









Our surgical strategies in repair of coarctation of aorta in adult patients and long-term follow-up

Kazım Ergüneş , İsmail Yürekli , Levent Yılık , Orhan Gökalp , Banu Lafcı , Habib Çakır , Yüksel Beşir , Ali Gürbüz 

Department of Cardiovascular Surgery, Izmir Katip Çelebi University, Atatürk Training and Research Hospital, Izmir, Turkey

ABSTRACT

Objectives: This study aims to examine the effect of surgical strategies in repair of coarctation of aorta on systolic hypertension and long-term results.

Patients and methods: A total of 13 adult patients (9 males, 4 females; mean age: 31.4±11.8 years; range, 18 to 51 years) who underwent aortic coarctation surgical repair between March 1990 and November 2016 were retrospectively analyzed. Data including demographic and clinical characteristics of the patients were recorded. Repair of coarctation of aorta was carried out with a left posterolateral thoracotomy through fourth intercostal space in 10 patients. Extra-anatomic aortic bypass grafting through median sternotomy was performed in three patients.

Results: The mean follow-up was 131.4±112.6 (range, 2 to 312) months. No mortality was observed in any of the patients. The systolic blood pressures of the patients receiving and not receiving medical treatment preoperatively significantly decreased postoperatively and during follow-up ($p \leq 0.05$). Pleural effusion was seen in one patient with recurrent coarctation postoperatively. Postoperative atrial fibrillation persisted, despite medical treatment, in four patients who had atrial fibrillation preoperatively. Twelve (92.3%) patients had New York Heart Association (NYHA) Class I and one (7.7%) patient had Class II symptoms during follow-up ($p < 0.05$). At the final follow-up visit, only three patients were normotensive without receiving any anti-hypertensive medication.

Conclusion: Different surgical methods can be performed conformably to aortic coarctation and associated cardiac disease. Surgical repair of aortic coarctation in adults has a low risk and is an effective method in decreasing the systolic hypertension, reducing the requirement of antihypertensive medications and clinical symptoms.

Keywords: Aortic coarctation, adult, congenital abnormalities.

The incidence of coarctation of aorta is 2 to 6/1,000 live births, accounting for 6 to 8% of all congenital heart diseases.^[1,2] Coarctation of aorta is often associated with congenital and acquired heart diseases as patent ductus arteriosus, ventricular septal defect, patent foramen ovale, coronary artery stenosis, aortic and mitral valve anomalies that may require surgical intervention.^[3]

If remained untreated, most of the patients are lost before the age of 50 years due to hypertension and associated complications, such as aortic dissection,

myocardial infarction, congestive heart failure, stroke, and infective endocarditis.^[4,5] Adult patients with or without associated intracardiac disease pose a surgical challenge. There is no consensus on the optimal approach for these patients.

There are several options for the treatment of coarctation including anatomic surgical repair, extra-anatomic bypass, balloon angioplasty with or without stenting and hybrid procedures.^[6,7] In this study, we aimed to examine the effect of surgical strategies in repair of coarctation of aorta on systolic

Received: June 01, 2020 Accepted: December 26, 2020 Published online: July 13, 2021

Correspondence: İsmail Yürekli, MD. 2040-2 Sokak, Selçuk-3 No: 2, Daire: 56, Mavişehir 35540 Karşıyaka, İzmir, Türkiye.
e-mail: ismoyurekli@yahoo.com

Citation:

Ergüneş K, Yürekli İ, Yılık L, Gökalp O, Lafcı B, Çakır H, et al. Our surgical strategies in repair of coarctation of aorta in adult patients and long-term follow-up. Turk J Vasc Surg 2021;30(3):175-181

©2021 Turkish National Vascular and Endovascular Surgery Society. All rights reserved.

