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Original Article

Surgical Treatment of the Aortic Coarctation in Adults: Extra Anatomical Ascending-to-descending Aortic Bypass and Concomitant Procedures

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Abstract

Objectives: Aortic coarctation is defined as the narrowing of the aortic lumen secondary to hypertrophy of the posterolateral aortic wall's media layer. The coarctation is locates between the junction from ductus arteriosus to the left subclavian artery and left hemi aortic arch. Aortic coarctation provokes many severe and lethal complications, such as severe aortic stenosis, aortic aneurysms, pseudoaneurysms, stroke, and premature coronary artery disease, unless it had not been repaired in the meantime the initiation of the symptoms.

Methods: We presented the consecutive nine patients who underwent aortic coarctation open surgical repair between 2015 and 2020 which initiated ascending-to-descending aortic bypass and then concomitant operations for the secondary cardiac pathology such as ascending aortic aneurysm, Type A aortic dissection and sinus valsalva aneurysm required in some cases. Patients were a median age of 26 years old (range, 19–41 years). About 11% of the patients (n=1) presented to our emergency room with severe chest pain and acute Type 2 aortic dissection was diagnosed by the surgical team, and he underwent operation immediately. The supracoronary aortic replacement and ascending to descending aortic bypass procedures were performed sequentially. About 44% of the patients (n=4) were diagnosed as isolated aortic coarctation and only ascending –to- descending aortic bypass was performed electively. About 22% of the patients (n=2) had ascending aortic aneurysm without aortic valve pathology. These patients underwent supracoronary aortic replacement as concomitant procedure to ascending to descending aortic bypass. About 22% of the patients (n=2) had bicuspid aortic valve and sinus Valsalva aneurysm; therefore, the Bentall procedure was implemented concomitantly.

Results: There were not any early deaths reported. Any neurologic complications including neither paraplegia nor stroke revealed during post-operative follow-up. About 88% of patients (n=8) were discharged with stable hemodynamic parameters in 2 weeks. About 11% of these patients (n=1) who underwent Bentall procedure concomitantly had third-degree atrioventricular block as a serious rhythm problem then a permanent pacemaker implanted. This patient had been discharged with stable hemodynamic parameters and pacemaker settings were controlled by the cardiology department.

Conclusion: The extra anatomical ascending-to-descending aortic bypass is a safe and feasible method for the open surgical coarctation repair, and it provides concomitant procedures for other cardiac pathologies, which require open surgical treatment.

Keywords: Aneurysm; aortic coarctation; extra-anatomical bypass.

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Aort Koarktasyonunun Erişkinde Cerrahi Tedavisi: Asendan-Desendan Aortik Bypass ve Konkomitan Prosedürler

Özet

Amaç: Aort koarktasyonu, aortik duvarın posterolateral orta tabakasının hipertrofisi sonucu aortik lümenin daralması olarak tanımlanır. Bu çalışmada, 9 yetişkin hastayı asendan-desendan bypass greft cerrahisi yöntemi

ve hastaların aort patolojilerine göre en bilinen klasik operasyon tekniklerinin kombinasyonları ile tedavi ettik. Bu raporda bu cerrahi stratejiyle olan deneyimimizi amaçladık ve onun avantajlarını ve risklerini tanımladık.

Gereç ve Yöntem: 2015-2020 yılları arasında açık cerrahi aort koarktasyon onarımı geçiren ardışık 9 hastayı sunuyoruz. Bu operasyonlar asendan-desendan aortik bypass ve bazı durumlarda asendan aort anevrizması , tip A aortik disseksiyon ve sinüs valsalva anevrizması gibi ikincil kalp patolojileri için eş zamanlı operasyonları içeriyordu.

