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Original Article

Balloon angioplasty for postoperative aortic recoarctation in children: A 10-year, single-center experience

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ABSTRACT

Objective: Coarctation of the aorta is a congenital anomaly observed in 8% to 10% of all cases of congenital heart disease. In patients with postoperative aortic recoarctation, reoperation is associated with high morbidity and mortality risk, and percutaneous balloon angioplasty is widely accepted as a first-line option in these patients regardless of the primary surgery or recoarctation anatomy. Our aim in this study was to share our experience with balloon angioplasty in patients who developed recoarctation after surgery for aortic coarctation.

Methods: A total of 39 patients aged 0-18 years who underwent percutaneous balloon angioplasty in the Pediatric Cardiology Department of Ege University between January 2010 and January 2020 were included in the study. All of the patients developed aortic recoarctation after surgical repair of aortic coarctation and were referred from various centers.

Results: On echocardiography performed before balloon angioplasty, the mean pressure gradient between the ascending and descending aorta was 50±11 mmHg. Transcatheter peak systolic pressure gradient between the ascending and descending aorta was 35 ± 13 mmHg before the procedure and decreased to 8 ± 11 mmHg after the procedure. The mean balloon diameter used for balloon angioplasty was 10 ± 4 mm. Adequate gradient reduction was achieved in all patients during balloon angioplasty. No major complications were observed.

In our study, after balloon angioplasty, the prevalence of recoarctation was 7%.

Conclusion: In conclusion, balloon angioplasty can be used safely in the treatment of postoperative recoarctations.

Keywords: Recoarctation, balloon angioplasty, aortic, surgery

INTRODUCTION

Coarctation of the aorta is a congenital anomaly observed in 8% to 10% of all cases of congenital heart disease. It refers to a segmental narrowing of the aorta that can occur at all levels, but most frequently (in 98% of cases) in the aortic arch, just distal to the origin of the left subclavian artery and directly opposite the insertion of the ductus arteriosus.[1] Patients with untreated aortic coarctation are at high risk of mortality and morbidity due to heart failure, intracranial hemorrhage, aortic rupture, and myocardial infarction.[1]

The first successful surgical treatment of aortic coarctation was performed by Crafoord and Nylin in 1945 by resection and a direct end-to-end anastomosis technique.[2] More recently, various other techniques have been described and successfully applied in the surgical treatment of aortic coarctation.[3-6] The risk of recurrent CoA is increased when surgery is performed in young

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infants, especially in those requiring prostaglandin infusions, which are thought to modify the arch anatomy and may mask the appropriate resection boundaries.[7] Meticulous, wide resection of ductal tissue should therefore be performed. The underlying substrate of significant arch hypoplasia in neonates who are significantly symptomatic enough to require surgery also increases the probability of residual or recurrent CoA. On the other hand, there is an increased risk of hypertension and long-term atherosclerotic heart disease if the repair is delayed until late childhood or adolescence.[6] Up to 30% of repaired adults require further intervention.

Since it was first reported in 1982, percutaneous transcatheter balloon angioplasty has been used as an alternative to surgery for the treatment of native coarctation and recoarctation in neonates, infants, children, and adolescents.[8-10] In patients with postoperative aortic recoarctation, reoperation is associated with a high risk of morbidity and mortality, and percutaneous balloon angioplasty is widely accepted as a first-line option in these patients regardless of the primary surgery or recoarctation anatomy.[11-13] Our aim in this study was to share our experience with balloon angioplasty in patients who developed recoarctation after surgery for aortic coarctation.

METHODS

Patient selection

A total of 39 patients aged 0-18 years who underwent percutaneous balloon angioplasty for postoperative aortic recoarctation in the Department of Pediatric Cardiology of Ege University between January 2010 and January 2020 were included in the study. Ethics committee approval was obtained from the Scientific Research Ethics Committee of the Ege University Faculty of Medicine. The parents or caregivers of all participants were informed in writing and provided informed consent before inclusion in the study. All of the patients developed aortic recoarctation after surgical repair of aortic coarctation and were referred from various centers. Patients who underwent stent implantation for recoarctation and those who underwent balloon angioplasty for native coarctation were excluded.

Definitions

Recoarctation

The diagnosis was made by physical examination, upper/lower limb arterial blood pressures, telecardiography, electrocardiography, echocardiography, and cardiac catheterization. Recoarctation was diagnosed in patients with an upper-lower limb blood pressure gradient ≥ 20 mmHg and an instantaneous peak pressure gradient ≥ 20 mmHg across the coarctation on echocardiography, with or without a diastolic tail pattern on continuous-wave Doppler.