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes (<http://creativecommons.org/licenses/by-nc/4.0/>).

hypertension and long-term results in adult patients with pure coarctation or complex cardiovascular disorders.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Department of Cardiovascular Surgery, Izmir Katip Çelebi University, Atatürk Training and Research Hospital between March 1990 and November 2016. A total of 13 adult consecutive patients (9 males, 4 females; mean age: 31.4 ± 11.8 years; range, 18 to 51 years) who underwent surgical repair of aortic coarctation in our institution were included. Exclusion criteria were as follows: atypical coarctation (mid-thoracic or abdominal coarctation), history of known vasculopathy with vascular dysfunction (Takayasu's arteritis, Raynaud's disease), genetic syndromes with diffuse arteriopathy, and severe obesity (body mass index >40 kg/m²). A written informed consent was obtained from each patient. The study protocol was approved by the Izmir Katip Çelebi University, Atatürk Training and Research Hospital Ethics Committee (date/no: 24.06.2021/0318). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient characteristics, comorbidities, associated cardiac diseases, presenting signs and symptoms, types of operative repairs and postoperative complications were collected. Systemic hypertension was defined, when the right arm blood pressure exceeded 140/90 mmHg. A residual gradient was defined as a systolic blood pressure gradient of more than 20 mmHg at rest between the right arm and either leg. All patients were investigated with angiography and echocardiography preoperatively. Follow-up of all patients was performed with a hospital office visit or by telephone interview. The patients were evaluated by clinical examination, electrocardiograms, chest roentgenograms, transthoracic echocardiographic examinations, and computed tomography (CT) angiography.

Repair of coarctation of aorta was carried out with a left posterolateral thoracotomy through fourth intercostal space in 10 patients and with a median sternotomy in three patients. A collagen-impregnated woven polyester Dacron® tube graft or patch angioplasty with expanded polytetrafluoroethylene (ePTFE) were used in the coarctation repair. Perioperative pressure measurements were made in all patients following the coarctation repair. Surgical treatment was performed via bypass

grafting between proximal and distal descending aorta in five patients (Patient no: 2,3,8,9,10) and bypass grafting from left subclavian artery to the descending aorta in four patients (Patient no: 5,6,7,13) (Figure 1, patient no: 7). The repair of the coarcted segment using patch aortoplasty and patent ductus arteriosus ligation were performed simultaneously with a left thoracotomy in one patient (Patient no: 1). Surgical repair of associated cardiac disorders was performed simultaneously in three patients.

Statistical analysis

Statistical analysis was performed using the SPSS version 15.0 software (SPSS Inc., Chicago, IL, USA). Descriptive data were presented in mean \pm standard deviation (SD), median (min-max) or number and frequency, where applicable. Systolic pressure gradients across the coarctation before and after repair were compared using the paired t-test. Comparison of numerical variables was performed using the Student's t-test. The Wilcoxon test was used to compare qualitative variables. A *p* value of <0.05 was considered statistically significant.

RESULTS

Four patients had Class I symptoms, five patients had Class II symptoms, and four patients had Class III symptoms preoperatively according to the New York Heart Association (NYHA) classification (Table 1). In echocardiograms there were left ventricular



Figure 1. Postoperative angiogram of the same patient in Figure 1 that shows subclavian artery to descending aorta bypass graft.

Table 1. Preoperative and postoperative NYHA Class, associated CVD and type of operation

Patient no	Preoperative NYHA Class	Associated CVD	Type of operation	Postoperative NYHA Class
1	I	PDA	PDA ligation + patch aortoplasty	I
2	II		PGB	I
3	II		PGB	I
4	III	MI+MS+TI	Extraanatomic PGB+ MVR + tricuspid de Vega annuloplasty	I
5	III	MI	PGB	II
6	I		PGB	I
7	I		PGB	I
8	III	Subvalvular AS + VSD	PGB	II
9	I		PGB	I
10	II		PGB	I
11	III	AI + ascending aortic aneurysm (54 mm)	Extraanatomic PGB + Bentall operation	I
12	II	Ascending aortic aneurysm (39 mm) + mild MS	Recoarctation, extraanatomic PGB	I
13	II		PGB	I

