

## Key Points and Challenges in Management of Coarctation of Aorta in Pediatrics: Review Article

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### ABSTRACT

**Background:** One of the most prevalent causes of shock and mortality in newborns is coarctation of the aorta (CoA). Because there are no audible murmurs and the blockage from the coarctation does not emerge for several days after birth, it may be the most difficult kind of serious congenital heart disease (CHD) to detect. Despite the ease of clinical diagnosis, pediatric patients often go undetected since they are often asymptomatic.

**Objective:** This review aimed to highlight the key points and challenges in management of COA in pediatrics.

**Methods:** We searched PubMed, Google Scholar, and Science Direct using the following keywords: Balloon dilatation, stent, coarctation of the aorta, and patent ductus arteriosus. The writers also assessed references from pertinent literature and they only included the most current or comprehensive study. Documents in languages other than English had not been included since there are insufficient sources available for translation. They excluded unpublished manuscripts, oral presentations, conference abstracts, and dissertations where they were not considered part of the scope of important scientific inquiries.

**Conclusion:** The majority of coarctation falls into two categories: Critical CoA, which causes symptoms within two months of birth and if left untreated, results in mortality, and asymptomatic CoA, which appears later, generally with hypertension in the upper limbs. Critical CoA accounts for approximately 60% of all coarctation. Despite, improvements in medical care and management strategies, long-term survival has not altered much.

**Keywords:** Pediatrics, CoA, PDA, LV, Balloon dilatation and stent.

### INTRODUCTION

Anatomically speaking, a CoA is a shelf of tissue that extends from the ductus arteriosus to the posterolateral aortic wall. Better known as juxtaductal, the shelf is located close to the patent ductus arteriosus (PDA), occasionally above or below it. Additional ductus muscle extends into the aortic wall above and below the shelf, forming a sling that encircles it. This is significant because, in contrast to the majority of other smooth muscles, the ductus smooth muscle tends to contract in response to elevated oxygen concentrations<sup>(1)</sup>.

The balance between dilators and constrictors determines whether the ductus arteriosus remains open in a developing baby. The primary cause of constriction is the ductus smooth muscle's heightened sensitivity to calcium<sup>3</sup> and endothelin. On the other hand, vasodilator prostaglandins, namely PGE<sub>2</sub>, which are generated in the ductus wall and also flow from the placenta, relax the ductus smooth muscle. Calcium sensitivity is reduced when intracellular amounts of cAMP are increased by PGE<sub>2</sub>. The ductus lumen's high pressure contributes to its ability to remain open<sup>(2)</sup>.

Following delivery, there is a decrease in PGE<sub>2</sub> due to a reduction in the number of PGE<sub>2</sub> receptors in the ductus wall and a loss of placental prostaglandins, which also lowers pressure in the ductus lumen. The ductus constricts as a result of many mechanisms caused by an increase in arterial oxygen concentration. Each of these modifications causes vasoconstriction<sup>(3)</sup>.

### Morbidity and mortality:

In order to prevent significant morbidity and mortality, CoA must be treated in newborns, children, and adults. A rising number of patients are finding that

balloon-expandable stent implantation is a safe and successful substitute for surgery or angioplasty thanks to recent technology advancements and increased collective expertise<sup>(4)</sup>.

The most frequent major consequences included cerebrovascular accidents, aneurysm development due to the femoral access artery, and aortic dissection. Many of these major issues happened in the same individuals. For a sizable portion of CoA patients, balloon-expandable stents should be regarded as a safe and very successful therapeutic option<sup>(5)</sup>.

### Clinical picture:

The age of the patient affects the clinical manifestations. An early manifestation usually indicates a more serious illness. It depends on the presence of upper body collateral circulation, weak and delayed femoral arterial pulses, hypertension in the upper body, and left ventricular hypertrophy<sup>(6-7)</sup>.

