## Anatomic Repair of Recurrent Aortic Arch Obstruction

<table>
<thead>
<tr>
<th>Patients</th>
<th>Results</th>
<th>Implications</th>
</tr>
</thead>
</table>
| **Indication:** Recurrent/residual aortic arch obstruction → **Surgical Anatomic Repair**  
N=39  
Median age 253 [100; 2198] months  
Whole body perfusion n=32 (82%) | **Follow-up:**  
Median 8.1 [2.6; 12] years  
- Mortality: 3 patients (8%, no death due to an AA complication)  
- Re-re-intervention: 1 patient (3%)  
- Gradient under surveillance: 3 patients (8%) |  
- Sophisticated reoperations on the AA can be performed safely.  
- Whole body perfusion may be a helpful tool.  
- In children, the growth potential can be sustainably preserved by avoiding interposition or extra-anatomic aortic bypass grafts. |

![Residual hypoplastic AA - preoperatively](image1)  
- Doppler 3.2 m/s  

![Postoperatively](image2)  
- AA, aortic arch
The Anatomic Repair of Recurrent Aortic Arch Obstruction in Children and Adolescents

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Informed consent statement: Informed consent was waived because of the retrospective nature of the study and the use of pseudonymized clinical data for the analysis.
Central picture

Central picture legend: Angiography before/after repair of a recurrent aortic arch stenosis in an HLHS patient

Central message

The surgical anatomic repair of recurrent aortic arch stenosis can be performed safely and is a sustainable therapeutic approach.

Perspective statement

The surgical treatment of a recurrent aortic arch stenosis is a highly challenging procedure. The two main therapeutic options are an anatomic repair on the one hand and an extra-anatomic aortic bypass graft on the other hand. This study confirms that the anatomic repair can be performed safely and seems to be a sustainable strategy in children and adolescents.
Abstract

Objective: Surgery for recurrent aortic arch obstruction is highly challenging and publications are rare. The aim of this retrospective single center study was to evaluate mortality, complications and reintervention rate after an anatomic repair.

Methods: Between 1999 and 2022, in total 946 operations on the aortic arch were performed at the Children’s Heart Center Linz. In 39 cases the indication was a recurrent or residual aortic arch obstruction or coarctation in a patient aged 18 years or younger. This is our study cohort. The aorta was reconstructed by a direct anastomosis/autograft in 20 patients, patch in 17 patients, interposition graft in 2 adolescents. In 32 procedures cardiopulmonary bypass with whole body perfusion, in 4 antegrade cerebral perfusion, in 2 a left heart bypass and in 1 no cardiopulmonary bypass was used.

Results: Median age at operation was 253 [100; 2198] d, weight 7.5 [4.5;17.8] kg. Median cardiopulmonary bypass time was 177 [115;219] min, cross clamp time 73 [49;102] min. 3 infants died during the hospital stay: 1 Williams syndrome, 1 HLHS, 1 heterotaxia. There was no death due to an arch complication. The main complications were 1 neurological injury after postoperative resuscitation (Williams syndrome), 1 permanent recurrent laryngeal nerve paralysis. During the follow-up period of median 8.1 [2.6;12] years 1 re-re-intervention on the aortic arch was necessary.

Conclusions: Sophisticated reoperations on the aortic arch could be performed safely. In children, the growth potential of all segments of the aorta could be sustainably preserved by avoiding interposition or extra-anatomic bypass grafts.

Abstract word count: 250

Keywords
Hypoplastic aortic arch, recurrent aortic arch obstruction, re-coarctation, aortic arch reconstruction

Main text

Abbreviations and acronyms

AA Aortic Arch
VSD Ventricular septal defect
RVPA Right ventricle to pulmonary artery
ICU Intensive care unit
HLHS Hypoplastic left heart syndrome
REEEA Resection and extended end-to-end anastomosis

