

# Surgical repair of coarctation of aorta in adults under left heart bypass

*Correção cirúrgica da coarctação da aorta em adultos sob assistência circulatória extracorpórea esquerda*

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## Abstract

**Objective:** To describe our experience with repair of coarctation of the aorta in adults using left heart bypass.

**Methods:** From November 2007 to October 2009, eight adult patients with coarctation of the aorta underwent surgical repair under circulatory support using a left atrium to femoral artery bypass circuit, with graft interposition tube through left posterolateral thoracotomy. Five patients were female, with mean age of  $31.5 \pm 13.1$  years. All patients had hypertension and others associated cardiovascular diseases.

**Results:** There were no deaths or neurological complications. The mean surgical time was 308 minutes with mean left heart bypass and distal aortic clamping time of 73 and 65 minutes respectively. Postoperative bleeding was 696 ml in average. Six patients developed severe hypertension postoperatively requiring intravenous vasodilators. The mean length of stay was 9 days. A significant reduction of gradient blood pressure occurred. Echocardiographic follow-up up to two months postoperatively showed mean aortic / graft gradient of 20.3 mmHg.

**Conclusion:** In this series the use of left heart bypass

showed to be a safe option in the surgical correction of coarctation of the aorta in adults, especially in patients with abnormal aortic wall. There was no spinal cord ischemia in the cases studied.

**Descriptors:** Aortic coarctation. Heart bypass, left. Paraplegia. Adult.

## Resumo

**Objetivo:** Descrever a experiência do serviço com a correção da coarctação da aorta em adultos utilizando assistência circulatória esquerda.

**Métodos:** De novembro de 2007 a outubro de 2009, oito pacientes adultos com coarctação da aorta foram submetidos a correção cirúrgica com interposição de enxerto tubular através de toracotomia póstero-lateral esquerda e uso de assistência circulatória com uso de circuito átrio esquerdo e artéria femoral. Cinco pacientes eram do sexo feminino e tinham idade média de  $31,5 \pm 13,1$  anos. Todos tinham hipertensão arterial sistêmica (HAS) e apresentavam doenças cardiovasculares associadas.

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#### Abbreviations, Acronyms & Symbols

ECC	extracorporeal circulation
CA	coarctation of the aorta
SAH	systemic arterial hypertension
DBP	diastolic blood pressure
SBP	systolic blood pressure

**Resultados:** Não houve óbitos ou complicações neurológicas. O tempo médio cirúrgico foi de 308 minutos, o tempo médio de assistência circulatória de 73 minutos e o de pinçamento aórtico médio de 65 minutos. O sangramento médio no pós-operatório foi de 696 ml. Seis pacientes

## INTRODUCTION

The coarctation of the congenital aorta (CoA) is a disease whose natural history was significantly altered by surgical correction in childhood [1], providing significant improvement in the expectation and quality of life of patients [2]. In addition to congenital coarctation, inflammatory diseases such as Takayasu's arteritis (or reversed coarctation) are important causes of aortic stenosis [3]. Several surgical techniques have been used, but they have limitations and specific applications [2].

The correction in adulthood has peculiarities, mainly due to the presence of comorbidities such as systemic arterial hypertension (SAH), severe calcification of the stenosed area and proximity, changes in the aortic wall [1,4], and other associated heart diseases (patent ductus arteriosus, ventricular septal defect, aortic valve changes and others) [5]. The risk of paraplegia is significantly higher in adolescents, adults and re-coarctations, with an incidence of 2.6% [6], especially when the collateral circulation is poor. The use of extracorporeal circulation (CPB) for correction of aortic coarctation can help maintain spinal cord perfusion during aortic clamping [7]. Thus, this study aims to describe the experience with the surgical correction of aortic coarctation in adult patients using extracorporeal circulatory assistance through circuit between the left atrium and femoral artery.

## METHODS

Eight adult patients aged between 23 and 62 years were operated from November 2007 to October 2009, (mean 31.5 ± 13.1 years), in which 5 of them were female. Six patients had echocardiographic and angiographic diagnosis of aortic coarctation, generating pressure gradient (mean 71.5 ± 20.7 mmHg) and two had total disruption of the thoracic

evoluíram com HAS grave no pós-operatório, sendo necessário uso de vasodilatadores endovenosos. As altas hospitalares ocorreram em média no 9º dia pós-operatório. Houve redução significativa do gradiente médio da pressão arterial sistêmica. O seguimento ambulatorial com ecocardiograma até dois meses de pós-operatório demonstrou gradiente aorta/enxerto médio de 20,3 mmHg.