Indications for balloon angioplasty

Regardless of the patient's age, balloon angioplasty of aortic recoarctation was performed in patients with suitable anatomy and a transcatheter systolic (peak-to-peak) coarctation gradient of > 20 mmHg. Balloon angioplasty for recoarctation is indicated in the presence of significant collateral vessels and suitable angiographic anatomy, irrespective of age, as well as in patients with univentricular heart or with significant ventricular dysfunction.

Balloon angioplasty procedure

All balloon angioplasty procedures were performed under sedation, with access via the femoral artery. Anteroposterior, 15-20° left oblique, and lateral angiographic images were obtained before and after the procedure. Systolic, diastolic, and mean arterial pressures in the ascending and descending aorta were measured before and after the procedure in all patients. A balloon diameter no larger than the diameter of the descending aorta at the level of the diaphragm and equal to or 1-2 mm larger than the diameter of the aorta at the left subclavian artery was selected for the procedure. Under fluoroscopic guidance, the balloon was positioned at the coarctation and inflated 2-3 times for less than 10 seconds until the waist disappeared. Balloon inflation pressure was not increased above the values specified by the manufacturer. In patients who did not show sufficient expansion of the coarctation and whose pressure gradient across the coarctation did not decrease below 20 mmHg at the end of the procedure on radiographic and hemodynamic evaluation, the procedure was repeated using a second balloon that was 1 or 2 mm wider but did not exceed the diameter of the descending aorta at the level of the diaphragm.

Follow-up after balloon angioplasty

After the procedure, patients were evaluated on days 1 and 15, at months 1-6, year 1, and annually thereafter. Clinical findings, upper/lower limb blood pressures, and transthoracic echocardiography results were evaluated at the follow-up visits. Patients with an upper-lower limb pressure gradient ≥ 20 mmHg at the clinical follow-up and patients with an instantaneous peak systolic pressure gradient ≥ 20 mmHg at the coarctation site in echocardiographic follow-up were diagnosed as having recoarctation.[14]

Statistical analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 21 (IBM Corp., Armonk, N.Y., USA). Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage.

RESULTS

Demographic findings

Of the 39 patients who underwent balloon angioplasty, 19 (48.7%) were female and 20 (51.3%) were male. The mean age at first diagnosis was 31.3 ± 40.7 months (range: 0-144). Some patients were diagnosed prenatally thanks to advances in fetal echocardiography techniques. The mean age at balloon angioplasty was 67 ± 10 months. The mean weight of the patients at the time of balloon angioplasty was 24 ± 14.5 kg. The follow-up period after balloon angioplasty ranged from 6 to 120 months (Table 1).

Primary operative procedure

All patients who underwent balloon angioplasty had previously undergone surgical repair of aortic coarctation. These procedures were performed in various centers and included extended end-to-end or end-to-end anastomosis in 34 patients, aortoplasty with a pericardial patch in 1 patient, aortoplasty with a Dacron patch in 1 patient, and tubular grafting in 3 patients (Figure 1). Coarctation repair with simultaneous patent ductus arteriosus (PDA) division was performed in 14 patients and pulmonary banding was performed in 1 patient.

Table 1. Demographic, echocardiographic and angiographic evaluation results of patients who underwent balloon angioplasty for aortic recoarctation

Age (month)	31.3 ± 40.7
Gender	
Female	19 (%48.7)
Male	20 (%51.3)
Weight (kg)	24 ± 14.5
First diagnosis age (month)	31.3 ± 40.7
Mean age at balloon angioplasty (month)	67 ± 10
Follow-up range (month)	6-120
Ejection fraction value mean (%)	68 (range 35-82)
Mean balon diameter (mm)	10 ± 4
Mean pressure gradient between the ascending and descending aorta (mmHg)	
Echocardiography gradient	50 ± 11
Angiography gradient	35 ± 13
Post-procedure gradient	8 ± 11

Echocardiography and comorbidities

Left ventricular ejection fraction was measured by a pediatric cardiologist using two-dimensional echocardiography (Vivid E9, GE-Vingmed Ultrasound AS, Horten, Norway). The same pediatric cardiologist evaluated the patients for concomitant congenital heart disease. Left ventricular ejection fraction was calculated using the Simpson method. The mean ejection fraction value of the patients was 68% (range: 35%-82%). On echocardiography performed before balloon angioplasty, the mean pressure gradient between the ascending and descending aorta was 50±11 mmHg. No concomitant anomalies were detected in 22 (56.4%) of the patients. The bicuspid aortic valve was diagnosed by echocardiography in 10 patients (25.6%), ventricular septal defect (VSD) in 5 patients (12.8%), secundum atrial septal defect in 1 patient (2.5%), and mitral stenosis in 1 patient (2.5%).