**Newborns and neonates** are often asymptomatic in the early postnatal period because PDA aids in lower body perfusion regardless of the degree of CoA. Upon delivery, neonates with severe or critical cardiomyopathy have symptoms of cardiogenic shock due to the closure of the ductus arteriosus. Babies may exhibit clinical symptoms such as mesenteric ischemia, myocardial depression, delayed capillary refill, feeding issues, diminished responsiveness, metabolic acidosis, and missing or weak femoral pulse<sup>(8)</sup>.

### Adolescent and Adults:

The hallmark of left ventricular hypertrophy is a powerful, heaving apical push during systole. Because the left subclavian artery is frequently hypoplastic or distant to the coarctation, blood pressure (BP) should be measured using an appropriate-sized cuff in both arms. Feel the femoral pulses if there is a high pressure in the arms. They are less strong than the radial pulses in CoA, and the femoral pulse is delayed when felt concurrently with the radial pulse. Using a cuff that is the right size, take the BP in your legs to gain confirmation <sup>(4)</sup>.

More than half of these individuals have noticeable collateral arteries, which are pronounced above the scapulae. There might be a systolic murmur at the base and in the space between the spine and the left scapula, similar to an ejection <sup>(5)</sup>. A chest radiograph that reveals the aortic indentation at the coarctation site (three sign) and lower rib notching from enlarged intercostal arteries can be used to confirm the diagnosis. If further heart abnormalities are suspected, echocardiography should be performed <sup>(6)</sup>.

Because left atrial pressure is lower when the foramen ovale is patent, there may be no or reduced pulmonary oedema as a result of a left-to-right atrial shunt, which can be rather substantial. Frequently, the patient experiences shock. If the aorta narrows very gradually, shock and congestive heart failure do not happen because the left ventricle (LV) has time to adjust to the higher pressure load and form a collateral circulation. These people are typically diagnosed at older ages with no symptoms <sup>(7)</sup>.

### Etiology:

Uncertainty surrounds CoA's cause. Usually, the illness is a congenital heart defect, which is a cardiac issue that exists from birth. CoA seldom appears later in life. Aortic narrowing can result in this condition and the following conditions or events: Injury caused by trauma, atherosclerosis, or severe arterial stiffening in adults, and Takayasu arteritis or "inflamed arteries. Although CoA can affect any area of the aorta, it often affects the area closest to the ductus arteriosus. The aorta and left pulmonary artery are joined by that blood channel. The LV has to work harder when there is CoA to push blood via the constricted aorta. The LV's BP increases as a result. The LV wall may thicken (hypertrophy). The aortic arch may be affected by this condition in a highly variable manner, and it may be associated with a variety of other left sided heart lesions. Additionally, it represents a wider vasculopathy within the pre-coarctation arterial tree, which may lead to a significant prevalence of hypertension by adolescence and an increased risk of early morbidity and death <sup>(9)</sup>.

### Risk factors:

Males are more likely than females to have CoA. The risk of CoA is also increased by some hereditary diseases, such as Turner syndrome.

### COA frequently coexists with other congenital cardiac abnormalities. The following heart ailments are linked to coarctation <sup>(10)</sup>:

- Bicuspid aortic valve. The lower left chamber (LV) of the heart and the aorta are divided by the aortic valve. Two flaps, or cusps, rather than the typical three, are present in a bicuspid aortic valve. Numerous CoA patients have bicuspid aortic valves.
- Subaortic stenosis. Blood flow from the lower left heart chamber to the aorta is obstructed by a constriction of the region underneath the aortic valve.
- Patent ductus arteriosus. It is a blood conduit that joins the aorta to the pulmonary (left lung) artery. This vein allows blood to circulate around the lungs as the infant is developing within the womb. The ductus arteriosus often shuts soon after birth. If it stays open, the gap is known as a PDA.
- Holes in the wall separating the heart's left and right sides. Lower chambers (ventricular septal defect) or chambers (atrial septal defect). As a result, blood with more oxygen on the left side of the heart and blood with less oxygen on the right side of the heart combine.
- Congenital mitral valve stenosis. This is an inherited heart valve issue. The left upper and lower cardiac chambers are separated by the mitral valve. It permits blood to pass via the heart's left side. The narrowing of the valve in mitral valve stenosis lowers blood flow. Breathing problems after physical activity, dyspnea while resting flat, and shortness of breath are among the symptoms <sup>(10)</sup>.

