Review Article

Management of Aortic Coarctation in Adults: Endovascular Versus Surgical Therapy

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Aortic coarctation (CoA) is one of the most commonly encountered congenital heart diseases, presenting either in isolation or in association with other cardiac defects. It comprises approximately 5-8% of all congenital heart defects and in the majority of cases it is diagnosed and treated during childhood. Aortic coarctation presenting during adult life most frequently represents cases of re-coarctation, following previous transcatheter or surgical therapy, or missed cases of native coarctation.

With the emergence and successful employment of transcatheter techniques for relief of aortic CoA in the past two decades, there is broad interest in defining the optimum management method–surgery or endovascular treatment–particularly in the adult population.

Surgical repair of CoA was first performed in 1944:[1] therefore, retrospective studies of the surgical results have been influenced by surgical learning curves, operative techniques, age of patient at initial operation, etc. On the other hand, endovascular therapy techniques, available equipment and operator skills have also improved since balloon dilation of aortic CoA was first introduced in 1982[2] and stent implantation in the early 1990s.[3,4]

In order to compare the results of surgical versus endovascular therapy for adult patients with aortic CoA, mortality as well as morbidity rates should be assessed. Acute morbidity refers to neurological complications, aortic dissection, haemorrhage and heart failure, whereas long-term morbidity refers to the development of aortic dissection and aneurysms, restenosis, persistent hypertension, left ventricular dysfunction and coronary artery disease. When presented with an adult case of CoA, we should take into consideration other coexisting medical conditions, such as diabetes mellitus and atheromatous coronary artery disease, as well as the estimated length of hospital stay, and procedural and hospitalisation costs, before deciding on the optimum treatment method for the individual patient.

Unfortunately, prospective randomised control trials of endovascular versus surgical therapy are unavailable in the adult population, whilst only two such studies are available in children.[5,6] Furthermore, adult patients are different to children, since they may have histological changes of the aortic wall, making them more susceptible to dissection.[7] More importantly, they are more likely to have other comorbidity, placing them at an increased risk of death or complications associated with cardiopulmonary bypass, aortic cross-clamping and hospitalisation in the intensive care unit.

The aim of this review is to discuss the different methods employed for the treatment of CoA in adults, and to compare their results based on mortality and morbidity data reported to date.

Available techniques

Surgical repair

Late mortality for the first patients treated surgically from the 1940s onwards has been reported to be as high as 31% at 40 years, predominantly secondary to persistent hypertension, coronary artery disease and heart failure, which are well known and significant long-term consequences of the disease, even in the presence of a good repair.[8] However, acute mortality in the current era is very low and has improved from 6-8% a few decades ago to 0-1%.[8,9]

Acute neurological complications, such as phrenic nerve or laryngeal nerve palsy, can occur postoperatively, whereas spinal cord ischaemia is rare and presents in 0.3-2.6% of cases.[10,11] The risk of paraplegia increases when the collateralisation network is poor and has been reported even weeks after surgery,[12] hence careful follow up is required for the first few weeks to months postoperatively. A recent meta-analysis of 6 surgical reports published from 1995-2005 found no cases of paraplegia, whilst laryngeal nerve palsy and bleeding from the operation site were the most common surgical complications.[9] Deterioration of cardiac function secondary to bypass injury can be seen in patients with already impaired ventricular function prior to surgery and older patients.

Resolution of hypertension has been observed in 65-75% of patients at 18-50 years' follow-up.[9,13] Paradoxical hypertension occurs even when there is no residual coarctation or restenosis. Late aneurysm formation at the site of the repair has been a well recognised problem, with an incidence as high as 23%, most commonly occurring when a patch has been used for aortic augmentation.[14-15] Patch repair of discrete coarctation is currently avoided and has been replaced by resection of the coarcted segment and end-to-end anastomosis where possible. The change in surgical techniques has led to a significant decrease in the incidence of aneurysms and aortic dissection to approximately 5-8%,[16-17] although the latter has been described even late after surgical repair.[18] Careful follow up is therefore required, with a low threshold for imaging when a suspicion is raised.[19] Finally, re-coarctation in patients who have previously been surgically treated occurs in 0-9% of cases. A percentage of those will require re-interventions, in the form of either reoperation or endovascular therapy.