Angioplasty results

The transcatheter peak systolic pressure gradient between the ascending and descending aorta was 35 ± 13 mmHg before the procedure and decreased to 8 ± 11 mmHg after the procedure. The mean balloon diameter used for balloon angioplasty was 10 ± 4 mm. Of the potential complications that can occur during and after balloon angiography, none of the patients developed aneurysm, peripheral artery thrombosis, bleeding requiring transfusion, cerebrovascular events, severe arrhythmias, or death.

Follow-up and recurrence

Three patients required surgery for aortic recoarctation detected by physical examination and echocardiographic evaluation after balloon angioplasty. In our center, 2 patients underwent left subclavian-descending aortic bypass with a Dacron tube graft and 1 patient underwent coarctation repair surgery with a Dacron graft (Figure 1). Patients who developed restenosis after balloon angioplasty were treated surgically; balloon angioplasty was not repeated. Because of other accompanying cardiac anomalies, 2 patients underwent discrete subaortic membrane resection, 1 patient underwent VSD closure, and 1 patient underwent mitral valve repair. No major complications or death occurred after coarctation balloon angioplasty or other surgical procedures.

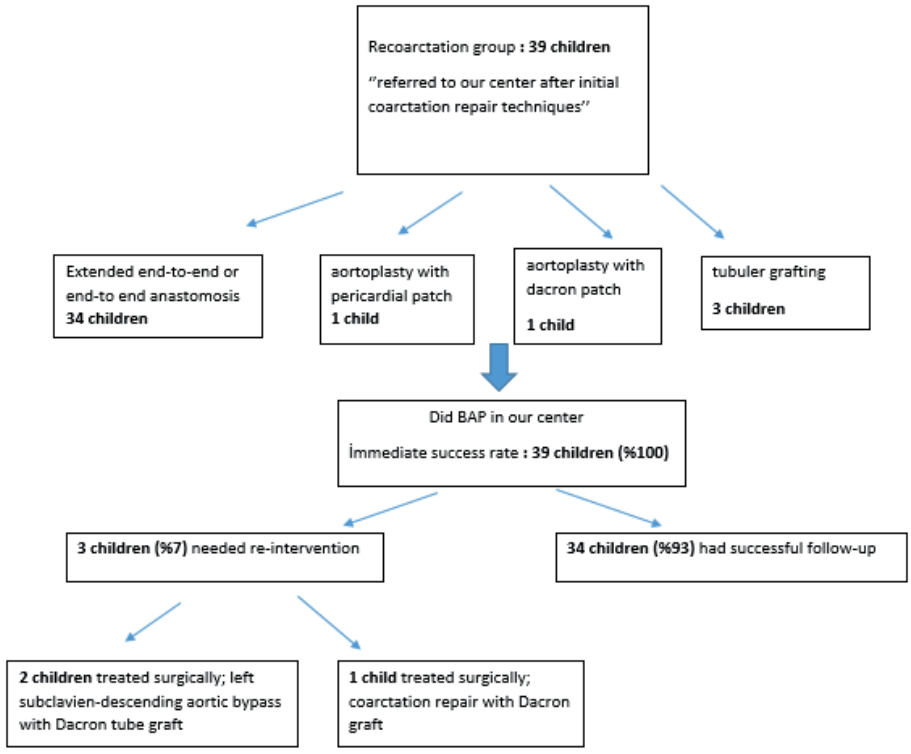

Figure 1. Detailed management and outcome of the study cohort

BAP : Balloon angioplasty

DISCUSSION

Although aortic coarctation is diagnosed across a wide age range, it is usually detected at 3-6 months of age, with a small proportion of patients diagnosed in adolescence and adulthood. Aortic coarctation is associated with intracardiac and extracardiac anomalies. Bicuspid aortic valve, VSD, PDA, and transposition of great arteries are among the most common. The bicuspid aortic valve is the most common intracardiac anomaly, with a prevalence of 45% to 62%.[15-17]

In most centers, surgical treatment is primarily chosen for symptomatic young infants and patients with long segment coarctation regardless of age. In asymptomatic and incidentally detected cases, elective coarctation repair is performed between 6 months and 2 years of age.[18] Younger age at surgery increases the risk of recurrence, while older age at surgery increases the risk of persistent hypertension.

