

# Surgery for congenital coarctation of the aorta in Icelandic children 1990–2006

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**Background and aims:** Coarctation of the aorta (CoA) is a congenital narrowing of the aorta, distal to the origin of the left subclavian artery. Treatment consists of surgical excision but balloon angioplasty is also a treatment option in selected patients. The aim of this study was to evaluate surgical outcome for children who underwent surgery for CoA in Iceland.

**Material & methods:** All Icelandic children (<18 yrs) who underwent surgery for CoA in Iceland between 1990 and 2006. Patients undergoing surgery abroad (n=17) or managed conservatively (n=12) were excluded. The mean follow-up period was  $8.5 \pm 4.3$  years.

**Results:** Of 67 children diagnosed with CoA, 38 underwent surgery in Iceland (mean age  $36 \pm 58$  months, 22 male, 16 female patients), 10 required immediate surgery for cardiac failure and eight were diagnosed incidentally. Extended end-to-end anastomosis was the most common procedure (n=31). Subclavian-flap aortoplasty was performed in seven patients. The average operation time was 134 min. and mean aortic closure time was  $21 \pm 9$  min. Hypertension (58%) and heart failure (11%) were the most common postoperative complications. Recoarctation developed  $35 \pm 56$  months after surgery in seven patients (18%) and was successfully treated with balloon angioplasty. There were no operative deaths and no patients developed paraplegia. One patient suffered an ischemic injury to the brachial plexus. Today all of the patients are alive, except for one patient who died four months after surgery from heart failure.

**Conclusion:** The majority of Icelandic children with CoA undergo surgery in Iceland with an excellent outcome, both regarding short-term complications and long-term survival.

## Introduction

Coarctation of the aorta (CoA) is a common congenital heart defect, and represents 3.8% of heart defects in Iceland.<sup>1</sup> It is a narrowing of the aorta that usually occurs in the region immediately distal to the origin of the subclavian artery, where the ductus arteriosus connects to the artery at the

foetal stage. Approximately 50% of patients with CoA have associated cardiac lesions, bicuspid aortic valve being the most common. Around 25% of the patients have extracardiac birth defects.<sup>2</sup> The condition can occur in conjunction with chromosomal defects such as Turner's syndrome.<sup>3</sup> However, most cases are sporadic with many steps in the pathogenesis of the disease poorly defined.<sup>4</sup>

The clinical presentation of CoA is variable, depending on the severity of the obstruction. Infants are often diagnosed with heart failure or reduced blood flow to lower limbs. On the other hand, older children and adults are more often diagnosed due to fatigue in the lower limbs or because of headaches that can be traced to hypertension in the upper part of the body.<sup>5</sup> Femoral pulses are generally weak and a bruit is often heard over the chest and on the back. Ultrasound and Doppler are the mainstays of diagnosis and confirmation of CoA. If ultrasound is not conclusive, angiography was usually performed to confirm the diagnosis, but in recent years this technique has been replaced by magnetic resonance imaging (MRI).<sup>6</sup> It is possible to diagnose CoA at the foetal stage, but such a diagnosis is a challenge.<sup>7</sup>

Treatment of CoA usually consists of surgical resection of the coarctation with an end-to-end anastomosis of the aorta. In the last decade, balloon angioplasty, with or without a stent, has become an option for the treatment of these patients. Balloon angioplasty has mainly been applied for re-coarctation after surgery, but is used increasingly as a first treatment choice.<sup>8</sup>

In Iceland, epidemiological research has been carried out on children with congenital heart diseases where, amongst other things, the incidence of CoA has been reported.<sup>1</sup> Research on the surgical outcome on congenital heart defects has not, however, been published in Iceland. The aim of this study was to investigate the results of surgery for CoA in Iceland over a 17-year period, with particular emphasis on early-onset complications and survival.