NYHA: New York Heart Association; CVD: Cardiovascular disease; PDA: Patent ductus arteriosus; PGB: Prosthetic graft bypass; MI: Mitral valve insufficiency; MS: Mitral valve stenosis; TI: Tricuspid insufficiency; MVR: Mitral valve replacement; AS: Aortic valve stenosis, VSD: Ventricular septal defect; AI: Aortic valve insufficiency.

hypertrophy in four patients. There were extensive collateral circulation with long segment coarctation in six patients, only extensive collateral circulation in four (Figure 2, patient no: 7), and extensive collateral circulation with calcification of the aortic wall in one patient on the angiographic examination.

Mean peak systolic gradient across the aortic coarctation was 61.0 ± 10.9 (range, 45 to 80) mmHg. Femoral pulses were weak or absent on palpation, but they were positive in Doppler examination.

Six (46.2%) patients had associated cardiac diseases. There were patent ductus arteriosus in one patient, mitral valve stenosis and regurgitation and tricuspid valve insufficiency in one patient, subvalvular aortic stenosis and ventricular septal defect in one patient, and mitral stenosis in one patient, aortic valve insufficiency and ascending aortic aneurysm (54 mm) in one patient, and ascending aortic aneurysm (39 mm) and mild mitral stenosis in one patient in addition to aortic coarctation (Table 1).

One of our cases was a 51-year-old male that underwent subclavian flap aortoplasty due to aorta coarctation 25 years ago. He had recurrent coarctation without any associated cardiac disease. Ascending-to-descending posterior pericardial aortic bypass grafting through a median sternotomy was performed in this patient because of recurrent coarctation. Pseudoaneurysm was seen in the distal

anastomosis site of distal descending aorta bypass grafting after four months from initial operation. He also had left-sided pleural effusion. The end-to-side anastomosis of a 10 mm ringed ePTFE graft-to-abdominal aorta was performed by using a



Figure 2. Preoperative angiographic image of a severe coarctation of the aorta in a 23 years old patient.

Table 2. Clinical characteristics

	Preoperative		Postoperative	
	n	%	n	%
Headache	10	77	3	23
Asthenia	5	38.4	3	23
Intermittent claudication	13	100	-	-
Dyspnea	5	38.4	2	15.3
Vertigo	3	23	-	-

side-biting clamp. Aortic clamp was then released, and this ePTFE graft itself was clamped. The proximal end of graft was anastomosed to distal portion of previous ascending-to-descending aorta bypass graft. A stent graft including region of previous graft anastomosis was implanted to distal descending aorta via right femoral artery and flow was established (Patient no: 12) (Table 1).

In a period of one to six months after the coarctation repair, two patients were operated for associated cardiac diseases. Mitral valve replacement was performed in one patient because of mitral valve insufficiency (Patient no: 5). Ventricular septal defect patch repair and subaortic membrane resection were performed in other patient owing to ventricular septal defect and subaortic stenosis (Patient no: 8) (Table 1).

None of the patients had perioperative and postoperative mortality. There were no complications like bleeding, spinal cord ischemia, left phrenic or recurrent laryngeal nerve damage, chylothorax, pneumothorax, and wound infection in the postoperative period.

Pleural effusion was seen during early postoperative period in one patient operated due to recurrent coarctation (Patient no: 12) (Table 1).

Atrial fibrillation persisted despite medical treatment postoperatively in four patients who had atrial fibrillation preoperatively (Patients no: 4,5,8,11) (Table 1). Preoperative symptoms like headache, asthenia, intermittent claudication, dyspnea, and vertigo improved dramatically during postoperative period (Table 2) ($p < 0.05$).

Eleven (84.6%) patients had NYHA Class I and two (15.4%) patients Class II symptoms postoperatively ($p < 0.05$) (Table 1).

Ten (76.9%) patients had persistent hypertension in the early postoperative period, which was then controlled with sodium nitroprusside and nitrate infusion.