**Conclusão:** O uso da assistência circulatória esquerda pode ser uma opção na correção cirúrgica da coarctação da aorta em adultos, principalmente em pacientes com alterações parede da aorta, não sendo observada isquemia medular nos casos estudados.

**Descritores:** Coarctação aórtica. Derivação cardíaca esquerda. Paraplegia. Adulto.

aorta to the level of the stenosed area. All patients had hypertension and were in regular use of antihypertensive medications. One patient had left ventricular dysfunction (according to guidelines of heart failure) [8]. Some patients had associated cardiovascular diseases (aneurysm of the aorta, bicuspid aortic valve without dysfunction, pulmonary hypertension, patent ductus arteriosus, subaortic stenosis, Takayasu's arteritis). One patient was diabetic.

Systolic blood pressure (SBP) measured in the preoperative period in the right upper limb ranged from 120 to 200 mmHg (mean 160 ± 25.6 mmHg) and diastolic blood pressure (DBP) 80-110 mmHg (mean 95 ± 9,2 mmHg). Demographic characteristics of all preoperative patients are shown in Table 1.

The study was descriptive, with all cases operated at Presidente Dutra University Hospital (São Luis, Maranhao, Brazil), being authorized by the Research Ethics Committee, without identification of the patients studied and no attitudes concerning the authors that were characterized as conflict of interest.

Data were analyzed using the software BioEstat ® 5.0 by calculating the mean and standard deviation. The systolic and diastolic blood pressures and systolic gradients through the coarctation before and after correction were compared using the paired Student's t-Test, in which *P* value was considered significant when less than 0.05.

## Surgical technique

We used the same surgical procedure in all cases, with the patient under general anesthesia using a selective double lumen cannula in the airway and exposure of the left inguinal region. We performed a left posterolateral thoracotomy at the fourth intercostal space. The aortic arch, left subclavian artery, the area of coarctation and the

Table 1. Preoperative characteristics of patients operated for aortic coarctation, in chronological order.

Patients	Gender	Age (years)	Associated Diseases	EF (%)	Ao Gradient (mmHg)	Preoperative AP (mmHg)
1	Female	62	Thoracic aortic aneurysm, diabetes	63	51	160x100
2	Female	24	Thoracic aortic aneurysm	61	75	180x100
3	Female	28	BAV	73	52	120x80
4	Male	23	Mild subaortic stenosis	75	62	150x90
5	Female	28	BAV, PDA, thoracic aortic aneurysm, severe PAH	50	110	200x110
6	Male	36	BAV, LVD	40	94	180x100
7	Male	22	Interruption of the descending aorta	66	70*	150x90
8	Female	29	Takayasu's arteritis, interruption of the descending aorta, abdominal aortic aneurysm	80	60*	140x90

BAV = bicuspid aortic valve, PDA = patent ductus arteriosus; PAH = pulmonary arterial hypertension, LVD = left ventricular dysfunction; Ao Gradient = pressure gradient between the aorta and the post-coarctation area; \* = estimated by the difference in SBP between upper limb and femoral artery in the intraoperative period.

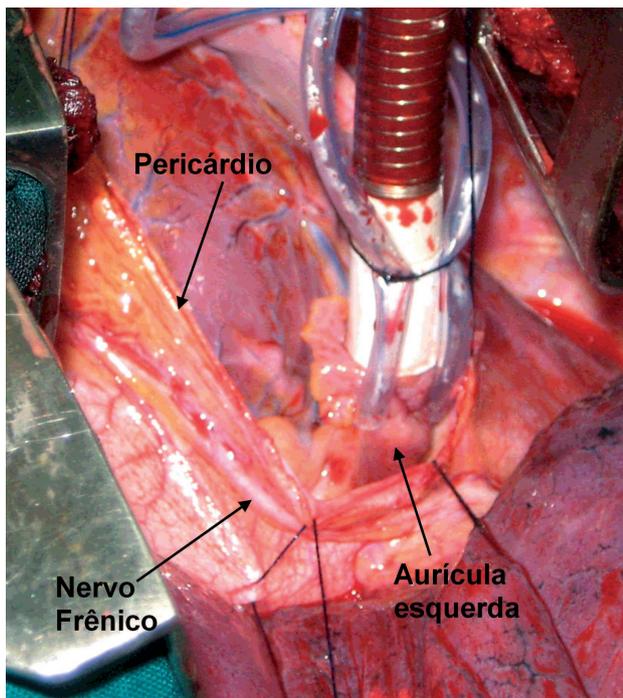


Fig. 1 - Pericardiotomy and left atrial cannulation; Phrenic nerve (Nervo Frênico); Left auricle (Aurícula esquerda); Pericardium (Pericárdio)