### Epidemiology:

Approximately 28% of all significant congenital abnormalities are caused by CHD <sup>[11]</sup>. Globally, it is estimated that eight babies out of every 1,000 live births have CHD <sup>[12]</sup>. CoA, which has an estimated frequency of four per 10,000 live births, contributes for 6–8% of all cases of CHD <sup>[13]</sup>. Men are more likely than women to experience it. CoA often coexists with extra- and cardiac abnormalities. The common related cardiac defects include bicuspid aortic valve, ventricular septal defect, patent ductus arteriosus and transposition of the major arteries, etc. With a frequency of 45–62%, the bicuspid aortic valve is the most common intracardiac defect <sup>[14]</sup>. A considerable proportion of individuals with Shone complex and other left heart obstructive lesions also have CoA. Patients with hereditary disorders such as Turner syndrome and William syndrome often have CoA. Patients with William syndrome may experience coarctation anywhere along the aorta's length, including the abdominal aorta <sup>[15,16]</sup>.

### Pathogenesis:

With relation to the establishment of CoA, there are three main developmental hypotheses. First, the tissue from the

ductus arteriosus may be integrated into the aortic wall at the point where it joins the descending aorta during the formation of the aortic arch. This tissue in the isthmus area constricts as the ductus arteriosus does after birth, which leads to the formation of CoA [17, 18]. Second, because there is not much blood flow in this location, the isthmus between the ductus arteriosus and the left subclavian artery is thin throughout fetal life. After delivery, the area often expands due to an increase in blood flow via this area. Development of CoA may result from this phenomenon's failure [17, 19]. Third, a little section of the left dorsal aorta may be abnormally involuting. Later, the left subclavian artery and this narrow section migrate cranially to create the CoA in the isthmus region [17].