Introduction

The aortic arch (AA) reconstruction in congenital heart surgery developed to a standardized and safe operation during the last decades. However, recurrent or residual stenosis still may occur\(^1-3\). While transcatheter intervention is preferred in some cases, certain patients face limitations due to specific AA morphology or insufficient growth potential, particularly in children\(^4,5\). Anatomic repair techniques may be challenging, as the approach to the complete AA is never easy and even more complex in redo situations. Cardiopulmonary bypass strategies vary from deep hypothermic circulatory arrest to antegrade cerebral or whole body perfusion\(^6-9\). Some centers prefer extra-anatomic bypass grafts instead of the anatomic reconstruction\(^10-12\).
This retrospective single-center study aimed to assess mortality, complication rate and mid- to long-term results of anatomic reconstruction for recurrent AA obstruction.

**Patients and methods**

**Patients**

This retrospective study was approved by the ethics committee of the Medical Faculty at Johannes Kepler University Linz on May 17th, 2023 (EK Nr: 1269/2021). Informed consent was waived because of the retrospective nature of the study and the use of pseudonymized clinical data for the analysis.

Statistical analyses were descriptive only and utilized Microsoft® Excel for Mac Version 16.78.3. Continuous variables were reported as medians and quartiles (in square brackets).

Between 1999 and 2022, 923 surgeries on the AA or isthmus were performed at the Children’s Heart Center Linz including 39 for recurrent or residual obstructions in patients aged 18 years or younger. This is our study cohort. We numbered the cases consecutively by the date of the AA reoperation (1 - 39). The patients’ characteristics are provided in table 1. According to the underlying disease patients were divided into three anatomical subgroups: patients with isolated AA pathology, patients with biventricular circulation but an AA issue with additional cardiac defect and univentricular patients. The AA reoperations in this univentricular cohort were performed at all stages of palliation, from one late conversion to one re-fenestration in a 12-year-old failing Fontan.

The indication for reoperation was an obstruction with a gradient of at least 20mmHg, in univentricular cases we do not accept any AA stenosis. The median preoperative gradient was available in 35 patients: 34 [25;55] mmHg measured by sonography. In 13 cases (33%) a transcatheter dilatation, in 4 other (10%) patients stent implantations had been performed 2.8, 6.7, 7 and 14 years before the surgical reintervention.
Operative technique

Since October 2003 we have performed all AA operations except an isolated coarctation repair using whole body perfusion and cardioplegic arrest (82% in this cohort). One arterial canula was inserted into the innominate artery, either directly or by using a polytetrafluoroethylene prosthesis. In 30 patients a second arterial canula was placed into the descending aorta just above the diaphragm, in 2 patients with a body weight of more than 40kg into a femoral artery. Antegrade cerebral perfusion was performed before this era. The approach for these 36 surgeries was a median sternotomy, as this is our preferred approach also in borderline cases of distal AA obstruction. In 3 cases the restenosis was located at the isthmus region, therefore the surgery was performed via a left thoracotomy. Twice a left heart bypass (35 and 65min), once no bypass was used. In one infant (patient 31) the operation started with a median sternotomy and a thoracotomy was performed additionally, as the end of the long interposition graft could only be reached by this approach.

We created a diagram that presents our strategy of decision making regarding the surgical approach (figure 1): The 2 preferred methods are a resection and extended end-to-end anastomosis (REEEA) and an ascending-to-descending anastomosis. In the case of a patch reconstruction, we exclusively use patches curved in two planes out of a pulmonary homograft, an AA homograft or a special vascular prosthesis (figure 2). If these techniques are not appropriate because of the lack of competent autologous material, we either perform a subclavian flap plasty or an aortic autograft (figure 3a and b). We try to completely avoid interposition grafts in children.

