Minimally invasive surgery to the aortic arch – endovascular repair combined with debranching: 4 case reports

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ABSTRACT

Traditional repair of aortic arch aneurysms requires cardiopulmonary bypass and a period of profound hypothermia and circulatory arrest - allowing detachment of the head vessels off the aneurysm, and their anastomosis onto the graft. The procedure is safe and reproducible, however morbidity is significant and includes air embolism, stroke, excessive bleeding and acidosis. In addition the procedures are time-consuming, and cardioplegic arrest is also necessary, resulting in the potential for low cardiac output. Aortic arch aneurysms are not typically suitable for endovascular intervention. With improving techniques of descending aortic repair with stent grafts, hybrid techniques, which involve aortic arch debranching - thereby creating a proximal landing zone of adequate length, followed by stenting over the aortic arch are becoming popular.

Methods: Four cases are presented. The technique involves initial sternotomy or upper sternal split, detachment of the innominate and left common carotid arteries, and their reattachment to the ascending aorta by separate grafts (debranching procedure). During this time a side clamp is placed on the ascending aorta. The left subclavian is usually left intact for technical reasons, unless there is a dominant left vertebral artery. This is safe as the shoulder has adequate collateral circulation, and stenting over this vessel is therefore well tolerated. The aortic arch is then completely covered with a stent graft which is inserted via the femoral artery. Arteriography was performed at the end of the procedure to confirm stent graft position and exclusion of the lesion.

Results: All surgical transpositions were successful, and the patients recovered without neurologic, bleeding or cardiac complications. Surgical conversion for aortic graft was never required. There were no endoleaks. Mean duration of follow up was 53.5 months (range 21-77).

Conclusions: Endovascular repair of the descending thoracic aorta, initially reserved for inoperable patients, is now becoming the accepted initial management. With improved technology and endografts it is now the safest option, especially for traumatic dissection. These techniques have now extended to the aortic arch. Debranching of the aortic arch enables endovascular grafting in this area, thereby avoiding cardiopulmonary bypass and circulatory arrest. Good pre-operative planning is necessary to make the procedure feasible. SAHeart 2010; 7:172-179

OBJECTIVE

Endovascular aortic arch repair is less invasive than open surgical aortic arch repair. The morbidity and mortality is lower.[1] Aortic arch pathologies, such as aneurysms and dissections, often involve the supra-aortic vessels. Therefore it may be necessary to cover the origin of these vessels with endovascular stent grafts, thereby extending the proximal landing zone. Surgical aortic arch debranching is therefore indicated before covering the brachiocephalic trunk or left common carotid artery by endovascular stent grafts.[2,3,4,5,6] It has been shown that the left subclavian artery does not always need to be revascularised initially,[7] but may be reserved for later if ischaemic symptoms occur,[8] or if there is a dominant left vertebral artery.

METHODS

Arch vessel debranching procedure

A sternotomy or upper sternal split is performed. The pericardium is opened, and the aortic arch and its branches exposed and dissected out. After systemic heparinisation, the aorta is partially clamped with a side-biting clamp and a longitudinal arteriotomy performed. An end-to-side anastomosis between the proximal part of a bifurcated graft (Gelseal, Vascutek, Renfrewshire, Scotland) and ascending aorta is performed using a continuous 4/0 polypropyline suture. The cross clamp is removed and the air removed from the graft. Alternately a 10mm straight graft is sutured to the aorta, and another 10mm piece grafted to the side of this to

produce a Y-configuration. The innominate artery is then partially clamped and an end-to-side graft performed with the first limb. Sometimes the innominate is cross-clamped and transected, and an end-to-end anastomosis performed. After this the left common carotid is side-clamped, and another anastomosis made. Following this the vessels are ligated proximal to the grafting area (if not already transected), to prevent a Type II endoleak.

Endovascular aortic arch repair

We selected commercial endovascular stent graft (ESG) devices according to length, required diameter and anatomical findings. The ESG diameter was calculated from the largest proximal neck diameter with an oversizing factor of 15%. The ESG devices were implanted in the angiography suite, under general anaesthesia, and via femoral artery cutdown. The ESG's were advanced under fluoroscopic guidance and deployed during systemic hypotension (systolic BP 60-70 mmHg), and sometimes with a bolus of adenosine. Usually an extra stiff Amplatzer guidewire is required to allow negotiation of the ESG through the arch. Latex balloons (Reliant balloon, Medtronic, Minneapolis, MN) are used in patients with aortic aneurysms to improve expansion for modelling the ESG to the aortic wall.

