival of patients who received reinforced aortic root reconstruction for acute type A aortic dissection involving the aortic root

Aortic annulus, sinus of Valsalva, and STJ size increased slightly over the 10 year follow-up period (Table 5). The mean aortic annulus size was 20.5 ± 1.2 mm at discharge, 21.3 ± 1.3 mm at 5 years, and 21.8 ± 1.3 mm at 10 years. The mean sinus of valsalva size was 30.9 ± 1.5 mm at discharge, 31.1 ± 1.6 mm at 5 years, and 32.1 ± 1.7 mm at 10 years. The mean STJ size was 27.2 ± 1.3 mm at discharge, 27.4 ± 1.4 mm at 5 years, and 28.2 ± 1.5 mm at 10 years.

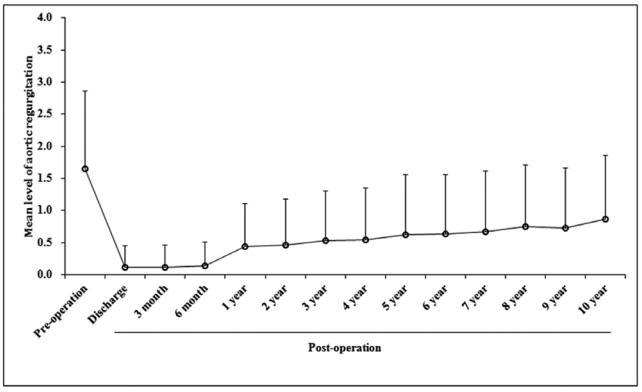


Fig. 5 – The change in degree of aortic regurgitation after reinforced aortic root reconstruction for acute type A aortic dissection involving the aortic root. Data are presented as the mean level of aortic regurgitation

Table 4. Associations between demographic and clinical variables and mortality and survival during hospitalization (N=161).

	Mortality[a]		Survival[b,c]	
Variable	OR (95% CI)	*P* value	HR (95% CI)	*P* value
Age, years	1.19 (1.07-1.32)	0.001*	1.02 (0.98-1.06)	0.296
Gender (male vs. female)	NA		0.38 (0.11-1.33)	0.129
Smoking	1.32 (0.33-5.37)	0.698	1.28 (0.33-5.00)	0.721
Hypertension	2.16 (0.44-10.56)	0.340	1.88 (0.40-8.91)	0.424
Pericardial effusion	3.38 (0.80-14.31)	0.098	2.28 (0.48-10.88)	0.300
Diabetes mellitus	1.01 (0.12-8.51)	0.995	1.06 (0.13-8.40)	0.954
Cardiogenic shock	2.90 (0.55-15.20)	0.209	0.04 (0-371.93)	0.494
Visceral malperfusion	55.13 (11.04-275.35)	<0.001*	0.05 (0-2.39×10^7)	0.766
Neurological symptoms	NA		2.80 (0.35-22.52)	0.334
Creatinine > 2 mg/dL	31.93 (4.57-222.88)	<0.001*	0.05 (0-1.94×10^{13})	0.860
DeBakey type (type II vs. type I)	NA		0.70 (0.09-5.56)	0.736
Time from symptom onset to surgery, days	1.00 (0.80-1.25)	0.997	1.00 (0.81-1.22)	0.983
Operation time, minutes	1.04 (1.02-1.06)	0.001*	1.00 (0.99-1.01)	0.393
Cardiopulmonary bypass time, minutes	1.03 (1.02-1.05)	<0.001*	1.01 (0.99-1.02)	0.312
Aortic occlusion time, minutes	1.07 (1.03-1.11)	<0.001*	1.00 (0.99-1.02)	0.751
Deep hypothermic circulatory arrest time, minutes	1.07 (1.03-1.11)	<0.001*	1.01 (0.98-1.04)	0.503

[a]Data are presented as odds ratios (OR) with 95% confidence intervals (95% CI). Variables with P<0.2 determined by univariate logistic regression analysis were entered into multivariate logistic regression analysis using a backward conditional method. However, results were not presented since there were no statistically significant variables identified by the multivariate logistic regression analysis.

NA: not applicable because of limited numbers.

[b]Ten patients who died during hospitalization were excluded from this analysis.

[c]Data are presented as hazard ratios (HR) with 95% confidence intervals (95% CIs) through Cox regression analysis.

** Indicates a significant association between the variable and mortality (P<0.05)*

Table 5. Table shows slightly increase of aortic annulus, sinus of Valsalva, and sinotubular junction over the 10 year follow-up period.