### Diagnosis:

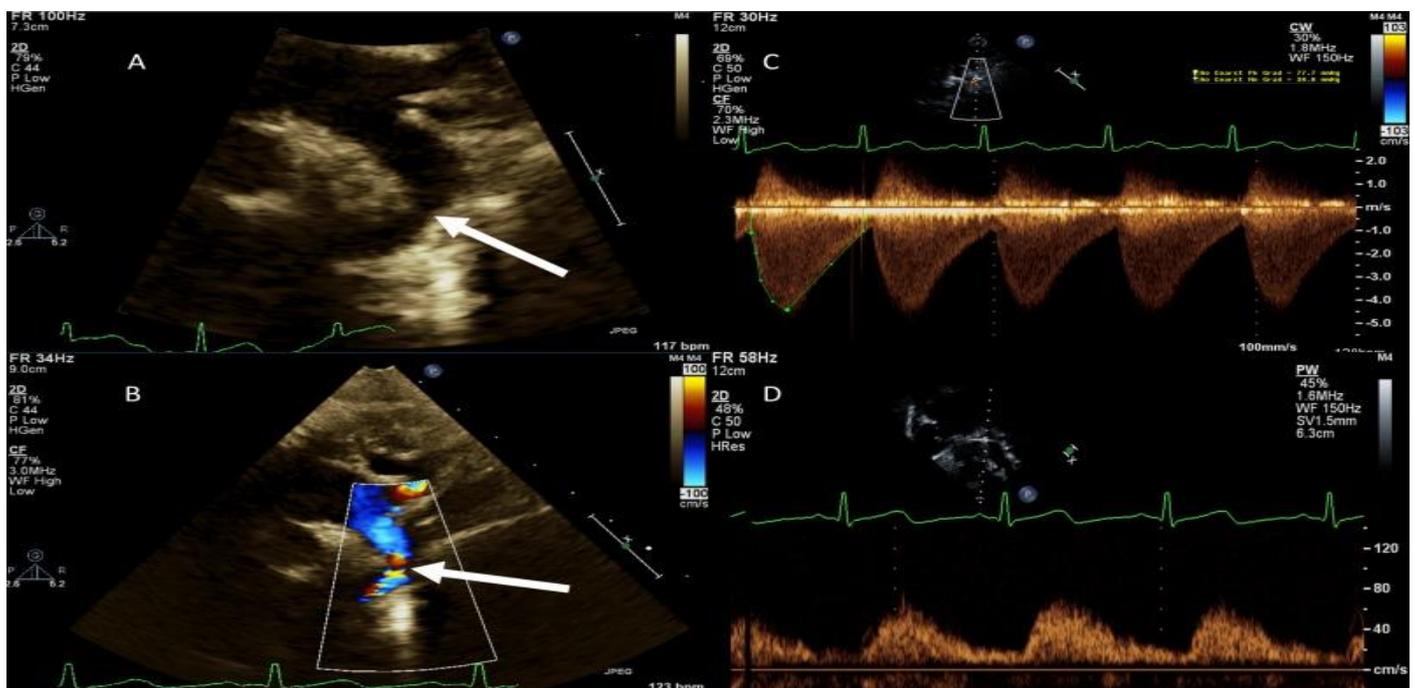
#### Echocardiography

##### I-Transthoracic 2D echocardiography (TTE 2D)

For postnatal diagnosis and follow-up regarding aortic arch malformations, TTE is still the gold standard. Finding the arch's architecture, the coarctation location, assessing the severity, and looking for related intracardiac anomalies are the objectives of TTE [21, 22]. The main tools for determining the location and severity of the CoA are the suprasternal and subcostal views [23].

When doing two-dimensional imaging of the aortic arch in the suprasternal sagittal view, one should look for widespread constriction of any segment of the aortic arch, distinct hypoplasia at the level of the aortic isthmus, and tissue infolding in the region of the aortic isthmus (also known as the "posterior shelf" (Figure 1). When using color Doppler imaging, it is important to look for signs of ductus arteriosus presence as well as flow turbulence or increased velocity with diastolic continuation of flow over the suspected coarctation zone. Because it links at the aortic isthmus and alters the flow dynamics at this location of interest, the existence of a ductus arteriosus makes it challenging to rule out or confirm the presence of CoA [21].

At the coarctation point, Spectral Doppler displays an enhanced velocity with a "diastolic runoff pattern." The Doppler pattern of the abdominal aorta is aberrant, exhibiting blunted pulsatility and low amplitude spectral Doppler. In addition to checking for left ventricular hypoplasia, bicuspid aortic valve, ventricular septal defect, and other often related intracardiac anomalies, a full TTE should be conducted on individuals with CoA. Each patient's aortic arch's sidedness and branching pattern should be ascertained to help with surgical planning, if needed (21-23).



**Figure (1):** Aortic coarctation as shown during transthoracic echocardiography. (A) Suprasternal sagittal two-dimensional image revealing aortic lumen narrowing at the isthmus (arrow). (B) Suprasternal sagittal color Doppler imaging reveals turbulent flow at the coarctation point (arrow). (C) Continuous wave spectral Doppler imaging of the coarctation segment from the suprasternal perspective. Doppler reveals higher flow velocity in systole and continued flow in diastole (diastolic runoff). (D) An abnormal Doppler pattern in the abdominal aorta due to aortic coarctation. Spectral Doppler reveals blunted velocity and a systolic upstroke with continuing forward flow (21).

### **Computed Tomography:**

CT angiography obtains intracardiac and extracardiac structural data with extremely high spatial resolution by using intravenous contrast and ionizing radiation [25]. CT allows for the evaluation of these structures in two dimensions as well as the reconstruction of three-dimensional data. In patients with inadequate preoperative arch imaging, CT angiography is an excellent tool for surgical planning. Metallic items do not cause major artifacts during CT imaging. This is particularly useful for arch imaging in individuals who have previously had coarctation stents [14]. The main disadvantages of CT imaging include exposure to ionizing radiation and the possibility of a response to contrast material.