We present 4 cases, specifically where debranching procedures have been performed, allowing further repair of the aortic arch without cardiopulmonary bypass. The aim is to re-implant the branches of the aortic arch more proximally onto the ascending aorta allowing a good landing zone for stent deployment over the aortic arch. If the whole arch needs to be stented, the innominate and left carotids can be moved, and the left subclavian left intact. Where a selective part of the arch needs to be stented, as in case 3, only the involved vessels need to be moved. Cardiopulmonary bypass is not routinely used for simple debranching, unless another procedure is being performed (cases 3, 4).

RESULTS

Case 1

Traumatic dissection of the descending aorta involving the aortic arch in a 33 year old male injured in a motor vehicle accident. The only evident injury was a fractured clavicle. Chest X-ray showed a widened mediastinum, and aortogram confirmed traumatic dissection of the descending aorta. This case displayed the rare event of retrograde dissection into the aortic arch (Figure 1). The dissection extended over the left carotid artery up to the origin of the innominate artery. Therefore clamping of the aorta in the normal place was impossible, and repair would require a period of hypothermic arrest, either via sternotomy or left thoracotomy. Therefore the patient was considered for a hybrid procedure.

An upper sternal split was performed. A side clamp was placed onto the mid-ascending aorta, and a 10mm diameter Dacron graft anastomosed to the aorta. Another 10mm graft was then grafted to the side of this graft, to construct a Y-graft configuration. The innominate artery was then clamped, and distal pressure measured a mean 60mmHg. The artery was then transected off the aorta and grafted to the right arm of the Y-graft. The origin of the innominate was oversewn. The left common carotid was side-clamped, and grafted to the left arm of the Y-graft. The proximal

FIGURE 1: Traumatic dissection of the descending aorta with retrograde dissection into the arch.

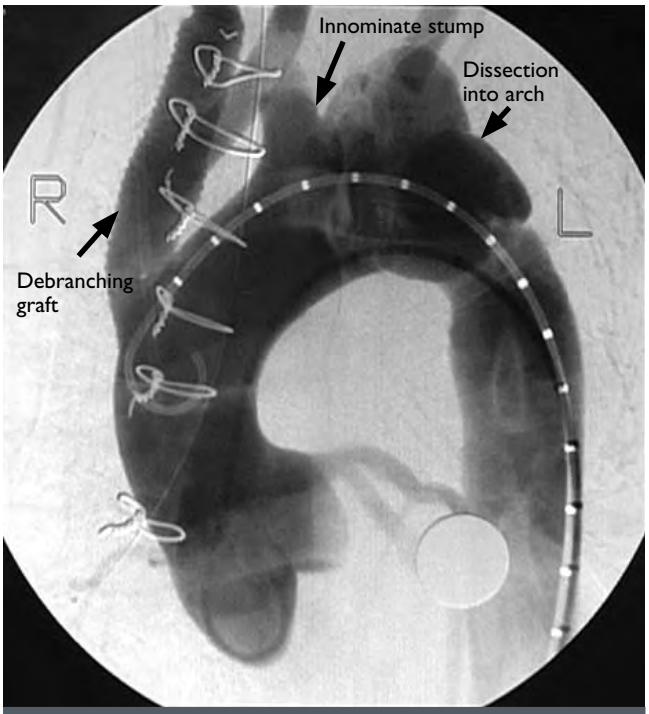

FIGURE 2: Innominate and left common carotid arteries grafted (debranched) lower down on the ascending aorta with two 10mm Dacron grafts. Note how the dissection into the arch appears more extensive than on the original angiogram.