All different AA techniques used in our 39 cases of recurrent AA obstruction are presented in figure 4. In the majority (19 patients) no patch was needed. In one 12-year-old girl (patient 36) there was not enough competent autologous material at the distal AA which was extremely long, narrow and fragile. Therefore, an aortic autograft out of the ascending aorta
was used (figures 3a and b). In 16 cases the AA was enlarged by a curved patch together with an extended end-to-end anastomosis between ascending aorta and AA (figure 2), in patient 31 together with a subclavian flap plasty (figures 5a+b). In 2 adolescents (169cm/60kg, 165cm/68kg) the implantation of a 20mm polyethylenterephthalat interposition graft had to be performed because of the lack of autologous material after removing a stenotic long interposition graft or stent. In 22 cases additional cardiac procedures were necessary: 6 supravalvular and 4 subvalvar aortic stenosis repairs, 4 VSD closures, 4 bidirectional Glenn operations, 3 pulmonary artery reconstructions, 2 systemic atrioventricular valve repairs, 2 right ventricle to pulmonary artery (RVPA) conduit exchanges and each 1 Norwood procedure, Fontan operation, Fontan fenestration, Ross procedure, valve sparing aortic root replacement, aortic valve repair and pacemaker procedure.

Results

Postoperative data and early mortality.

Peri- and postoperative data are presented in table 2. Thirty-six patients (92%) could be discharged from hospital, 3 patients died during the ICU stay. Patient 5, a 6-months-old girl with heterotaxy syndrome, situs inversus, unbalanced atrioventricular canal, hypoplastic AA and left atrial isomerism, experienced a challenging recovery following her Norwood operation. Due to a gradient of 25mmHg at the distal AA with reduced ventricular function, she was reoperated by an REEEA at the age of 6 months. Her ventricular function recovered slowly, but she ultimately deceased to a rhythm disorder on postoperative day 40. Patient 7 was a girl at the age of 1 month who was status post patch plasty performed at another center. In the echocardiography we found a hypoplastic AA with a gradient of 30mmHg and a severe mitral stenosis. We decided for a Norwood operation. Postoperatively, the saturation was low and a catheterization showed pulmonary hypertension. This happened before the implementation of extracorporeal membrane oxygenation therapy at our center, and the baby
died due to progressive ventricular failure on postoperative day 1. Patient 15 was a girl with Williams syndrome and status post REEEA. She was reoperated at the age of 53 days because of a supravalvar aortic stenosis, hypoplastic AA and hypoplastic pulmonary arteries.

Unfortunately, she also had peripheral pulmonary stenoses and a persisting suprasystemic right ventricular pressure postoperatively. She died due to ventricular failure a few hours after the operation. In none of these mortality cases a residual AA obstruction was found, neither at pre nor at post mortem examination.

Complications

The major complications on the ICU were 3 cases of resuscitation. In two infants this happened on the day of operation and in both a ventricular fibrillation could be terminated by defibrillation and volume substitution after a few minutes. The first patient (patient 9) ended up without any consequential sequelae, the second case concerned a boy with Williams-syndrome (patient 4). Although no pathologies could be seen in his cerebral sonography examinations, the boy was still neurologically impaired at his last follow-up examination 19.5 years later. The third case of resuscitation was an infant with a multiple malformation syndrome. She happened to have a serious bradycardia on postoperative day 9 after extubation. She was reintubated and ended up without any consequential damage, the second extubation was successful.

There was one postoperative bleeding and one hemothorax with the indication for a re-thoracotomy each, both patients were in the complex biventricular group with further concurrent performed cardiac procedures. We had 1 sternal infection, 1 temporary unilateral phrenic nerve paralysis and 4 patients with temporary postoperative stridor. A diagnostic examination regarding the function of the laryngeal nerves had not been performed routinely, as the stridor had no serious clinical consequence. There was only one patient with a
persistent unilateral laryngeal nerve paralysis at his last follow-up examination after 9 years, clinically he showed a slight hoarseness.

Long-term outcome and late mortality

The follow-up period was defined as the interval between the AA reoperation and the last cardiac examination including an echocardiography. At least one postoperative echocardiography of all 36 survivors was available. Therefore, the follow-up was complete and ranged from 10 days to 19.5 years, median 8.1 [2.6;12] years. There was no case of late mortality. One patient needed two unplanned re-re-interventions on the descending aorta (patient 31, figure 5a): The AA could be repaired successfully, but the dissection of the very distal descending aorta could not be treated sufficiently by surgery. Therefore, 2 stents were implanted 7 days and 4.5 years later (figure 5b).