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**Table I.** Concomitant congenital heart defects in 38 children that underwent surgery for aortic coarctation in Iceland 1990–2006 (number, percentage in parenthesis).

	n (%)
Bicuspid aortic valve	25 (65.8)
Ventricular septal defect	12 (31.5)
Patent ductus arteriosus	11 (28.9)
Hypoplastic aortic arch	8 (21.1)
Mitral valve regurgitation	4 (10.5)

### Materials and methods

Over the research period, which extended from 1 January 1990 to 31 December 2006, 67 Icelandic children were diagnosed with CoA in Iceland, 43 boys and 24 girls (ratio boys/girls 1.8,  $p=0.03$ ). Of these 67 children, 38 underwent surgery in Iceland, 22 boys and 16 girls, and form the patient material of this study. The average age at surgery was  $35 \pm 58$  months; the youngest child was three days old and the oldest individual 17 years. Seventeen patients who underwent surgery overseas during the same period were not included, likewise 12 patients with asymptomatic CoA who did not undergo surgery and were treated conservatively.

Cases were identified through a diagnosis and surgery registry at Landspítali and information on patients was obtained from medical records. The following data were recorded: age, other congenital defects, symptoms, signs and method of diagnosis, indication for surgical treatment, type and duration of operation, aortic closure time (cross clamp time), complications during and after surgery, and the outcome for patients, including crude survival. Operative mortality was defined as death within 30 days of the operation.

**Table II.** Presenting symptoms and signs for 38 children, divided by age at diagnosis, that were operated on for CoA in Iceland 1990–2006. Patients can have more than one symptom (number of patients).

	< 1 year (n=22)	≥ 1 year (n=16)	Total (n=38)
<b>Symptom</b>			
Dyspnea on rest	14	2	16
Fatigue on exercise	0	7	7
Lethargy / irritability	6	2	8
Perspiration	5	1	6
Headache	0	2	2
No symptoms	3	5	8
<b>Sign</b>			
Systolic murmur	17	16	33
Weak/absent femoral pulses	17	15	32
Heart failure	12	0	12
Blood pressure mismatch	11	11	22
Hepatomegaly	7	0	7
Hypertension	3	8	11

Re-coarctation after surgery was defined as  $>20$  mmHg pressure gradient (measured with Doppler) across the end-to-end anastomosis of the aorta. Paradoxical (or early postoperative) hypertension was defined as severe hypertension ( $>35$  mmHg increase in systolic pressure) during the first week after surgery. Such paradoxical hypertension frequently requires intensive antihypertensive therapy but usually resolves after several days.

The operations were performed through left lateral thoracotomy, usually between the 3<sup>rd</sup> and 4<sup>th</sup> rib bones. Clamps were placed on both sides of the coarctation, and the coarctation then resected. Usually an extended end-to-end anastomosis was used to connect the aortic ends but in complex cases a *subclavian flap* aortoplasty was used. An extracorporeal circulation (ECC) only had to be used in one instance (see below). Patients were kept in intensive care overnight but were then moved to a paediatric ward.

It was noted whether the patients were still alive according to Statistic Iceland's National Register on 31 March 2009 (crude survival). The follow-up time was on average  $9.7 \pm 4.2$  years. The Student t-test and Fisher/Exact test were used to compare groups, with the significance level considered as  $p<0.05$ .

Before the research started, all necessary permits were obtained from the Landspítali Ethics Committee, the Icelandic Data Protection Authority (Persónuvernd) and the Chief Executive of Landspítali.

### Results

Of 38 children who underwent surgery in Iceland, two had a positive family history of CoA (first or second degree relatives). Four children were diagnosed with CoA as part of a syndrome: two with Turner syndrome and one each with Arnold-Chiari and Williams syndromes. Concomitant congenital heart defects were diagnosed with 33 patients (86.8%), of which bicuspid aortic valve, ventricular septal defect and patent ductus arteriosus were the most common. A summary of concomitant heart defects and their frequency is shown in table I.