Postoperative mean systolic blood pressure was 130 ± 11.5 (range, 110 to 140) mmHg in those patients not receiving antihypertensive drug whereas it was 129.2 ± 12.4 (range, 115 to 145) mmHg in those patients receiving antihypertensive drug during preoperative period.

The systolic blood pressures of the patients receiving and not receiving medical treatment before the surgery dropped significantly during early postoperative period and follow-up ($p \leq 0.05$) (Table 3).

Mean peak systolic gradient across the aortic coarctation was 61.0 ± 10.9 (range, 45 to 80) mmHg preoperatively. After the operation two patients had no blood pressure gradient between upper and lower

Table 3. Preoperative and postoperative medication and systolic blood pressure measurements

Patient no	Age/Sex	Date of operation	Preoperative systolic BP (mmHg)	Preoperative medication	Postoperative systolic BP (mmHg)	Postoperative medication	Systolic BP at follow-up	Medication follow-up
1	18/M	26/12/1990	160		120		130	
2	37/M	19/04/1995	180		140	a	140	a
3	41/M	27/09/1996	175		140	a	140	a
4	35/M	13/04/1999	150	a+d+f	135	a+d+f+g+h	130	d+f+g+h
5	19/M	9/07/2001	150	a+d+f	120	a+f+e	110	a+f+e+g+h
6	25/M	1/04/2003	165		130	c	120	c
7	23/F	9/10/2003	160		110	c	110	
8	30/F	31/05/2004	145	b+f	120	b+f	120	b+f
9	18/F	18/04/2016	160	-	130	a+b+g	120	b
10	21/F	15/05/2016	170	-	140	a+b	130	b
11	50/M	31/08/2016	175	b+f+g	145	b+g	135	b+g
12	51/M	27/11/2016	170	b+c+g	140	b+g	130	a+g
13	40/M	05/12/2016	140	a+b	115	a+b	110	-

a: Angiotensin-converting enzyme inhibitors; b: β -adrenergic blockers; c: Calcium-antagonists; d: Diuretics; e: Isosorbid-5 mononitrat; f: Digoxin; g: Acetyl salicylic acid; h: Coumadin-5 mg th.

extremities at rest, whereas six patients had a mild gradient of less than 20 mmHg.

The average stay in the intensive care unit was 1.9 ± 0.8 (range, 1 to 4) days. The average length of postoperative hospital stay was 5.5 ± 1.5 (range, 4 to 10) days.

In our patients, the mean follow-up time was 131.4 ± 112.6 (range, 2 to 312) months. Ten (76.9%) patients needed fewer numbers and dosages of antihypertensive drugs (Table 3).

In follow-up, mean systolic blood pressure was 127.1 ± 11.1 (range, 120 to 140) mmHg among the patients not receiving antihypertensive drug whereas it was 122.5 ± 10.8 (range, 110 to 135) mmHg among the patients receiving antihypertensive drug.

At the last follow-up control, three (23.1%) patients were normotensive without the need for any antihypertensive medication. During follow-up, mean systolic blood pressure was 122.7 ± 8.8 mmHg ($p < 0.05$). Twelve (92.3%) patients had NYHA Class I and one (7.7%) patient had Class II symptoms during follow-up ($p < 0.05$). Left ventricular hypertrophy regressed during follow-up in four patients who had left ventricular hypertrophy preoperatively. All patients are alive and active so far.

DISCUSSION

Although the aortic coarctation is usually seen in childhood period, it can also be diagnosed purely or with associated intracardiac disease in the adult period. The life expectancy of patients with aortic coarctation is about 35 years without correction, and 80% of these patients die before reaching the age of 50 years due to complications including aortic rupture, heart failure, and intracranial hemorrhage.^[5] In our study, we found concomitant congenital heart defects as subvalvular aortic stenosis, ventricular septal defect, patent ductus arteriosus, mitral and tricuspid valve abnormalities in some of our patients, similar to other studies.^[3,8]