	Years of post-operation													
	Preoperation	Discharge	3 month	6 month	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
Follow-up, n	161	151	151	151	150	148	128	111	97	76	63	47	36	22
Patients who died, n	0	10	0	0	1	2	1	0	1	2	0	1	0	1
Censored patients, n	0	0	0	0	0	0	19	17	13	19	13	15	11	13
Aortic regurgitation														
None	38	135	134	133	99	97	80	70	61	46	37	25	19	10
	(23.6%)	(89.4%)	(88.7%)	(88.1%)	(66%)	(65.5%)	(62.5%)	(63.1%)	(62.9%)	(60.5%)	(58.7%)	(53.2%)	(52.8%)	(45.5%)
Trivial	33	15	16	16	36	34	30	25	19	17	15	13	11	7
	(20.5%)	(9.9%)	(10.6%)	(10.6%)	(24%)	(23%)	(23.4%)	(22.5%)	(19.6%)	(22.4%)	(23.8%)	(27.7%)	(30.6%)	(31.8%)
Mild	44	1	1	2	15	16	16	13	10	8	6	5	3	3
	(27.3%)	(0.7%)	(0.7%)	(1.3%)	(10%)	(10.8%)	(12.5%)	(11.7%)	(10.3%)	(10.5%)	(9.5%)	(10.6%)	(8.3%)	(13.6%)
Moderate	39	0	0	0	0	1	2	3	7	5	5	4	3	2
	(24.3%)	(0%)	(0%)	(0%)	(0%)	(0.7%)	(1.6%)	(2.7%)	(7.2%)	(6.6%)	(7.9%)	(8.5%)	(8.3%)	(9.1%)
Severe	7	0	0	0	0	0	0	0	0	0	0	0	0	0
	(4.3%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)
Aortic annulus, mm	20.8 ± 1.5	20.5 ± 1.2	20.5 ± 1.2	20.6 ± 1.2	20.9 ± 1.4	21.1 ± 1.3	21.0 ± 1.3	21.1 ± 1.3	21.3 ± 1.3	21.3 ± 1.2	21.3 ± 1.2	21.4 ± 1.3	21.4 ± 1.2	21.8 ± 1.3
Sinus of Valsalva, mm	ND	30.9 ± 1.5	30.9 ± 1.5	30.9 ± 1.5	30.9 ± 1.5	30.9 ± 1.5	30.9 ± 1.5	31.0 ± 1.5	31.1 ± 1.6	31.1 ± 1.6	31.3 ± 1.5	31.5 ± 1.6	31.6 ± 1.6	32.1 ± 1.7

DISCUSSION

For a technique to be considered successful in cardiac surgery, it should have low operative mortality, excellent durability/effectiveness, and should be easily adoptable by surgeons. We reported the feasibility, safety, and long-term reliability of a novel surgical approach for the treatment of AAAD with aortic root involvement. Key features of our approach include the placement of an autologous pericardial patch in the false lumen, lining of the STJ lumen with a polyester vascular ring, and wrapping the vessel with Teflon strips for reinforcement. We found this approach to be safe and durable/effective, as indicated by low rates of in-hospital/follow-up mortality and postoperative complications.

Our long-term survival rate compares favorably with those reported in previous studies after aortic root reconstruction with valve sparing, in which the 10-year survival rates were found to be 57% [12] and 70% [18]. Notably, we did not find that any preoperative factors were associated with survival, indicating that our procedure may be applicable for most patients who meet the specified criteria. Our in-hospital mortality rate (6.2%) and follow-up mortality rate (6.8%) also compares favorably to that associated with supracommissural replacement, which typically ranges from 20% to 30% [1]. Our mortality rates are also lower than those reported for aortic-valve sparing surgery [12,18-21].

Approximately 20% of patients experienced postoperative complications, and around 6% of patients died from postoperative complications, most commonly gastrointestinal tract necrosis and sepsis. Unsurprisingly, postoperative complications were found to be significantly associated with visceral malperfusion, operation time, and cardiopulmonary bypass time. Importantly, none of our patients experienced postoperative recurrent aortic dissection, aortic aneurysm, or pseudoaneurysm, all of which are known complications of supracomissural replacement of the ascending aorta and aortic valve [1,16].

We suggest that the aforementioned complications are a consequence of intimal and adventitial fragility. With our modified method of reinforced aortic root reconstruction, Teflon felt is placed in the false lumen only, and the suture needle is passed through the intima and the adventitia, leaving small pinholes. Under pressure, blood may penetrate into the false lumen through these pinholes, leading to increased pressure in the false lumen and recurrent dissection. If dissection does not occur, blood in the false lumen may be absorbed, resulting vascular wall weakness and an increased risk of aortic aneurysm. Blood within the false lumen may also seep into the extravascular space or form a pseudoaneurysm under the adventitia. Our surgical approach directly addresses the potential leakage of blood through the suture pinholes via the placement of an artificial polyester vascular ring in the lumen. This vascular ring compresses and blocks the suture pinholes, thus preventing the blood from seeping into the false lumen. The placement of an autologous pericardial patch in the false lumen reinforces the vessel wall, helping to prevent aneurysm formation and blocking the suture pinholes. Preventing blood from entering the false lumen obviates the risk of blood exudation into the extravascular space or formation of pseudoaneurysm under the adventitia.

If the aortic valve has no apparent lesions, the main mechanism of aortic regurgitation associated with AAAD is STJ avulsion and the loss of traction on the valve leaflets. In such cases, the main goal of root construction should be reconstruction of the STJ. With the approach described herein, the main function of the artificial vascular ring is restoration of the normal anatomical morphology of the STJ. This is the most critical step for the long-term maintenance of aortic valvular function. The vascular ring should be a complete ring (to resist long-term vascular dilation) and smaller than the lumen diameter to help facilitate inward contraction. In addition to inserting a vascular ring and pericardial patch, we also reinforced the vessel by wrapping the vessel (outside the adventitia) with Teflon felt strips. Thus the previous 3-layered vessel was modified to a 5-layered vessel. This reinforcement of the aortic root allows for better control of aortic root diameter, maintenance of optimal aortic root shape, and, therefore, maintenance of aortic valvular function. We found that the extent of aortic regurgitation was dramatically improved after surgery and thereafter slightly increased with time. This slight increase with time may reflect the natural increase in aortic regurgitation that occurs with aging and/or indicate that aortic regurgitation was not completely resolved with surgery.

Our study is limited in that it was a retrospective study without any comparison group. Although our mortality and survival results compare favorably with those in the literature, a more direct comparison of our surgical approach with alternative surgical approaches is warranted.

In summary, we have described a modified surgical technique for the treatment of AAAD with aortic root involvement. We suggest that that this approach is feasible, can be mastered relatively quickly, and according to our results is safe and has acceptable durability as indicated by relatively low mortality and high survival.

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