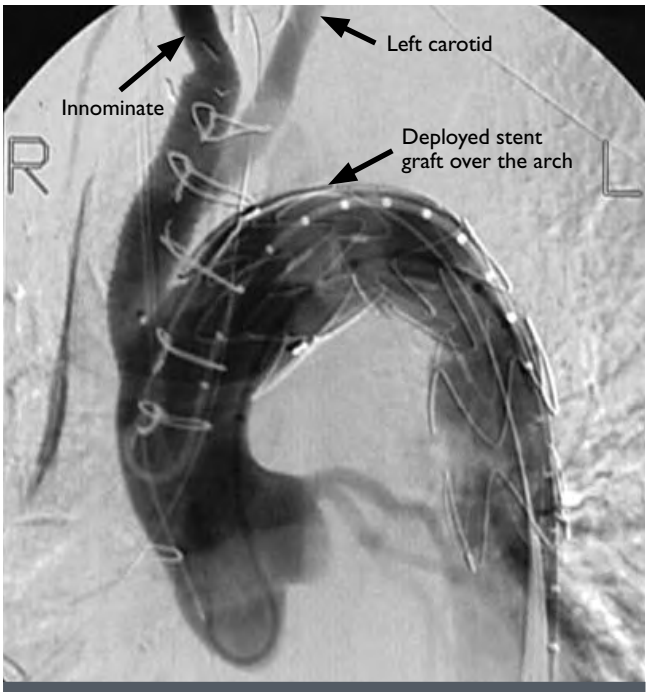

FIGURE 3: After arch vessel debranching, the whole arch and dissection has been excluded by a stent graft. The innominate and left common carotid are now supplied by a graft with inflow from the ascending aorta. The stent graft covers all the vessels originating from the arch, and has also sealed off the injured area.

end was then ligated. After closure, the patient was transferred to the angiography suite. A 26mm Medtronic "Talent" stent (Medtronic, Minneapolis, MN) was inserted via right femoral artery cutdown (Figure 2, 3). This sealed off the entire aortic arch from the orifice of the new graft to the descending aorta. Control aortogram showed no endoleak and complete exclusion of the left subclavian artery. The patient recovered well, with no claudication of the left arm. Latest follow-up CT scan (after 4 years) shows good position of the graft (Figure 4).

Case 2

Off-pump repair of a saccular aneurysm: A 65 year old male patient presented with chest discomfort, and a mass on chest X-ray. Aortogram confirmed a saccular aneurysm of the aortic arch, involving the origin of the innominate and left carotid arteries. Sternotomy was performed. A side-clamp was placed low down on the ascending aorta and a 16x8mm bifurcated Dacron graft grafted to the side of the aorta. The innominate artery was transected and grafted to one of the limbs of the

FIGURE 4: Follow-up after 2 years showing intact stent graft and patent grafts to head vessels.

graft. The left carotid was then transected and grafted to the other limb (Figure 5). The origins of the vessels were oversewn. Then a long vascular clamp was placed across the base of the aneurysm (Figure 6). The surrounding aortic tissue was normal. The aneurysm was excised, and then the base of the aneurysm sutured with a double row of sutures. The repair was satisfactory, so no stent was placed over the arch. The patient made an event-free recovery.

Case 3

Repair of a left subclavian aneurysm with dissection into the descending aorta: This 75 year old male patient presented with chest pain. Cardiac catheterisation confirmed triple vessel disease, as well as a saccular aneurysm of the left subclavian artery. This had caused a dissection which extended into the descending aorta. CABG was performed, with vein grafts to LAD, circumflex and right coronary, and at the same time the left carotid and subclavian arteries were detached and grafted to a 18x10mm bifurcated graft from the ascending aorta (Figure 7). One month later a stent graft was placed over the distal aortic arch into the descending aorta, thereby excluding the aneurysm. There was some difficulty negotiating the ESG past the aneurysm, and this was solved by passing a Reliant balloon into the aneurysm, thus preventing the tip of the ESG from passing into the aneurysm (Figure 8).

Case 4

Procedures where the whole thoracic aorta is involved: A 58 year old female patient presented for repair of an ascending aortic aneurysm. This measured 55mm, the arch 35mm, and descending aorta 42mm. The aneurysm extended up to and involved the innominate artery. Cardiac catheterisation showed proximal LAD disease. Stage 1 involved a vein graft to the LAD, transection of the innominate artery, graft replacement of the ascending aorta up to level of the left carotid, and re-attachment of the innominate lower down onto the ascending aortic graft via a 10mm graft. Stage 2 was performed when the patient (lost to follow-up) presented after 5 years with a symptomatic 7cm aneurysm of the distal descending aorta. Two 45mm x 15cm stent grafts (Goretag, WL Gore, Flagstaff, Arizona) were inserted from the mid-thoracic

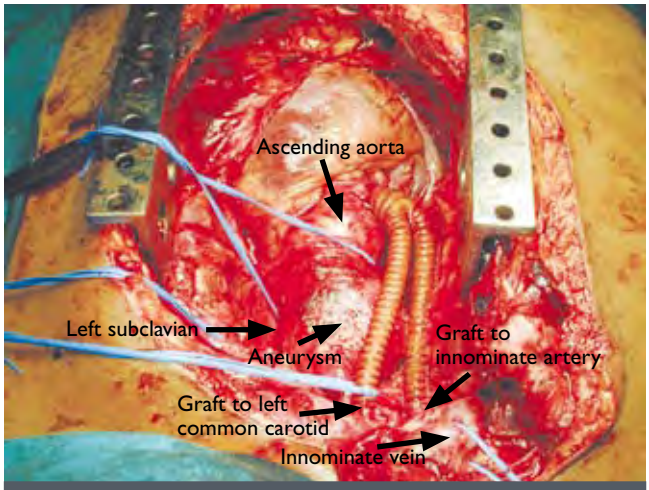

FIGURE 5: Completed debranching with grafts from the ascending aorta to innominate artery and left common carotid artery.