Bulgular: Hastaların yaş ortalaması 26 yıl idi (19-41). Hastaların %11'i (n=1), ciddi göğüs ağrısı ile acil servisimize başvurdu ve cerrahi ekibi tarafından akut tip 2 aortik disseksiyon tanısı kondu ve hemen operasyona alındı. Suprakoroner aort greft replasmanı ve asendan-desednan aortik bypass işlemleri ardışık olarak gerçekleştirildi. Hastaların %44'ü (n=4), izole aort koarktasyonu tanısı aldı ve sadece asendan-desendan aortik bypass işlemi elektif olarak yapıldı. Hastaların %22'si (n=2) aortik kapak patolojisi olmaksızın yükselen aortik anevrizmaya sahipti. Bu hastalara asendan-desendan aortik bypass işlemine ek olarak suprakoroner aortik replasman uygulandı. Hastaların %22'si (n=2) biküspit aortik kapak ve sinüs valsalva anevrizmasına sahipti; bu nedenle Bentall prosedürü eş zamanlı olarak uygulandı. Erken ve geç dönemde mortalite görülmedi. Ameliyat sonrası takip sırasında parapleji veya inme dahil herhangi bir nörolojik komplikasyon ortaya çıkmadı. Hastaların %88'i (n=8), iki hafta içinde stabil hemodinamik parametrelerle taburcu edildi. Bentall prosedürü eş zamanlı olarak uygulanan bu hastalardan %11'i (n=1), ciddi bir ritim sorunu olarak üçüncü derece atrioventriküler blok yaşadı ve ardından kalp cerrahisi bölümü tarafından kalıcı bir kalp pili takıldı. Bu hasta stabil hemodinamik parametrelerle taburcu edildi ve pil ayarları kardiyoloji bölümü tarafından kontrol edildi.

Sonuç: Ekstra anatomik asendan-desendan bypass operasyonu , açık cerrahi ile erişkinlerde koarktasyon onarımı için güvenli ve uygulanabilir bir yöntemdir ve açık cerrahi tedavi gerektiren diğer kalp patolojileri için eş zamanlı prosedürleri güvenle yapabilme olanağı sunar.

Anahtar sözcükler: Anevrizma; koarktasyon; extra-anatomik by-pass.

Introduction

Aortic coarctation is a prevalent condition, occurring in approximately 4 out of every 1000 live births, with a higher incidence in males.[1] While it can manifest in isolation, it is frequently associated with other congenital anomalies such as bicuspid aortic valve in 50–75% of cases, interrupted aorta, various types of arch hypoplasia, mitral valve abnormalities, subaortic stenosis, patent ductus arteriosus (PDA), and septal defects. Notably, cerebral aneurysms are present in up to 10% of coarctation patients, representing a fivefold increase compared to the general population, highlighting the importance of considering cerebrovascular disorders before and after surgical intervention.[2] Aortic coarctation is defined as the narrowing of the aortic lumen secondary to hypertrophy and incrassating of the aortic media layer.

The narrowing is generally located against to the insertion of the PDA (juxta ductal); besides, it can be located proximal (pre-ductal) or distal (post-ductal) to the PDA. It can also locates in the transverse aortic arch and abdominal aorta, or be a part of a long segment arch hypoplasia very seldom.[1]

According to the results of the largest necropsy series of Campbell,[3] the median age of uncorrected coarctation patients was 31 years, which is two times shorter than the normal population's average. Myocardial infarction, aortic dissection, cerebral hemorrhage, and heart failure are the most common reasons of death in patients with coarctation. In the adults, all of these comorbidity and mortality occur and progressively eventuate worse due to the nature of hypertensive angiopathy. Due to this; after the treatment of coarctation, there must be a significant regression in systolic hypertension.

Despite advancements, there remains a lack of consensus regarding the optimal surgical approach and its efficacy in adults, with some authors reporting limited regression of systolic hypertension postoperatively in older patients.[4,5] While hypertension is the predominant presentation in adults, untreated coarctation can manifest with symptoms such as angina, dyspnea, back pain, cold feet, dizziness, headache, vertigo, or palpitations.