descending aorta were carefully dissected and mobilized, as well as the isolation of adjacent lumbar branches and exposure of the left femoral artery. The pericardiotomy was performed through a parallel incision to the phrenic nerve. Heparin was administered systemically (4 mg / kg) followed by cannulation of the left auricle (Figure 1) and the left femoral artery (Figure 2). Left circulatory assistance was initiated maintaining the blood supply to the descending aorta through the left femoral artery using a peristaltic pump without the use of a membrane oxygenator. The aorta was

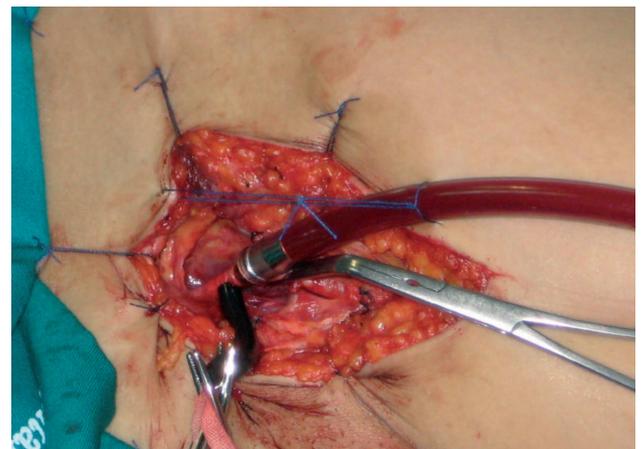


Fig. 2 - Cannulation of the left femoral artery

clamped at first in conjunction with the proximal left subclavian artery and then the distal portion of the defect. The ventilation was selectively maintained during blood deviation. During the procedure, blood pressure was maintained without difficulty on the average of 60 mmHg by restricting the drained blood (partial drainagel) of the left atrium. The flow of the roller pump was maintained according to the pre-pressure monitoring cannula in the femoral artery above 50 mmHg. The temperature was maintained during surgery around 36.0° C. The segment was replaced by Dacron tube (16 mm to 18 mm) ranging from 6 cm to 10 cm long, sutured with a 4.0 polypropylene wire, and the use of hemostatic biological glue in some cases (Fig. 3). We tried to preserve, wherever possible, the branches that irrigated the spinal cord. We conducted distal and proximal declamping and removal of the atrial and femoral cannulae, followed by heparin reversal.

Table 2. Evaluation of postoperative patients operated for aortic coarctation, in chronological order.

Patients	Surgical Time (min)	CAT (min)	C-time (min)	Tube (mm)	Discharge (dias)	Ao Gradient (mmHg)	Postoperative AP (mmHg)	PO complications
1	360	80	75	18	6° PO	31	130x90	---
2	300	70	65	18	7° PO	18	100x60	SAH, hoarseness
3	240	45	41	18	7° PO	23	100x70	SAH
4	280	80	59	18	7° PO	10	120x70	SAH
5	310	75	60	16	9° PO	37	130x80	SAH, Chronic pain
6	300	65	61	18	26° PO	15	110x60	AF, SAH, fever with positive HMC
7	320	75	69	18	6° PO	16	130x80	---
8	360	100	90	18	4° PO	13	140x90	SAH

CAT = circulatory assistance time; C-time = aortic clamping time; Ao Gradient = pressure gradient between the aorta and graft, PO Complications = postoperative complications; AF = atrial fibrillation; HMC = hemoculture