The main symptoms are shown in table II. Of 22 children under one year of age, 19 (86.4%) were diagnosed due to symptoms of CoA, usually because of dyspnea and weakness. With older children ( $\geq 1$  year) 7 out of 16 (43.8%) were diagnosed due to fatigue on exercise, mainly in the lower limbs. The most common signs in both groups were a systolic murmur and an absent or attenuated femoral pulse. Other signs are shown

in table II. Eight children (21.1%) were diagnosed incidentally, five of whom were older than one year. The most common reason for incidental diagnosis was a weak femoral pulse that was discovered during well-baby care. One case was diagnosed prenatally when ultrasound was performed at the 20<sup>th</sup> week of pregnancy. Many of the children turned out to have an enlarged heart on a chest X-ray and signs of an enlarged ventricle on electrocardiography. Rib notching was seen on a chest X-ray in two children (fig. 1).

Diagnosis was confirmed by ultrasound in all cases. Ten patients, most often the older ones, also went for angiography and one for magnetic resonance imaging (fig. 2). In 30 cases (83.3%) the coarctation was located distal to the left subclavian artery but with 6 children just proximal to it. In two patients there was no information about the location of the coarctation.

The pressure gradient across the coarctation was on average  $49 \pm 13$  mmHg (range 25–83) before surgery and  $12 \pm 8$  mmHg (range 0–30) after surgery ( $p < 0.001$ ).

The commonest operation was extended end-to-end anastomosis, carried out on 31 patients, while *subclavian-flap* repair was done on 7. The operations took an average of  $134 \pm 39$  minutes (range 80–260) and cross clamp time was  $21 \pm 7$  minutes (range 11–35). Ten patients (26%) had an emergency operation, usually because of severe heart failure and shock; their mean age was 11 days (range 3–25 days). A heart and lung machine (ECC), connected to the groin for a total of 109 minutes, only had to be used in one case. This was for a 17-year-old boy who was also the only case in which an artificial vascular graft (Hemashield®) had to be used.

Complications during surgery were observed in two patients, bleeding in one of them and lymphatic vessel leakage in the other. Table III shows postoperative complications, the most common of which were paradoxical hypertension ( $n=22$ ) and recoarctation ( $n=7$ ). One child received



**Figure 1.** Chest X-ray of a 17 year old boy who was incidentally diagnosed with CoA. Characteristic rib notches are seen bilaterally (arrows).

by mistake an intravenous life-threatening dose (17.2 mg/kg) of labetalol, but survived without complications<sup>9</sup>. None of the patients were paralysed in the lower limbs after surgery and none received damage to the left recurrent nerve or phrenic nerve. One patient who underwent a *subclavian flap* repair received damage to the left brachial plexus that caused impaired mobility in the left arm. Recoarctation was diagnosed on average 35 months  $\pm$  50 (range 0.5–145) after surgery and the average age of the children then was 5.5 months  $\pm$  13.6 (range 0.1–36). All cases of recoarctation were treated with balloon angioplasty. None of the patients had to undergo a second operation due to recoarctation but one child underwent re-do surgery because of aortic aneurysm, which was diagnosed after balloon angioplasty.

The median hospital stay was 9 days, or from



**Figure 2.** A magnetic resonance imaging (sagittal view) of the boy from fig. 1, showing a coarctation of the aorta (arrow), distal to the left subclavian artery.

**Table III.** Postoperative complications for 38 patients that were operated for CoA in Iceland between 1990–2006 (number, percentage in parenthesis).

	n (% , n=38)
Paradoxical hypertension	22 (57.9)
Recoarctation	7 (18.4)
Heart failure	4 (10.5)
Pneumonia	3 (7.9)
Bleeding	2 (5.3)
Injury to the brachial plexus	1 (2.6)
Wound infection	1 (2.6)