In 32/35 cases no gradient and/or normal flow patterns at the AA and isthmus were described at last follow-up, 3 patients showed conspicuous results: Patient 38 still showed a gradient of 30mmHg at the proximal AA. The narrowest part of his former recurrent AA obstruction was found in a stent in his descending aorta. He was operated by a lateral thoracotomy for a stent removal and interposition graft (65kg). As there was no left heart hypertrophy at his last follow-up 9 months after this procedure, he currently stays under observation and will probably need an operation including an RVPA conduit exchange by sternotomy in the future.

In patient 2 a slight re-coarctation with a flow acceleration of 2.8m/s, but normal flow patterns in the abdominal aorta, no aggravation and therefore no need for reintervention was described after 16 years of follow-up. In patient 4 with Williams syndrome (see ‘complications’) a long-distance obstruction of the descending thoracic aorta with a gradient of 4.1m/s was seen after 19.5 years. However, there is a normal abdominal aortic flow as well as an early deceleration and the gradient is probably overestimated. An additional diagnostic
imaging will be necessary in the future, but his cardiologist and parents are reluctant because of his poor neurological condition.

Unplanned reinterventions on other cardiac structures regarded the left pulmonary artery of 2 HLHS patients as well as the right or both pulmonary arteries after 2 Ross-Konno procedures and in 1 further complex biventricular patient. There was no case with a left bronchial stenosis.

Discussion

Anatomic Repair versus Extra-Anatomic Aortic Bypass

The surgical treatment of a recurrent AA stenosis is a challenging procedure, and therefore alternatives as extra-anatomic aortic bypasses were invented. McKellar et al\(^1\)\(^1\) demonstrate very good intermediate-term results of an ascending-descending posterior pericardial bypass in a large cohort of 50 patients. However, this study only includes adults and adolescents using 21±2mm grafts. Kanter et al\(^1\)\(^2\) published their experience with ascending aorta–descending aorta bypass grafting in children, and they report no indication for reintervention during the follow-up period of mean 7.9 years using 10mm grafts. Nevertheless, they conclude that the use of bypass grafts should be avoided whenever possible and an anatomic repair should be preferred. The main concerns, which are also mentioned in their discussion, are potentially difficult further operations, tethering of the aorta and the development of aorto-esophageal fistulas.

In the current era of congenital cardiac surgery, the AA reconstruction developed to a routine operation, as can be seen on the total amount of 946 cases at our medium volume center. The different cardiopulmonary bypass techniques with the possibility of perfusing the brain and the lower parts of the body enable maximum safe conditions for even complex and long AA operations\(^1\)\(^3\). We are convinced that especially in young patients the surgical anatomic repair
is the most sustainable strategy for recurrent or residual AA stenosis and coarctation. The
different surgical techniques may be extremely challenging, as the approach to the complete
AA is never easy and even more complex in a redo situation. However, the chance of
preserving the growth potential together with excellent results regarding complications,
mortality and reintervention rates of our study strengthens our opinion. Therefore, at the
Children’s Heart Center Linz no extra-anatomic bypass has ever been performed.

Surgical approach

We now perform every reoperation on the AA through a median sternotomy on
cardiopulmonary bypass during whole body perfusion. Exceptions are cases of recoarctation
with implanted stents or interposition grafts that reach more distal parts of the descending
aorta. Zoghbi et al published a large series of 63 patients including adults, who underwent
anatomic surgical repair for recurrent AA obstruction. Their approach in 52 cases (83%) was
a left thoracotomy, and their outcome was impressive with 1 in-hospital death and 2 re-re-
interventions. Our group identified an access through a left thoracotomy as the only risk
factor for reintervention after AA or coarctation repair. We feel much safer with a median
sternotomy, as it allows addressing the entire AA. Furthermore, the time pressure decreases
by using whole body perfusion, which we regard as essential during complex AA
reinterventions.