There are various strategies in the treatment of aortic coarctation associated with or without cardiac anomalies. Adult patients with native or recurrent coarctation with or without associated intracardiac disease pose a surgical challenge. There is no consensus on the optimal approach for these patients. The main step is to stratify the repair modality individually according to the severity of the disease. Repair of coarctation of the aorta in the adults represent technical

difficulties, due to the long segment coarctation, large collateral circulation, relatively immobile aorta, and aortic calcification. There are also several techniques available to repair aortic coarctation including patch aortoplasty, resection with end-to-end anastomosis, extra-anatomic bypass, interposition graft replacement, subclavian flap aortoplasty, patch aortoplasty, and stent graft.^[9,10]

In our study, we used end-to-side conduit interposition between the proximal and distal descending aorta in 37.4% of patients, end-to-side conduit interposition between left subclavian artery and descending aorta in 30.7% of patients, extra-anatomic ascending-to-descending aorta bypass grafting in 23% of patients and patch aortoplasty in 7.6% of patients.

Hehrlein et al.^[11] and Carvalho et al.^[12] reported the higher rates of false aneurysm seen after patch graft aortoplasty. Pseudoaneurysm was seen in our patient while performing ascending-descending posterior pericardial aortic bypass grafting through a median sternotomy.

In redo operations, mobilization of the intercostal arteries and large collaterals in the region of the coarctation to facilitate proximal aortic cross-clamping is often not feasible and carries a substantial risk of injuring the surrounding structures. Accordingly, we favor direct repair using extracorporeal circulation and hypothermic circulatory arrest, which has also been described to be a safe and suitable technique in redo operations.^[13] This technique offers several advantages. These include minimal dissection and manipulation of the surrounding tissues in the coarctation area greatly reducing the risk of injury and excessive bleeding. Another advantage is the avoidance of clamping in diseased segment and, sometimes, extremely adhesive and delicate aorta.

Endovascular approach gives the advantage of avoiding complex dissection of the previous operative site and around extensive collateral vessels. Endovascular treatments tend to offer a shorter durability compared to direct surgical repair.^[14]

Additionally, serious procedural complications have been reported such as antegrade dissection, retrograde dissection, stent collapse, restenosis, paraplegia, femoral artery complications, stent fracture, stent migration and aortic rupture.^[15]

In our study, we found balloon dilatation unsuitable for our patients, as they mostly had complex forms of coarctation. Our current report of surgically treated aortic coarctation patients demonstrates that open

surgery is quite safe (no spinal ischemia, no stroke, and no death).

In patients having aortic coarctation and associated valvular lesions, treatment of the cardiac lesions in the first stage may be the cause of bleeding, renal, hypertensive complications, and hemodynamic instability.^[16,17] Atrial fibrillation and ischemia may occur in the dilated ventricle due to an increase in afterload, after cross-clamping.^[18] Also, ischemia may occur in the distal segment of the coarctation as a consequence of low perfusion resulting in the development of low cardiac output syndrome.^[19]

Repair of the aortic coarctation with an ascending-to-descending bypass is safer and easier, particularly in patients with cardiac diseases associated with coarctation or recoarctation.^[20-22] We performed ascending-to-descending bypass operations in three patients. We monitored the femoral arterial blood pressure during surgery via an arterial line, and we performed ascending aortic and femoral arterial cannulations due to need for perfusion below the coarctation in one patient.

In our study, through a period of one to six months after the coarctation repair, two patients were operated on for associated cardiac diseases. Coarctation repairs and cardiac operations were performed with two-staged approach owing to the fact that these patients had no complex coarctation (i.e., aortic calcification, long-segment coarctation and recurrent coarctation).

The main goals of surgical treatment in the patients having coarctation of the aorta are to decrease left ventricular afterload, to increase efficacy of antihypertensive medication after operation, to improve symptoms, and to obtain long-term survival.