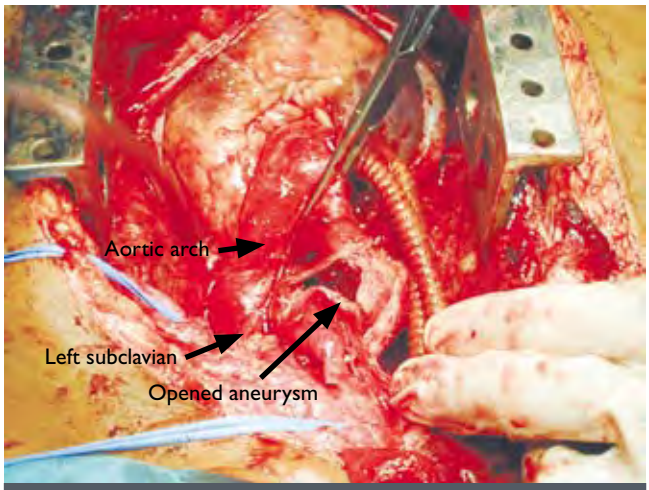

FIGURE 6: A large curved clamp excludes the aneurysm which has been opened and is being oversewn.

aorta to the level of the coeliac artery. Stage 3 is proposed if the arch and proximal thoracic replacement is indicated in future (presently measures 40mm). This would involve a stent across the arch after performing carotid-carotid grafting from the right carotid.

DISCUSSION

Endovascular stent graft repair of the descending thoracic aorta has produced promising results. The procedure was already performed

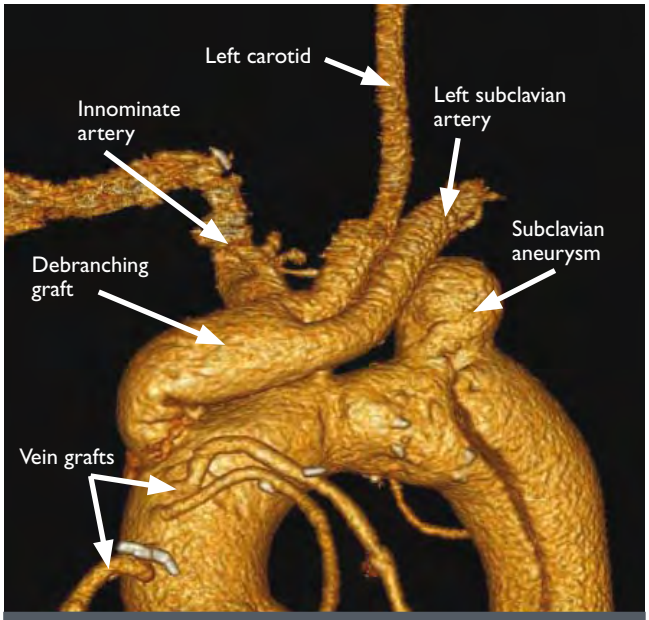

FIGURE 7: Debranching of left subclavian and left common carotid artery at the same time as CABG. A bifurcated graft has been attached to the ascending aorta, and the distal limbs to the left common carotid and left subclavian. The proximal origins of the latter vessels have been ligated and transected at the aortic origin.