Interventional therapy is indicated in all patients with a non-invasive blood pressure difference >20 mmHg between upper and lower limbs, regardless of symptoms but with upper limb hypertension (>140/90 mmHg in adults), pathological blood pressure answers during exercise or significant left ventricular hypertrophy.[1]

The surgical approximation is based on age, comorbidities, and the aortic arch anatomy.[6,7] There are several surgical options for coarctation repair, such as resection with end-to-end anastomosis, subclavian flap aortoplasty, extended end-to-end anastomosis, a synthetic patch aortoplasty, interposition grafting, and extra anatomical bypass grafting, which is new and less experienced among others.[8–10]

In this report, we present our experience treating nine adult patients using ascending-to-descending bypass grafting surgery, either alone or in combination with traditional surgical techniques tailored to the individual patient's aortic pathology. We aim to discuss the merits and drawbacks of this surgical strategy, initially described by Vijayanagar et al. and subsequently refined by Powell et al.[11,12]

Materials and Methods

Between 2015 and 2018, our center performed open surgical repair for aortic coarctation using an extra-anatomical ascending-to-descending aortic bypass in nine adult patients. The median age of the patients was 26 years old, ranging from 19 to 41 years. The ethical application of the study was procured from Kartal Koşuyolu High Specialization Training and Research Hospital's Clinical Research Ethics Committee, (Approval Date: September 25, 2018, and Approval Number: 2018/6/5-105).

One patient (11%) presented to our emergency room with severe chest pain, and an acute Type 2 aortic dissection was diagnosed by the surgical team. Immediate intervention was deemed necessary, and consequently, the patient underwent sequential procedures including supracoronary aortic replacement followed by ascending-to-descending aortic bypass.

Table 1. Pre-operative clinical and demographic characteristics of the patients

Patient	Sex	Age (years)	Diagnosis	NYHA	Symptoms	Arch anomaly	AI (1-4)	Aortic diameter (mm)	CBAV
1	F	19	CoA+AscAA	2	Dyspnea	None	1	41	+
2	M	41	CoA	1	Dyspnea	None	2	32	-
3	M	35	CoA	1	Dyspnea	ARSA	0	31	-
4	M	22	CoA	1	Palpitation	Bovine arch	0	28	-
5	M	19	CoA+AscAA+SVA	1	Dyspnea	None	4	68	+
6	M	19	Type-2 AAD+CoA	3	Angina	None	1	60	-
7	F	19	CoA	1	Dyspnea	Bovine arch	0	26	-
8	M	32	CoA+AscAA	1	Dyspnea	None	1	55	-
9	M	34	CoA+SVA+CBAV	1	Headache	none	0	46	+

NYHA: New York heart association; AI: Aortic insufficiency; CBAV: Congenital bicuspid aortic valve; F: Female; M: Male; CoA: Coarctation of the aorta; AscAA: Ascending aorta aneurysm; AAD: Acute aortic dissection; SVA: Sinus Valsalva aneurysm; ARSA: Aberrant right subclavian artery.

Four patients (44%) were diagnosed with isolated aortic coarctation, and therefore, only ascending-to-descending aortic bypass was performed.

Two patients (22%) presented with ascending aortic aneurysms without concomitant aortic valve pathology. These patients underwent supracoronary aortic replacement in addition to ascending-to-descending aortic bypass as a concurrent procedure.

About 22% of the patients (n=2) had bicuspid aortic valve and sinus valsalva aneurysm; therefore the Bentall procedure was implemented concomitantly.

Surgical Technique

All patients were operated on through median sternotomy with total cardiopulmonary bypass. In seven patients, the right axillary artery was cannulated for arterial return. In two patients, the ascending aorta was cannulated for arterial return. For venous return, the right atrium is cannulated in every case.

After cross-clamping aorta, posterior pericardium was incised, and the descending aorta was freed for the anastomose area's safety. The Dacron graft (10 or 12 mm graft size) anastomosed to the descending aorta with 4/0 prolene sutures one by one while the descending aorta was clamped with side clamp. The graft routed from the transverse sinus of the heart and anastomosed to the lateral side of the ascending aorta qua end-to-side anastomosis style.

Statistical Analysis

Data are presented as the mean±standard deviation. Systolic and diastolic mean pressures before and after coarctation repair were compared using a paired t-test, SPSS version 23.0, IBM Corp., New York, USA. A value of $p<0.05$ was considered and reported significant.