Endovascular therapy

Balloon angioplasty

The technique was first introduced in 1982 and is currently used either in isolation or along with stent deployment in the coarcted segment. The acute mortality is <1%,[20-21] whilst no late deaths have been described at 15 years follow up.[20] No procedure-related neurological complications have been described in the last 10 years,[9] while haemorrhage and haematomas, previously commonly encountered at the groin sites, have been made rare by the use of femoral artery perclose devices and haemostatic valves. Acute aortic dissection or aneurysms can be encountered, but in the current era they would be immediately dealt with by the use of covered stents implanted at the same sitting.

Late aneurysm formation is encountered in up to 20% of patients,[20-22] but most remain haemodynamically insignificant and are followed up conservatively. When the aneurysms appear more sinister or there is an indication for re-intervention, the use of covered stents is recommended to exclude the aneurysmal bulge and deal with the residual gradient.[23] Persistence of arterial hypertension remains a problem for the patient with aortic coarctation, irrespective of the method of treatment. Following balloon dilation approximately 21-37% of patients remain hypertensive.[20-21] Interestingly, in contrast to children, restenosis in adult patients who have been treated with balloon dilation is relatively rare when the gradient has been reduced to <10 mmHg after the procedure.[20-21,24] In addition, adult patients with discrete coarctation who had a reduction of systolic gradient to levels <10 mmHg following isolated balloon dilation have been reported to have midterm results similar to those of patients who went on to have stent implantation following balloon predilation.[25]

Stent implantation

Stenting of the aortic coarctation was first introduced in the early 1990s.[4,26-29] The acute mortality rate is 0-3%, whereas neurological complications have not been encountered.[9] Groin haematomas due to the large sheath sizes required are prevented by the use of perclose and haemostatic devices as described above, although interruption of the femoral and iliac vessels can occur during advancement of the long sheath. Hence a low threshold for diagnosing retroperitoneal haemorrhage should be applied in the presence of acute anaemia and hypotension. Acute aortic dissec-

tion and aneurysms following bare stent implantation may be seen in up to 13% of patients.[30] However, this percentage probably reflects the arbitrary definition of aortic aneurysms and therefore the wide variation in their reported incidence. In the study by Mahadevan et al,[30] for example, an aneurysm was defined as dyskinesis of the aortic wall of >2 mm, whereas other studies use a cut-off limit of 5 mm and others define an aneurysm as a discrete bulging of the aorta at the dilation site to >150% of the diameter of the aorta at the level of the diaphragm.[25]

Late aneurysm formation has been encountered in up to 5% of patients who underwent bare stent implantation,[9,31-33] whereas restenosis is encountered in approximately 0-11% and is attributed to a degree of intra-stent intimal proliferation.[9,30] Lastly, reduction or discontinuation of anti-hypertensive therapy following stent implantation is achieved in 41-88% of patients.[23,26,29]

New advances in endovascular therapy

Covered stents

The first covered stent was used in 1999.[34] Since then, different types have emerged and been reported in a limited number of papers to date: (a) the AneuRx (Medtronic, Watford, UK) self-expanding stent covered with a stretchable polytetrafluoroethylene membrane; (b) the graft Jomed stent (Jomed, Rangendingen, Germany); (c) the self-expanding stent grafts (Braile stent, Braile Biomedica, Sao Jose do Rio Preto, Brazil); and (d) the balloon-expandable Cheatham-Platinum stent covered with expanded polytetrafluoroethylene membrane (NuMED Inc., Hopkington, New York). Cheatham-Platinum (CP) covered stents were introduced in 2001 and are currently considered as the stent of choice for primary stenting of CoA in patients above 65 years of age and complex native lesions, such as near aortic arch interruption and significant arch tortuosity.[23] In addition, covered CP stents are also used to deal with previous bare stent complications, such as aneurysms, stent fractures and intra-stent thrombosis, or in the acute setting of aortic dissection or aneurysm formation following balloon dilation or bare stent implantation.