**Table IV.** Results of surgical treatment for CoA, comparison of selected studies.

Study (year)	No. of patients	Age	Study period	Op. mortality (< 30 d, %)	Mean follow-up (yrs)	Rate of re-coarctation (%)
Cohen et al. (1989)	646	Allir	1946-1981	3	20	3
Kappetein et al. (1994)	109	< 3 yrs	1953-1985	32	16,7	41
Beekman et al. (1986)	125	< 1 yr	1960-1985	NA	5	14
Høimyr et al. (2006)	229	All	1965-1985	6	27	5
Smith Maia et al. (2004)	103	< 14 yrs	1970-1996	NA	5	14
Knott-Craig et al. (1993)	111	< 1 mo	1973-1991	14	4,2	20
Backer et al. (1995)	125	All	1979-1993	3	4,5	8
van Heurn et al. (1994)	151	< 3 mo	1985-1990	8	4	19
Quagebeur et al. (1994)	322	< 1 mo	1990-1991	15	1,2	7
Wright et al. (2005)	83	< 1 mo	1990-2000	1	4,5	6
Backer et al. (1995)	55	< 1 mo	1991-1997	2	3,3	4
Present study	38	< 18 yrs	1992-2006	0	8,5	18

NA = information not available

4 up to 127 days. All of the patients survived the operation, and on 31 December 2007 all children were still alive apart from one. This child died four months after surgery due to heart disease (Shone's anomaly). The one-year crude survival was thus 100% and 97.3% after five years.

### Discussion

This study shows that surgery for CoA is a safe procedure and the frequency of complications is low. All the children survived the operation and were discharged. During follow up, only one child had died due to heart failure.

Our results are very similar to other comparable studies; the main ones are shown in table IV. This table shows that operative mortality is generally in the range of 1-14%<sup>10-20</sup> but was 0% in this study. While comparing this study to other series, it must be kept in mind that 17 of the Icelandic children had complicated CoA and were sent abroad for surgery and thus not included. This group included children with other serious heart and birth defects where operative mortality can be as high as 32%<sup>11,18</sup>. Therefore, our study does not extend to all of the cases that were diagnosed in Iceland during this 17-year period, but rather only to cases in which surgery was performed in Iceland.

Post-operative complications were usually minor. Bleeding and infections were uncommon (<3%) and lymphatic vessel leakage, which arose due to leakage from the thoracic duct, was only seen in one case. In another case there was damage to the brachial plexus, probably related to ischemia causing impaired mobility to the left arm. This is a rare complication but has been described before

<sup>21</sup>. Injury of either the left recurrent nerve or the phrenic nerve was not observed and none of the children were diagnosed with a spinal chord injury and paraplegia. Paraplegia is one of the most serious complications related to surgery, its frequency being about 0.4% in other studies<sup>22</sup>. The cause is impaired blood flow to the spinal chord when the aorta is clamped during surgery. Thus an attempt is made to shorten the cross clamp time. In this study cross clamp time was only 21 minutes, which is similar or shorter compared to other studies<sup>23,24</sup>. In more complex cases it may be possible to use a shunt and direct flow over the coarctation, or use a heart and lung machine (ECC) that is connected to the groin and sustains blood flow for the lower part of the body. An ECC only had to be used once: on a 17-year-old patient with a complex CoA where a vascular graft had to be used for connecting the aorta.

More than half the patients suffered from severe hypertension in the first few days after the operation, but the condition had resolved within a week from the operation with all patients. This is a well-known complication, called *paradoxical* or *early postoperative hypertension*. The increase in blood pressure appears to be seen primarily after operations and less often with balloon angioplasty<sup>25</sup>. Often a considerable increase in blood pressure is involved that usually responds well to treatment<sup>26</sup>. The cause of the complication is yet to be identified, but both the sympathetic nervous system and the renin angiotensin system have been implicated in the pathogenesis of paradoxical hypertension.