Our strategy of avoiding interposition grafts or stents could not be put into practice in patients
who were treated primarily by long interposition grafts or stents. This was the case in 2
adolescents weighing 60 and 68kg due to limited availability of autologous material.
However, in retrospect, using 20mm interposition grafts in nearly fully grown patients did not
pose significant problems, as evidenced by the absence of notable gradients during follow-up
periods of 277 days and 11.7 years. Mery et al performed a very similar study with 48
patients aged 9 months (range, 22 days to 36 years) receiving a surgical repair of recurrent
AA obstruction. Their results were excellent with 1 in-hospital mortality and 2 re-re-
interventions. They advocate for reconstruction techniques utilizing autologous material or
patch plasty, though interposition grafts were required in two cases.
In one special case from abroad we tried very hard to restore an aorta with growth potential
after removing a 2cm-long interposition graft in a 6-months-old girl (patient 31, figures
5a+b). We thought to be successful by performing a subclavian flap and a patch plasty, but
could not treat the distal descending aorta surgically. This was the only case of re-re-
intervention in our center so far. However, we regard this ‘hybrid strategy’ as superior to an
interposition graft, given the potential for stent dilation. When the girl is older and hopefully
nearly full-grown, she probably will need an interposition graft nevertheless.
Until now we only used one aortic autograft (figure 3a+b) with no gradient after a follow-up
of 645 days. Of course, this is not a long observation period. The use of an aortic autograft
was already described by Metras et al15 for pulmonary artery reconstruction and it showed
excellent long-term performance.
Several groups9,16 describe the ‘sliding arch aortoplasty’ as a further option for AA
reconstruction without a patch, and they also used it for cases of re-obstruction. Until now, we
only performed this technique together with a curved patch (figure 2), but it will be
considered as further option in future cases.
Transcatheter re intervention
Transcatheter dilatation is an often-described option for a recoarctation17, and it is also
standard in our center. A former study conducted by our group3 describing a cohort of 139
patients, who received an AA or isthmus repair in our center, showed 11 cases with recurrent
AA obstruction or coarctation necessitating reintervention. Eight of the reinterventions were
performed by catheterization, 3 by surgery. In the current study 33% of the patients had a
dilatation before the surgery. The exact date in several cases was missing as the transcatheter intervention had been performed in foreign centers. Considering the patients in which the date was available, we saw that the surgical intervention was performed only days to weeks after the dilatation, demonstrating that the strategy was not successful in these patients.

Four patients of the current study were treated primarily by a stent 2.8-14 years preoperatively. Hence, this strategy seems to enable a substantial delay of the surgery. However, we regard an operation after stent implantation as much more difficult than a re-operation without a stent in a smaller patient, and the lack of autologous material after stent excision may be a problem (patient 38). Therefore, we do not see an indication for a stent implantation into the aorta of a child per se, and special cases should be discussed among cardiologists and surgeons before any reintervention (patient 31).

Mortality and Morbidity

Despite a lot of experience and innovative bypass techniques serious complications may occur. In our series there were 3 cases of in-hospital mortality and 1 case of cerebral ischemia because of postoperative resuscitation. Two of these patients had complex univentricular conditions, two a Williams syndrome, in which a high risk for acute heart failure after the correction of supravalvar aortic stenosis is described\textsuperscript{18,19}. No coronary pathology was diagnosed in the two cases. However, this study should again raise awareness for the high perioperative risk in Williams syndrome patients.

Limitations

The limitations of this study are the small number and the very heterogenous group of patients summarized as well as the lack of a control group. Further surveys with also longer follow-up periods will be necessary and useful.

Conclusion
Sophisticated reoperations on the AA could be performed safely by using whole body perfusion in the majority of procedures. The most serious complications and cases of death were associated with the Williams syndrome or with complex univentricular conditions. There was one case of unplanned re-re-intervention. The results concerning mortality, complication and re-re-intervention rate confirm our strategy of preferring the anatomic repair to extra-anatomic bypass grafts even in complex cases of recurrent AA stenosis.