The timing and choice of therapeutic intervention in patients with aortic coarctation depend on the presence of ductal patency in a symptomatic newborn, the anatomy and severity of the coarctation, the patient's age, size, and symptoms at the time of diagnosis, and other concomitant cardiac anomalies. In patients with a large VSD, coarctation repair and palliative pulmonary banding can be performed, or in patients with a smaller VSD, coarctation repair can be performed with the aim of reducing the left-to-right shunt and facilitating defect closure. In some centers, the choice of surgical or transcatheter methods in neonates and infants is controversial. The risk of recurrence and re-intervention after balloon angioplasty is higher in this patient group.[19]

Surgical techniques consist of extended end-to-end anastomosis, end-to-end anastomosis, subclavian flap repair, patch aortoplasty, and interposition grafting. Extended end-to-end anastomosis is the most preferred method and is thought to allow normal development of the transverse arch and isthmus.[20] In our patient group, end-to-end anastomosis techniques were used most frequently.

The most important factors affecting the formation of recoarctation are low weight, young age, need for PGE1 infusion at birth, abandonment of ductal tissue, and presence of aortic arch hypoplasia.[21] The older age at coarctation diagnosis in our patient group compared to the literature increased the risk of recoarctation. Acute postoperative complications, including bleeding, injury to the recurrent laryngeal nerve, chylothorax,

hypertension, and the need for prolonged mechanical ventilation, are more common in patients with intracardiac abnormalities.[22]

While balloon angioplasty was initially used for recurrent aortic coarctations, with increasing experience it has also been used more frequently in native coarctation patients. Balloon angioplasty reduces the coarctation pressure gradient to within normal limits in 80% of cases. Rates of recoarctation and aneurysm are below 10%.[23] In our study, the prevalence of recoarctation was 7%. Patients with native coarctation and recoarctation had similar restenosis rates in follow-ups.[23]

Aneurysm formation in and around the area of stenosis may be observed in the early and late periods following balloon angioplasty in children. The reported frequency of aneurysm development varies considerably, but some studies have found the rate ranging from 0% to 5%.[24,25] Although it is difficult to establish a causal relationship with the factors in aneurysm development, the use of large balloons, incorrect catheter, and guide wire maneuvers, tears in the intima and media layers of the vessel during angioplasty, and the formation of cystic medial necrosis have been implicated.[26,27] Apart from this, as with the likelihood of restenosis, the risk of aneurysm development is higher in patients who undergo balloon angioplasty in the first 3 months of life.

Femoral artery injuries are the most common early problem in children undergoing balloon angioplasty, especially in neonates and infants, and complete occlusion occurs in approximately 8% of these cases.[12] Although these patients develop good collaterals in the long term, they should be monitored for the sequelae of occlusion. These complications can be reduced by using balloons with a smaller diameter and lower profile, placing a smaller sheath in the artery[28], and using different access routes (umbilical artery or antegrade route in neonates). Patients undergoing balloon angioplasty due to aortic coarctation may rarely experience bleeding requiring blood transfusion, cerebrovascular events, and death. Mortality is uncommon except in the neonatal period. The mortality rate in children undergoing balloon angioplasty is reported to range from 0.7% to 4.5%, and most of these deaths are believed to be attributable to concomitant heart disease.

In conclusion, balloon angioplasty can be used in the treatment of postoperative recoarctations. Balloon angioplasty for recoarctation is effective and is associated with the accelerated growth of the dilated segment at follow-up in many patients. In many patients, it provides a permanent improvement in hypertension.

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Ethical approval

This study has been approved by the Ege University Medical Research Ethics Committee (approval date 24/03/2022, number 22-3.1T/45). The parents or caregivers of all participants were informed in writing and provided informed consent before inclusion in the study.

Author contribution

Surgical and Medical Practices: ED, EL; Concept: ED, ZÜ, EL; Design: ED, ZÜ, EL; Data Collection or Processing: ED, ZÜ; Analysis or Interpretation: ED, DA, ZÜ; Literature Search: ED, DA; Writing: ED, DA. All authors reviewed the results and approved the final version of the article.

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Conflict of interest

The authors declare that there is no conflict of interest.

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