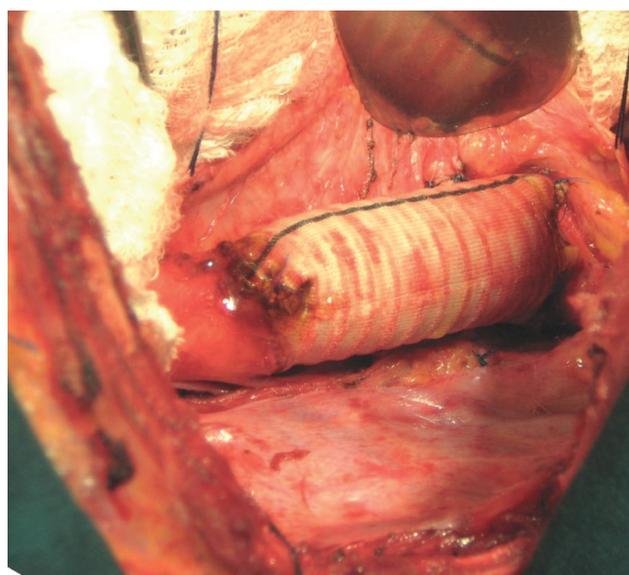


Figure 3 - Corrected aortic coarctation with Dacron tube

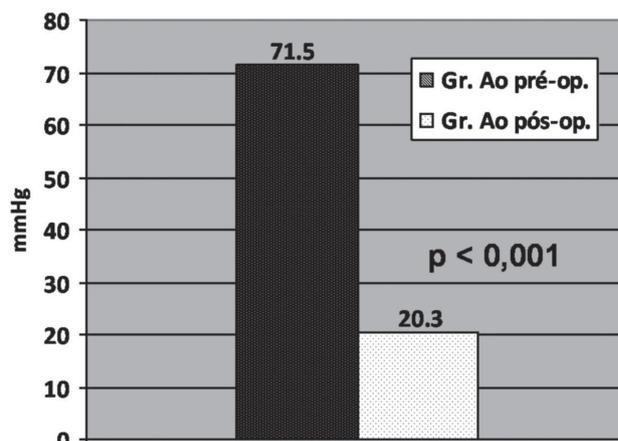


Fig. 4 - Comparison of aortic pressure gradients in the preoperative period (Preoperative Ao Gradient) and in the postoperative period (Postoperative Ao Gradient);  $P = 0.0019$  (SBP);  $P = 0.0023$  (DBP)

## RESULTS

Table 2 shows the main variables in the surgical repair of aortic coarctation. The average time of surgery was  $308 \pm 39.7$  minutes, the mean circulatory assistance of  $73 \pm 15.5$  minutes and aortic cross-clamping was  $65 \pm 14.1$  minutes. They were discharged from the ICU between the 2<sup>nd</sup> and 3<sup>rd</sup> postoperative day, with six patients who develop severe systemic arterial hypertension, necessitating the use of intravenous vasodilators. There were no deaths or neurological complications. One patient had transient hoarseness.

The hospital discharges occurred between the 4<sup>th</sup> and 26<sup>th</sup> postoperative days, with an average of  $9 \pm 7.0$  days.

Only one patient had their hospital stay after surgery due to increased bacteremia and made use of intravenous antibiotics.

The follow-up period with echocardiography performed up to the 2<sup>nd</sup> postoperative month showed good surgical results in all cases, only two patients with aortic / graft gradient greater than 30 mmHg (mean =  $20.3 \pm 9.3$  mmHg) (Figure 4). A patient with chronic pain in the wound was referred to outpatient clinic specialized in pain.

The SBP in postoperative period was 100 to 140 mmHg (mean  $120 \pm 15.1$  mmHg) and DBP was 60-90 mmHg (mean  $75 \pm 11.9$  mmHg) (Figure 5).

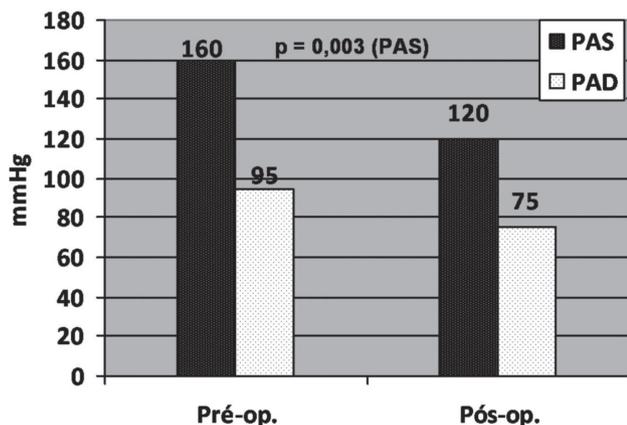


Fig. 5 - Comparison of systolic blood pressure (PAS) and diastolic (PAD), means in the preoperative and postoperative periods;  $P = 0.003$  (PAS);  $P = 0.003$  (PAD);  $P < 0.001$

## DISCUSSION

Aortic coarctation is a congenital malformation that can lead to premature death if not treated without correction, with 50% mortality without treatment at the age of 30 years, 75% at 46 years and 90% at 58 years [9]. Inflammatory diseases such as Takayasu's arteritis (reversed coarctation) also involve the aorta and its branches, which may lead to stenosis or obstruction [10]. Surgery in older patients differs from the standard repair of coarctation in children, mainly due to severe calcification of the distal aortic arch and left subclavian artery [4].