Acknowledgement

The authors thank Peter Kreuzer, Dr Niklas Krenner and Markus Gatterbauer for their support.

References


Table 1: Patients’ characteristics and operative data

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Isolated AA pathology</th>
<th>Biventricular complex</th>
<th>Univentricular</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Patients (female)</td>
<td>12 (6)</td>
<td>18 (8)</td>
<td>9 (4)</td>
<td>39 (18)</td>
</tr>
<tr>
<td>Age (days)</td>
<td>1535 [98; 4751]</td>
<td>352 [123;1075]</td>
<td>124 [101;184]</td>
<td>253 [100; 2198]</td>
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<tr>
<td>Weight (kg)</td>
<td>15 [5.5;47.2]</td>
<td>9.2 [4.4;13.5]</td>
<td>5.2 [4.1;5.8]</td>
<td>7.5 [4.5;17.8]</td>
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<td>Time between 1st and 2nd AA repair (days)</td>
<td>302 [92;3436]</td>
<td>408 [81;1221]</td>
<td>119 [96;178]</td>
<td>224 [90; 1651]</td>
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<td>- Down</td>
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<td>- Williams</td>
<td>1 (8%)</td>
<td>2 (11%)</td>
<td>0 (0%)</td>
<td>2 (5%)</td>
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<td>Additional cardiac malformation</td>
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<td>- VSD (5)</td>
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<td>- Williams Syndrome/ multiple vascular stenoses (2)</td>
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<td>- Truncus arteriosus (1)</td>
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<td>- Taussig Bing (1)</td>
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<td>0 (0%)</td>
<td>4 (10%)</td>
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<td>- Sternotomy</td>
<td>8</td>
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<td>- Left thoracotomy</td>
<td>1</td>
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<td>Primary AA repair</td>
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<td>- R(E)EEA</td>
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<td>- Patch plasty</td>
<td>12</td>
<td>67%</td>
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<td>- Interposition graft</td>
<td>0</td>
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<td>- Ascending-descending anastomosis</td>
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<td>17%</td>
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<td>- 2 unknown AA reconstruction techniques + extra-anatomic bypass</td>
<td>0</td>
<td>0%</td>
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<tr>
<td>Primary AA repair performed in our center</td>
<td>4</td>
<td>33%</td>
<td></td>
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<td>Stent in AA/Isthmus</td>
<td>0</td>
<td>0%</td>
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</tbody>
</table>

Data are presented as the median [1st; 3rd quartile] or numbers. AA, aortic arch; AS, aortic stenosis; CAVC, common atrio-ventricular canal; ccTGA, congenitally corrected transposition of the great arteries; HLHS, hypoplastic left heart syndrome; LVOTO, left ventricular outflow tract obstruction; min, minutes; pts, patients; R(E)EEA, resection and (extended) end-to-end anastomosis; TA, tricuspid atresia; TGA, transposition of the great arteries; VSD, ventricular septal defect.
Table 2: Peri- and postoperative data.

<table>
<thead>
<tr>
<th>Subgroups</th>
<th>Isolated AA pathology (12)</th>
<th>Biventricular complex (18)</th>
<th>Univentricular (9)</th>
<th>Total (39)</th>
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<tbody>
<tr>
<td>Bypass time (minutes, 38pts)</td>
<td>114 [88;134], 11pts</td>
<td>217 [179;237], 18pts</td>
<td>179 [131;205], 9pts</td>
<td>177 [115;219]</td>
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<tr>
<td>Aortic crossclamp time (minutes, 36pts)</td>
<td>46 [30;65], 10pts</td>
<td>97 [91;111], 17pts</td>
<td>58 [45;65], 9pts</td>
<td>73 [49;102]</td>
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<tr>
<td>In-hospital mortality</td>
<td>0 (0%)</td>
<td>1 (6%)</td>
<td>2 (22%)</td>
<td>3 (8%)</td>
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<tr>
<td>Stay on intensive care unit (days, 36pts)</td>
<td>3 [2;6.5], 12pts</td>
<td>9 [3;11], 17pts</td>
<td>14 [10;16], 7 pts</td>
<td>7.5 [2;12]</td>
</tr>
<tr>
<td>In hospital stay (days, 36pts)</td>
<td>9.5 [7.8;12.5], 12pts</td>
<td>14 [10;23], 17 pts</td>
<td>21 [20;33.5], 7 pts</td>
<td>14 [9.8;21.3]</td>
</tr>
<tr>
<td>Follow-up period (years, 36pts)</td>
<td>5.5 [2;8.9], 12pts</td>
<td>7.5 [3.4;14.8], 17pts</td>
<td>11.8 [8.9;12.9], 7 pts</td>
<td>8.1 [2.6;12]</td>
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</table>
Figure 1: Decision making regarding the surgical approach at the Children’s Heart Center Linz. AA, aortic arch, AscDescA, ascending-to-descending aortic anastomosis, CPB, cardiopulmonary bypass, prox, proximal, REEEA, resection and extended end-to-end anastomosis.