Most of our patients were in NYHA Class I postoperatively and patients showed a significant improvement according to the preoperative NYHA Class. Hypertension which was seen before or after the operation has a significant role in the morbidity and mortality. Several factors are effective in the presentation of hypertension after coarctation repair including anatomic aortic alterations, structural wall alteration of thoracic and peripheral vessels, poor compliance of the arterial tree, altered renin-angiotensin system, sodium and water retention, and neural reflex.^[23,24] Some authors reported that they achieved the control of the systolic hypertension and a decrease in need of antihypertensive medication after surgical repair of coarctation of the aorta.^[25-27]

In our study, the mean follow-up was 131.4±112.6 months. Systolic blood pressures of the patients receiving and not receiving medical treatment preoperatively dropped significantly during postoperative period and throughout follow-up ($p \leq 0.05$). We showed that hypertension significantly decreased following the surgical repair of aortic coarctation in our patients. During follow-up, three of our patients were normotensive without the need for antihypertensive medication and 10 patients received lesser antihypertensive medications in terms of either dosage or number of drugs.

Limitations of this study include the retrospective cohort of the patients. One other limitation is the small number of cases and heterogeneity of the accompanying operations.

In conclusion, different surgical methods can be performed conformably to the aortic coarctation and associated cardiac disease. Surgical repair of the aortic coarctation in adults can be performed safely and it is a necessary method to effectively control malignant hypertension, and to decrease clinical symptoms.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

REFERENCES

- Cardoso G, Abecasis M, Anjos R, Marques M, Koukoulis G, Aguiar C, et al. Aortic coarctation repair in the adult. *J Card Surg* 2014;29:512-8.
- Kouchoukos NT, Blackstone EH, Hanley FL, Kirklin JK, editors. *Kirklin/Barret-Boyes Cardiac Surgery*. 4th ed. Philadelphia: Elsevier Saunders; 2013. p. 1717-79
- Yousif A, Kloppenburg G, Morshuis WJ, Heijmen R. Repair of adult aortic coarctation by resection and interposition grafting. *Interact Cardiovasc Thorac Surg* 2016;23:526-30.
- Güler M, Kırılı K, Dağlar B, Akıncı E, Demirsoy E, Toker ME, et al. Erişkin yaş aort koarktasyonu cerrahisinin hipertansiyon açısından değerlendirilmesi. *Damar Cerrahisi Dergisi* 1998;3:142-6.
- Brown ML, Burkhart HM, Connolly HM, Dearani JA, Cetta F, Li Z, et al. Coarctation of the aorta: Lifelong surveillance is mandatory following surgical repair. *J Am Coll Cardiol* 2013;62:1020-5.
- Holzer R, Qureshi S, Ghasemi A, Vincent J, Sievert H, Gruenstein D, et al. Stenting of aortic coarctation:

- Acute, intermediate, and long-term results of a prospective multi-institutional registry--Congenital Cardiovascular Interventional Study Consortium (CCISC). *Catheter Cardiovasc Interv* 2010;76:553-63.
7. Hu ZP, Wang ZW, Dai XF, Zhan BT, Ren W, Li LC, et al. Outcomes of surgical versus balloon angioplasty treatment for native coarctation of the aorta: A meta-analysis. *Ann Vasc Surg* 2014;28:394-403.
 8. Connolly HM, Schaff HV, Izhar U, Dearani JA, Warnes CA, Orszulak TA. Posterior pericardial ascending-to-descending aortic bypass: An alternative surgical approach for complex coarctation of the aorta. *Circulation* 2001;104(12 Suppl 1):I133-7.
 9. Charlton-Ouw KM, Codreanu ME, Leake SS, Sandhu HK, Calderon D, Azizzadeh A, et al. Open repair of adult aortic coarctation mostly by a resection and graft replacement technique. *J Vasc Surg* 2015;61:66-72.
 10. Roselli EE, Qureshi A, Idrees J, Lima B, Greenberg RK, Svensson LG, et al. Open, hybrid, and endovascular treatment for aortic coarctation and postrepair aneurysm in adolescents and adults. *Ann Thorac Surg* 2012;94:751-6.
 11. Ehrlein FW, Mulch J, Rautenburg HW, Schlepper M, Scheld HH. Incidence and pathogenesis of late aneurysm after patch graft aortoplasty for coarctation. *J Thorac Cardiovasc Surg* 1986;92:226-30.
 12. Carvalho JS, Redington AN, Shienbourne EA, Rigby ML, Gibson D. Continuous Wave Doppler echocardiography and coarctation of the aorta: gradients and flow patterns in the assessment of severity. *Br Heart J* 1990;64:133-7.
 13. Gudbjartsson T, Mathur M, Mihaljevic T, Aklog L, Byrne JG, Cohn LH. Hypothermic circulatory arrest for the surgical treatment of complicated adult coarctation of the aorta. *J Am Coll Cardiol* 2003;41:849-51.
 14. Carr JA. The results of catheter-based therapy compared with surgical repair of adult aortic coarctation. *J Am Coll Cardiol* 2006;47:1101-7.
 15. Forbes TJ, Garekar S, Amin Z, Zahn EM, Nykanen D, Moore P, et al. Procedural results and acute complications in stenting native and recurrent coarctation of the aorta in patients over 4 years of age: A multi-institutional study. *Catheter Cardiovasc Interv* 2007;70:276-85.
 16. Sun LZ, Luo XJ, Liu YM. Single-stage treatment of aortic coarctation and aortic valve disease. *Asian Cardiovasc Thorac Ann* 2003;11:208-12.
 17. Ugur M, Alp I, Arslan G, Temizkan V, Ucak A, Yilmaz AT. Four different strategies for repair of aortic coarctation accompanied by cardiac lesions. *Interact Cardiovasc Thorac Surg* 2013;17:467-71.
 18. Horai T, Shimokawa T, Takeuchi S, Okita Y, Takanashi S. Single-stage surgical repair of type II acute aortic dissection associated with coarctation of the aorta. *Ann Thorac Surg* 2007;83:1174-5.
 19. Morris RJ, Samuels LE, Brockman SK. Total simultaneous repair of coarctation and intracardiac pathology in adult patients. *Ann Thorac Surg* 1998;65:1698-702.
 20. Goksel OS, Inan K, Ucak A, Temizkan V, Tatar T, Sahin S, et al. Posterior pericardial ascending-to-descending aortic bypass through median sternotomy. *J Card Surg* 2008;23:515-8.
 21. Wu Q, Chen X, Li H, Wang L, Xue H. Ascending-to-descending aortic bypass via posterior pericardium for complex coarctation of aorta. *J Card Surg* 2009;24:167-9.
 22. Duvan I, Ates MS, Onuk BE, Bakaloglu B, Sungur UP, Kurtoglu M, et al. Single stage repair for aortic coarctation associated with intracardiac defects using extra-anatomic bypass graft in adults. *Korean Circ J* 2016;46:556-61.
 23. Carr JA, Amato JJ, Higgins RS. Long-term results of surgical coarctectomy in the adolescent and young adult with 18-year follow-up. *Ann Thorac Surg* 2005;79:1950-5.
 24. Kirklin JW, Barratt Boyes BG. *Cardiac surgery*. 3rd ed. Philadelphia: 2003:1315-1375.
 25. Wang R, Sun LZ, Hu XP, Ma WG, Chang Q, Zhu JM, et al. Treatment of complex coarctation and coarctation with cardiac lesions using extra-anatomic aortic bypass. *J Vasc Surg* 2010;51:1203-8.
 26. Bouchart F, Dubar A, Tabley A, Litzler PY, Haas-Hubscher C, Redonnet M, et al. Coarctation of the aorta in adults: Surgical results and long-term follow-up. *Ann Thorac Surg* 2000;70:1483-8.
 27. Hashemzadeh K, Hashemzadeh S, Kakaei F. Repair of aortic coarctation in adults: The fate of hypertension. *Asian Cardiovasc Thorac Ann* 2008;16:11-5.