Follow-up

All patients were followed up at our cardiology and cardiovascular surgery clinics. Information on survival, surgical and non-surgical problems, and other complications were obtained from our hospital records.

Follow-up was performed at 1st week after discharge then 1st, 6th, and 12th months postoperatively, and then individually at least once in a year using 2D echocardiography and computed tomographic scanning.

The mean duration of the follow-up was 26±5.8 months (range from 4 to 35 months).

Results

About 88% of patients (n=8) discharged with stable hemodynamic parameters in two weeks. No hospital and early-term deaths occurred. There were no complications such as reoperation for bleeding or tamponade, renal failure, acute respiratory distress syndrome (ARDS), stroke, myocardial failure, or spinal cord injury. Only one patient had a permanent blockage of AV node so required a permanent pacemaker insertion (n=1, 11.1%).

The mean CPB time was 151.5 min (range 72–294 min) and the mean cross-clamping time was 106.8 min (range 42–244 min).

Mean extubation time was 9.6 h (range 3–15 h). The mean hospital stay was 8.3 (range 5–22 days). Pre-operative and post-operative demographics were indicated in Tables 1 and 2.

During the follow-up (26±5.8 months), there has been neither recurrence of coarctation, pseudoaneurysm, nor dissection. There were no late graft-related complications or reoperations related to this.

Only one patient who underwent Bentall and extra anatomical bypass procedure simultaneously needed a permanent pacemaker and inotropic support after surgery temporarily (n=1, 11.1%).

Mean systolic blood pressure decreased significantly in the post-operative period; from preoperatively 145±10 mmHg to 124±17 mmHg at discharge which means after 7 days ($p<0.05$).

The decreasing in the diastolic pressure was not significantly ($p>0.05$).

Blood pressure measured at the upper and lower extremities showed no gradient in any patient.

Only one 19-year-old male patient had not been used any antihypertensive medication before surgery but this patient had Type-A dissection coexisted for coarctation; due to this after surgery, he started to take antihypertensive therapy.

The antihypertensive medication necessity was decreased significantly after surgery in discharge ($p<0.001$). The blood pressure values during follow-up are shown in Table 3.

Table 2. Operative characteristics and post-operative findings

Patient	Coexistent procedure	Axillary cannulation	Graft size	Cross-clamp time	Total perfusion	Hospital stay
1	Supracoronary aortic replacement	1	12	103	133	7
2	–	0	12	70	90	7
3	–	0	12	63	90	6
4	–	1	10	119	180	6
5	Bentall	1	12	124	164	5
6	Supracoronary aortic replacement	1	10	104	137	8
7	–	1	10	42	72	5
8	Supracoronary aortic Replacement-aortic valve resuspension	1	10	93	204	9
9	Bentall	1	12	244	294	22

Discussion

Repair of the coarctation with an ascending-to-descending aorta bypass was extra anatomically first described by Vijayanagar et al. for the combined aortic or other cardiac pathology with aortic coarctation. Besides, this technique can be used in isolated aortic coarctation in adulthood safely either.[10,11]

Ugur et al.[13] reported 25 patients with coarctation accompanied by cardiac pathology who were treated by four different surgical approaches. One patient who underwent an isolated extra anatomical bypass died after surgery so they declared that a two-stage endovascular and surgical repair algorithm was more effective and safe.

In our report, a median sternotomy approach was utilized for every patient. While some case series in the literature have explored the combination of sternotomy with left lateral thoracotomy, our analysis did not demonstrate a significant advantage in comparison with the classical median sternotomy approach. In addition, employing two incisions may lead to increased post-operative pain, cosmetic concerns, and a higher risk of atelectasis among patients.[14]

Ozkokeli et al.[14] reported their article for assessment of the effect of aortic coarctation surgery in adult patients on arterial blood pressure in the early post-operative period. They evaluated 93 patients undergoing coarctation surgical repair with different approaches. They found out that the systolic and diastolic blood pressures reduced significantly but persistent hypertension seemed to increase in the older age groups.