### **TREATMENT**

#### **Treatment modalities available for management of CoA:**

Three methods: transcatheter stent insertion, balloon angioplasty, and surgery [24].

The patient's age, size, other comorbidities, and the morphology of the coarctation all affect the preferred course of therapy [25]. The following are a few generally acknowledged indications for the management of native coarctation [14, 26-29]:

- An upper and lower limb non-invasive systolic BP gradient of at least 20 mmHg.
- Peak-to-peak transcatheter gradient via the coarctation site of  $\geq 20$  mmHg.
- Significant enlargement of the left ventricle.
- Systolic dysfunction of the left ventricle.
- Uncontrolled hypertension throughout the body when there is an aortic coarctation.
- Unusual BP during a stress test involving exercise [14].

#### **Transcatheter balloon angioplasty:**

Early in the 1980s, transcatheter balloon angioplasty for native CoA was initially made available [30]. Using an antegrade or retrograde technique, a balloon catheter is inserted over the coarctation site during the treatment. The coarctation site and the aorta, both proximal and distal to the lesion, are sized angiographically. Based on the readings, the right-sized balloon is selected to dilate the coarctation area [28].

The procedure's objective is to overstretch the restricted vascular site, resulting in a rip in the intima media. Aortic wall remodeling is anticipated to produce a long-term resolution of CoA and avoid recoil following this dilatation and tear formation [31].

For older children, balloon angioplasty is the recommended treatment [24]. In younger patients with recoarctation, it is also the recommended option. Currently, patients with concomitant ventricular dysfunction are the primary candidates for balloon angioplasty, which is used to stabilize them before final

surgical repair [32]. Its high recurrence rate and danger of vascular problems have made it less useful as an initial intervention in this extremely young age group [32].

#### **Transcatheter stent implantation:**

In the early 1990s, transcatheter stent implantation gained widespread acceptance as a therapeutic intervention for patients with CoA, having been developed in the late 1980s [33]. For older children, adolescents, and adults with native and recurrent CoA, this is the recommended course of therapy [25, 34]. In comparison with balloon angioplasty, this is technically more difficult and necessitates a bigger vascular sheath for access [31]. Stents offer consistent gradient alleviation and uniform radial force distribution once they are fixed to the aorta [29, 35]. Patients who get stents experience fewer acute problems than those who undergo surgery or balloon angioplasty [24, 25]. However, they are more likely to need a scheduled reintervention for stent dilatation, particularly if the patient is younger [34]. Stent migration, stent embolization, and aortic dissection are examples of acute problems following stent implantation [24, 25].

#### **Long-term complications:**

Planned reintervention for stent dilatation, aneurysm, stenosis, and neo-intimal proliferation in the stent should be included [24, 25]. The incidence of aneurysms and dissection following stent implantation has reduced with the use of covered stents [35].

In comparison with balloon angioplasty, the surgical and stent treatment resulted in a decreased upper-lower extremity blood pressure gradient both immediately and during the short-term follow-up. At the intermediate follow-up, these differences were no longer present. Patients who underwent stent implantation experienced less acute problems than those who underwent the other two treatment methods, but they also required more planned treatments in the future [24]. A higher chance of CoA recurrence is linked to younger age at the time of intervention [34]. In older and more modern postsurgical patients, survival rates of around 93% at 10 years, 86% at 20 years, and 74% at 30 years are recorded [35].

### **CONCLUSION**

The majority of coarctation falls into two categories: Critical CoA, which causes symptoms within two months of birth and, if left untreated, results in mortality, and asymptomatic CoA, which appears later, generally with hypertension in the upper limbs. Critical CoA accounts for approximately 60% of all coarctations. Despite, improvements in medical care and management strategies, Long-term survival has not altered much.

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