Paraplegia is a devastating complication after the correction of the aortic coarctation, with an overall incidence of 0.3% to 1.5%. The prevention of paraplegia should always be decisive in the mind of the surgeon every time the surgery is performed, especially in adult patients [11], which the incidence of paraplegia almost doubles [6]. The lack of development of collaterals that provide an adequate supply to the spinal cord can be determined by clinical circumstances as: primary mild aortic coarctation, recurrent coarctation after surgery (with or without aneurysm), origin of the distal subclavian artery to the coarctation and coarctation after inadequate balloon dilation or stent placement by interventional [12].

Several techniques of circulatory deviations have been employed during surgical procedures on the thoracoabdominal aorta over the years in an effort to prevent distal ischemia of the spinal cord [13]. Studies have shown benefits in spinal cord protection in surgery of temporary interruption of the aortic blood flow when the circulatory assistance is installed [12,14]. In our series, there were no neurological complications, despite the limited

sample.

The aortic coarctation present until adulthood is uncommon, being observed by Bouchart et al. [9] annual average of 1.75 adult patients operated in 20 years, being more prevalent in males (2 to 3:1) [15]. Wong et al. [6], between 1997 and 2000, underwent correction of nine cases of aortic coarctation using extracorporeal circulation, but only 3 patients were 18 years old or more. In our series, there was a greater female predominance and the presence of eight cases of coarctation in adults over a period of two years can be explained by the difficulty of early diagnosis in the region.

The pre-cannula pressure in the distal aorta was maintained above 50 mmHg, according to Hughes and Reemtsma analysis [16], which recommended a safe perfusion pressure in the distal aorta above this value.

Carr et al. [17], assessing the correction of aortic coarctation in 45 adolescents and young adults, reported a mean operative time of  $3.8 \pm 0.7$  hours (228 min) and average clamping time of  $31 \pm 15$  min, and in five patients of his series, extracorporeal circulation was used. The increased surgery duration in the study presented was mainly due to the time of preparation for circulatory support and technical difficulties, arising especially from the aortic wall calcifications, and presence of large collateral circulation, mobilizing more time consuming areas of aneurysmal inflammatory adhesions, besides corrections of bleeding in the suture.

Von Oppell et al. [18] published a meta-analysis of spinal cord protection in patients with acute traumatic aortic transection, a situation where adequate collateral circulation to the spinal cord is often insufficient. These authors demonstrated that: simple aortic clamping and clamping time longer than 30 minutes were associated with increased risk of paraplegia and left extracorporeal circulatory support provided greater protection of the spine when compared to techniques of passive perfusion.

In aortic coarctation, the previous evidence or unknown risk of spinal cord ischemia encourage the surgeon to minimize the time of spinal cord ischemia [19], especially in cases of the techniques without the use of active perfusion. In the group of Wong et al. [6], the three patients who were operated with ECC had clamping time from 35 to 49 min. In our study, the clamping time was longer, but a similar study using extra-anatomic technique with conventional ECC [20]. Another benefit noted was the well-being provided in the correction of aortic surgical complications, because the surgeon has the concept that distal perfusion may help to minimize the time of spinal cord ischemia. The SAH, even in the corrected aortic coarctation, is the most frequent cause of morbidity and mortality with advancing age [9]. The series studied always showed reduction in blood pressure in the postoperative period, with most patients requiring the use of antihypertensive drugs

[4,9,17]. In the group evaluated, there were a significant reduction ( $P < 0.05$ ) of systolic and diastolic blood pressures, with all patients using antihypertensive drugs at hospital discharge and in a short-term follow-up period.

## CONCLUSION

Surgical correction of aortic coarctation in adults with use of extracorporeal circulatory support in the left atrium and femoral artery may be an option in the prevention of spinal cord ischemia, especially in cases with need for longer aortic clamping time, as patients with abnormal aortic wall or cardiovascular associated diseases, showing minimum rates of complications. However, the main disadvantage was the time of surgery greater than in other techniques without extracorporeal circulation, in addition to the disadvantages of the installation of extracorporeal circuit, which is well established in literature. A multicenter study is necessary to evaluate real advantages of circulatory assistance in the prevention of paraplegia in aortic coarctation in adults, since its incidence is low.

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