Mckellar et al.[15] retrospectively reviewed 50 consecutive patients with congenital aortic coarctation or recurrent coarctation who underwent ascending–descending posterior pericardial aortic bypass between January 1985 and November 2005, and they reported the results as there was no in-hospital death and in their report there was a significant decreasing in mean systolic pressure after surgery either.

Nakamura et al.[8] reported a case series with five patients required combined surgery for aortic coarctation and coexistent pathology; they had no hospital death and re-intervention, but they used extra anatomical bypass in one patient and they performed with thoracotomy. They could not give us statistical results for residual hypertension and reducing hypertensive therapy due to the number of cases.

Table 3. Evaluation of blood pressure and antihypertensive medication pre-operative and first week after surgery

Patient	Pre-operative mean blood pressure	Medication	Post-operative 7th mean blood pressure	Post-operative med
1	135/85	a,b	119/62	b
2	159/80	b,c	147/66	b
3	140/86	b,c	118/82	b
4	150/82	b,c	137/45	b
5	148/50	a,b	134/67	b
6	140/85	0	125/87	a, b, c, d
7	153/89	a,b,c,d,e	101/76	a, b
8	125/95	B	98/75	0
9	150/98	a,b	145/70	a, c

a: ACE inhibitors; b: Beta blockers; c: Calcium channel blockers; d: Diuretics; e: Alfa-blockers

Yamashita et al.[9] treated an adult case of coarctation by using bypass grafting from the left subclavian artery to the descending aorta, but they published only the early-term results they may need long-term results for convince us it is a superior technique than the others.

Erben et al.[16] published a multicenter experience with endovascular treatment of aortic coarctation in adults with consecutive 93 patients undergoing endovascular treatment for primary coarctation or post-repair complication treatment at nine institutions between 1999 and 2015. They suggested that endovascular repair is effective with an acceptable safety but there was a death after sudden aortic rupture. This complication is not so common but in endovascular treatment the surgical team need to be more careful and consider all the consequences and make a decision according to every individual patient's aortic structure.

In consideration of this report, we can declare that the ascending–descending aortic bypass through a posterior pericardial approach is a safe and feasible, and easy surgical treatment and is more effective than improving hypertension medication relieving than endovascular and catheter-based treatments intermediate-term results.[13,15,16]

Yin et al.[17] displayed a series with 60 patients who underwent coarctation repair in their center. However, just like our series nine of them underwent extra-anatomical bypass procedure concomitantly other surgeries. During their follow-up, 3 in-hos-

pital mortality was declared; however, in our study, no hospital and early-term deaths occurred. Besides their mean follow-up was 1 year, our mean follow-up time is 26 months. One patient had chylothorax, none in our series and two patients had renal, three patients had had respiratory failure. In our study, there was none. There were no complications as reoperation for bleeding or tamponade, renal failure, ARDS, stroke, myocardial failure, or spinal cord injury. Only one patient had a permanent blockage of the AV node so required a permanent pacemaker insertion. Abjigitova et al.[18] declared the most common surgical technique for adult coarctation is extra-anatomical bypass in all cases. They showed satisfactory results during their 5 years follow-up.

In addition, post-operative antihypertensive medication was necessitated in only one patient in our study. The other studies declared more worsened results.

Conclusion

There is a paucity of articles and reports detailing long-term results, and prospective data are limited in the field of aortic coarctation treatment. Conversely, for endovascular treatments such as balloon angioplasty and aortoplasty techniques, numerous retrospective studies have highlighted their association with significant complications, including mortality, and have rendered re-operations and re-interventions more challenging for surgeons.

In the future, we propose conducting prospective, long-term studies with larger patient cohorts to elucidate the potential advantages of the ascending-to-descending aorta bypass technique in suitable cases more effectively and conclusively. It is imperative that treatments are individualized for each patient, whether they have native coarctation or residual coarctation following surgical or interventional treatment. Such personalized approaches can optimize outcomes and minimize risks associated with the management of aortic coarctation.

Disclosures

Ethics Committee Approval: The study was approved by the Kartal Koşuyolu High Specialization Training and Research Hospital's Clinical Research Ethics Committee (no: 2018/6/5-105, date: 25/09/2018).

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