Chronic hypertension is a common problem with these patients. In an Italian study, almost 70% of patients were diagnosed with hypertension 30 years after surgery<sup>28</sup>. In our study accurate

information on chronic hypertension and its frequency was not available for many cases. Patient records from Landspítali were the main source used, and occasionally data from paediatric out-patient clinics. However, chronic hypertension has been studied in another Icelandic study where exercise-induced hypertension was more common in patients who were older than one year when they underwent surgery<sup>29</sup>. The reasons for long-term hypertension after surgery are not understood, but the frequency appears to increase when the operation is carried out later in life. It is important to exclude recoarctation in these patients, as hypertension can be one of the symptoms of recoarctation<sup>3</sup>.

Recoarctation was diagnosed in 18% of the patients, on average 35 months from the operation. For comparison, the frequency in most other series is in the range of 3-14%, though studies exist where the frequency is up to 41%<sup>11</sup> (table IV). Risk factors for recoarctation are a young age of surgery (< 1 year) and a hypoplastic aortic arch<sup>30</sup>. In our study, 8 children had isthmus or arch hypoplasia and two of them were diagnosed with recoarctation. Six patients (35%) under one year of age suffered recoarctation after surgery but only one (5%) who underwent surgery after one year of age. The difference is significant ( $p=0.02$ ) but it must be kept in mind that other factors beside age can explain this difference. For instance, younger children more often had severe CoA and some also had an under-developed isthmus or hypoplastic aortic arch. *Subclavian flap* repairs are often resorted to in these cases, but several studies have shown a higher frequency of recoarctation with these than after extended end-to-end anastomosis<sup>31</sup>, though with some exceptions<sup>28</sup>. In this study, 3 out of 7 patients with *subclavian flap* repair got recoarctation (43%) but only 4 out of 31 (13%) who had extended end-to-end anastomosis ( $p=0.09$ ).

In all cases, repair of the recoarctation with balloon angioplasty was successful, and without early-onset complications. One patient had an aneurysm as a late-onset complication, three years after angioplasty. This is a known complication and occurs in approximately 5% of cases after angioplasty for recoarctation<sup>32</sup>.

In Iceland, like in most of our neighbouring countries, surgery has been considered the treatment of choice for CoA. Balloon angioplasty has then been used for recoarctation or as an alternative for primary CoA. Recently angioplasty is being used increasingly often as a first treatment. Balloon angioplasty with stent insertion is also being more common as a treatment for primary CoA. In Iceland, angioplasty has been applied as a

first treatment in only one case. This was the case of a teenage girl, and the treatment was successful. It is difficult to compare the results of surgery with angioplasty, as most studies have few patients. In addition, there is a lack of randomised trials and thus a risk of selection bias<sup>33-35</sup>. The mortality rate seems to be somewhat lower after angioplasty (<1%) than for open surgery (<2%), at least for isolated CoA<sup>3, 36</sup>. Serious complications such as recoarctation and aortic aneurysm are, on the other hand, more common after balloon angioplasty<sup>33, 37</sup>.

Today, surgery is considered the treatment of choice for children with CoA in the first 6 months of life<sup>38</sup>. These children often have complicated heart defects and are therefore treated surgically as soon as possible. Angioplasty can, though, be used as an alternative treatment, e.g. for children who are not thought to survive an operation. After 6 months of age and up to 5 years, angioplasty is more of a possibility, as it has been shown that the frequency of recoarctation (10-15%) and formation of aneurysms at the site of recoarctation (5-7%) is similar to after surgery<sup>39, 40</sup>. Angioplasty with a stent insertion is then considered an option for older children and teenagers (>25 kg), although it is not yet clear what the long-term success of stent treatment is.

Whether angioplasty treatment will increase at the cost of surgery will be clarified in the coming years. Our results show that the results of surgical treatment are very good and new treatment options will have to be compared to the success of surgery. Therefore, today, surgery continues to be a valid option for the treatment for CoA.

**Conclusion:** Over half of children with CoA underwent surgery in Iceland. Children with complicated CoA were treated abroad. The surgical outcome is very good in Iceland, both in terms of complications and long-term survival. Balloon angioplasty has proved successful for the treatment of recoarctation after surgery.

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