Stenting of transverse arch hypoplasia with bare stents

Stenting of the hypoplastic transverse arch has been attempted successfully in the past few years.[35] Boshoff et al treated 20 patients with implantation of 23 stents, of which 3 were placed between the innominate and left carotid artery, 10 between the left carotid and left subclavian artery and 10 in the isthmus. No major complications occurred, though 2 patients developed groin haematomas. Median follow up of 2.2 yrs revealed no late complications and resolution of hypertension in 50% of patients.

The technique appears appealing in the treatment of patients with transverse arch hypoplasia with or without coexisting coarctation.

Endovascular versus surgical therapy for aortic coarctation

Assessment of the lesion

The method of choice for assessing cases of aortic coarctation and evaluation of the lesion's suitability for transcatheter or surgical treatment is magnetic resonance angiography (MRA) with three-dimensional reconstruction of the obtained images.[36] MRA helps to differentiate discrete coarctations from more complex lesions (Figures 1, 2), identifies aortic dissections and aneurysmal formations, and provides detailed arch measurements prior to cardiac catheterization (Figure 3), thus aiding careful planning of the interventional procedure. Alternative methods of assessment, such as computed tomographic (CT) angiography with three-dimensional reconstruction, or routine fluoroscopic angiography, can be used, although the latter is best reserved for cases when there is intention to treat during the same session. We recommend repeat CT or MRA 2-3 months after transcatheter stent placement to assess the patency of the stent and identify potential complications such as aneurysmal formations and stent fractures (Figure 4). When using MRA as the follow-up imaging modality, stent interference precludes accurate three-dimensional reconstruction of the images obtained (Figure 5); hence a black blood sequence is utilised.

Figure 1. Posteroanterior (A) and lateral (B) projection of a three-dimensionally reconstructed magnetic resonance angiogram (MRA) showing discrete coarctation of the aorta (CoA) in a patient who was deemed suitable for transcatheter stent implantation.

Figure 2. Three-dimensionally reconstructed MRA of a patient with complex CoA anatomy, who was treated surgically with extended arch repair and Goretex interposition graft anastomosed end to end into the subclavian artery.

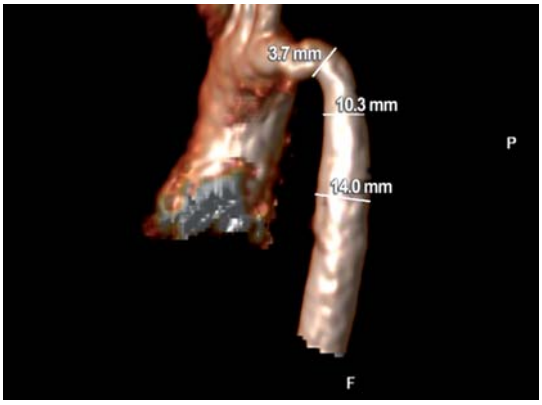

Figure 3. Assessment of CoA and aortic arch dimensions prior to transcatheter intervention.

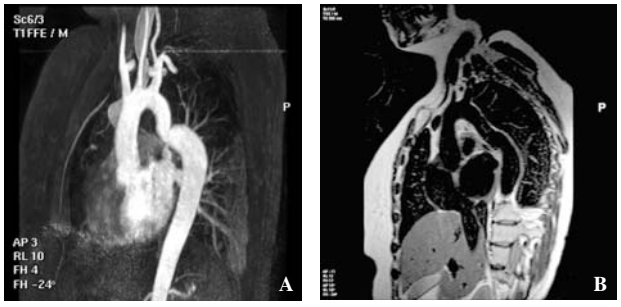

Figure 4. A: Gadolinium enhancement for assessment of CoA prior to stent implantation; and B: black blood sequence 3 months post-implantation revealing complete resolution of CoA.