Figure 2: The most frequent performed technique for enlargement of the complete AA: resection of a re-coarctation, incision of the descending aorta, implantation of a curved patch and extended end-to-end anastomosis between ascending aorta and AA.

Figures 3a,b: Use of an aortic autograft out of the ascending aorta for the reconstruction of the distal AA.

Figure 4: Surgical approach in the study cohort. AA, aortic arch, ACP, antegrade cerebral perfusion, AscDescA, ascending-to-descending anastomosis, REEEA, resection and extended end-to-end anastomosis, WPB, whole body perfusion.

Figures 5a,b: Only case of re-re-intervention. 5a: 6-months-old girl status post interposition graft. Residual stenosis at AA and isthmus, dissection of the descending aorta. 5b: Stent implantation 7 days after reoperation.

Figure 6: Graphical abstract. Magnetic resonance imaging, left: After coarctation repair as a newborn, gradient AA (echocardiography) 46mmHg. Right: 2 years after reoperation.
Recurrent AA obstruction:
No interposition grafts in children

First choice:
Median sternotomy
with CPB + whole body perfusion

Exception:
Lateral thoracotomy

Stenosis distal AA/isthmus:
REEEA/ AscDescA

Stenosis prox/complete AA:
Curved patch

Lack of autologous material:
Subclavian flap/ aortic autograft
(Exception, only adolescents: interposition graft)
Recurrent AA obstruction
N=39

Isolated AA pathology
N=12
- Sternotomy N=9
  - WBP N=7
  - ACP N=2
- Lateral thoracotomy N=2
  - Left heart bypass N=1
  - No bypass N=1
- Both N=1
  - WBP N=1

Biventricular complex
N=18
- Sternotomy N=17
  - WBP N=15
  - ACP N=2
- Lateral thoracotomy N=1
  - Left heart bypass N=1

Univentricular
N=9
- Sternotomy N=9
- WBP N=9

Patch plasty
N=4
- AscDescA/REEEAAutograft N=5
- REEEA N=1
- Interposition graft 20mm N=1
- Subclavian flap/Patch plasty N=1
- Patch plasty N=9
- AscDescA/REEEAAutograft N=8
- Interposition graft 20mm N=1
- REEEA N=6
- Patch plasty N=3
# Anatomic Repair of Recurrent Aortic Arch Obstruction

## Patients

**Indication:** Recurrent/residual aortic arch obstruction → **SURGICAL ANATOMIC REPAIR**

N=39  
Median age 253 (100; 2198) d  
Whole body perfusion n=32 (82%)

## Results

**Follow-up:** Median 8.1 [2.6;12] years  
- Mortality: 3 patients (8%, no death due to an AA complication)  
- Re-re-intervention: 1 patient (3%)  
- Gradient under surveillance: 3 patients (8%)

## Implications

- Sophisticated reoperations on the AA can be performed safely.  
- Whole body perfusion may be a helpful tool.  
- In children, the growth potential can be sustainably preserved by avoiding interposition or extra-anatomic aortic bypass grafts.

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*AA, aortic arch*