Benefits and drawbacks of each approach

A recent meta-analysis comparing the results of catheter based therapy with surgical repair of aortic coarctation in adults found that stent implantation carried the lowest morbidity, whereas surgery and isolated balloon angioplasty had slightly higher morbidity risks (surgery: odds ratio [OR] 1.3 ± confidence interval [CI] 0.2, relative risk [RR] 1.2; balloon angioplasty: OR 2.4 ± CI 0.9, RR 2.1; with 84% power). Repeat interventions were more common following endovascular treatment compared with surgery (stenting: OR 16.1 ± CI 2.8, RR 14; angioplasty: OR 14.8 ± CI 2.7, RR 13; with 95% power). Amongst the causes for re-interventions, the restenosis rate appeared higher in the stenting group (0-25% as compared to 0-9% for surgery).[9] However, the incidence of restenosis and re-interventions may have been skewed by the fact that the meta-analysis extended back to 1995, when the equipment used and the stents available were not as refined as today, and the procedure might have been more easily complicated by aneurysmal formation and stent fractures. It is hoped that the use of the newer generation, reinforced bare and covered stents will further decrease the incidence of complications, the number of re-interventions required, and the restenosis rate in the future.[30] Further studies and longer follow-up assessment of the implanted stents are required to provide information on the long term safety and efficacy of stent implantation in adults with aortic coarctation.

Endovascular therapy is currently the treatment of choice when there is ventricular dysfunction or other significant comorbidity, such as diabetes, coronary

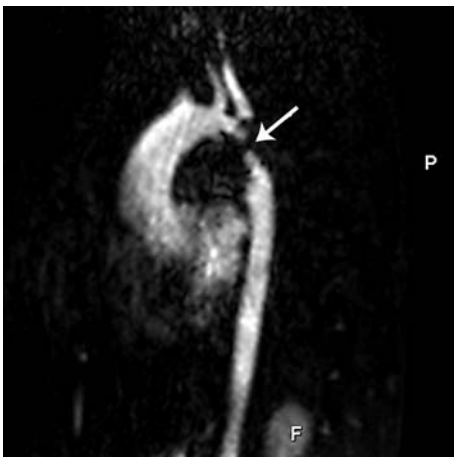

Figure 5. Three-dimensional reconstruction of an MRA showing interference from the metallic stent. Black blood imaging is used instead during magnetic resonance imaging assessment at follow up.

disease, previous neurological insults, and in older patients with multiple comorbidities.

The average duration of hospitalisation following transcatheter therapy of aortic CoA is 48 hours, as compared to 5-14 days following surgical relief. Patients undergoing transcatheter treatment are allowed to return to work 1 week later, whereas a convalescence period of 6 weeks to 3 months is recommended for surgically treated patients. Furthermore, the cost of balloon dilation of CoA is 58% less compared to surgical therapy ($5,292 ± 898 vs. $12,478 ± 2,455).[22]

Follow up

Attention should be paid and re-interventions should be considered in patients with residual gradients of >10 mmHg, following either management method, as this has been shown to be the cut-off point for differentiation of the high from low risk patients in terms of future cardiovascular events.[25] Furthermore, it has been shown that the systolic blood pressure of patients with small residual gradients can rise to levels of >200 mmHg on exercise, even when they are normotensive at rest.[37] Exercise testing is therefore critical in all patients with residual gradients in order to reveal latent, but haemodynamically significant, exercise-induced hypertension.

A chest radiograph is recommended approximately 3 months following stent implantation to identify potential fractures. MRA or CT is essential approximately 2-3 months following stent implantation, in order to assess for dissections, aneurysmal formations or intimal proliferation. Surgically repaired coarctation lesions are followed up echocardiographically, with no routine MRA or CT required unless clinically indicated.

Conclusions

Surgical repair of adult coarctation in the current era has very low morbidity and mortality, comparable to the transcatheter treatment. However, recent advances in endovascular techniques and equipment available, as well as the shorter hospitalisation time and costs, have made endovascular therapy the preferred method for treatment of adult CoA in most institutions. Surgery remains the mainstay of treatment for paediatric patients, particularly those <1 year of age, and in cases with complex arch abnormalities.

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