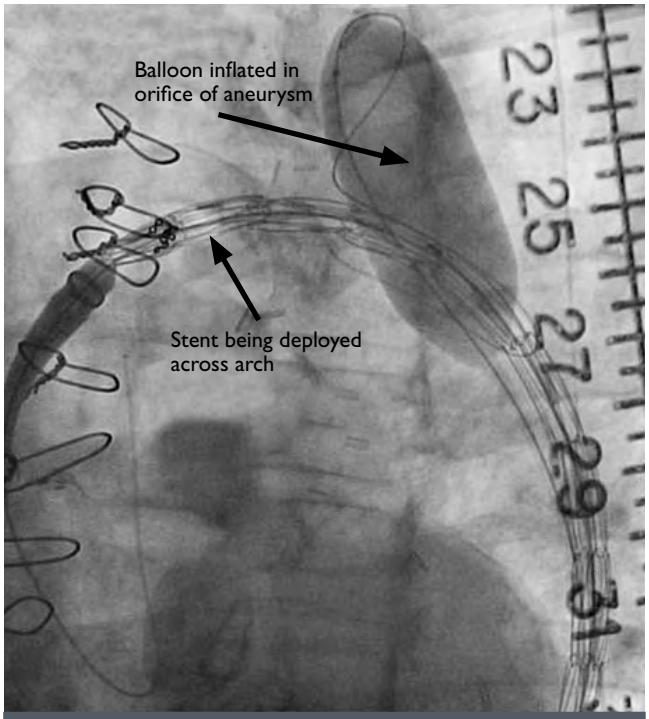

FIGURE 8: During deployment of the stent graft over arch, deploy-ment of a balloon around and in the subclavian aneurysm prevents the graft from migrating into the aneurysm, and allows it to negotiate the difficult curve of the arch.

in the 1990's.[9] The greatest impact has been in traumatic dissection. This has a significant incidence of paraplegia and death when repaired in the traditional manner.[10] Spontaneous dissection of the descending aorta is initially treated conservatively, as surgical repair has a high mortality. Surgery may become necessary when complicated by aneurysmal dilation or distal vessel occlusion. Stent grafting has become popular in this setting, and the indications have been extended to simple thoracic aneurysms. Repair of an aortic arch aneurysm necessitates sternotomy, hypothermic arrest, arrest of the heart, division of the head vessels, suture of a graft to the descending aorta, reattachment of the head vessels to this graft, then attachment of the graft to the ascending aorta during which time circulation and rewarming has commenced. This is obviously a complex and risky procedure, with the potential for many local and systemic complications. Therefore hybrid procedures (aortic arch debranching followed by stenting of the arch) have been advocated, and although initial reports are limited to small series and case reports, results have been good. Complications such as bleeding, respiratory failure and neurological problems are decreased when compared with the traditional repair method.[11] The early stroke rate can be as high as 25% using traditional methods.[12]

Experience with surgical bypass grafting in conjunction with endovascular stent grafting is limited. Reasons for this are the novelty of the combined approach, and the paucity of patients with aortic arch disease who are potential candidates for this procedure. At present patients referred for this are often inoperable via the conventional method,[13] and the disease is limited to the arch and descending aorta. Isolated arch disease with sparing of the ascending aorta is less common.

Debranching can be partial or total arch exclusion can be performed. Partial debranching involves a cervical incision and a carotid-to-carotid bypass graft,[5,14] or a graft from the right carotid to left carotid and subclavian.[15] Cervical debranching allows stenting over the orifices of the left common carotid and left subclavian arteries. Where the area around the innominate artery, or where

the whole arch needs to be stented, total debranching is required. Total debranching is possible via an upper sternal split, allowing a less invasive incision. Complete sternotomy may be necessary if the procedure is performed in conjunction with another cardiac procedure, as we did with case 3. A small anterior thoracotomy has been described in a patient with proximal arch involvement and previous ascending aortic aneurysm repair.[16] We use an inverted bifurcated graft from the ascending aorta to the innominate and left common carotid artery, or alternatively a 10mm T-graft, as proposed by other groups.[1] This avoids cardiopulmonary bypass and deep hypothermic circulatory arrest. It has been shown that it is not necessary to transpose the left subclavian artery[7,8,17] – unless it is diseased, as in case 3. Other indications for bypassing (from left common carotid) or transposing the subclavian include patients with previous coronary bypass grafts with left internal mammary, those with carotid or vertebral stenoses, or anatomical variants of the subclavian, vertebral, or basilar arteries. It is important to document a dominant left vertebral artery, as the subclavian should be bypassed before stenting over it in these patients. It may be argued that transposing or bypassing the left subclavian may prevent Type II endoleaks, however one study had no such endoleaks after covering the left subclavian with ESG's without ligating the left subclavian.[18] The conclusion is that stent graft coverage of the left subclavian is well tolerated (in the absence of dominant left vertebral) and should be managed expectantly – in a series of 19 patients, 3 (15.8%) developed symptoms, and 1(5.8%) developed rest-pain which was treated with a stent.[7]

In most cases the aorta may be side-clamped without the backup of cardiopulmonary bypass. Extreme care should be taken, and the blood pressure should be lowered by the anaesthesiologist to reduce clamp dislodgement, or damage by the clamp leading to dissection of the ascending aorta. Indeed, this feared complication has already been described in this situation, during off-pump coronary bypass.[19] Cardiopulmonary bypass may be required in aneurysms also involving the ascending aorta where the graft may need to be placed much more proximal on the aorta.[20]

Technical difficulties with stent grafting may be encountered. Vascular access may be limited by small or sick femoral arteries. A more proximal arteriotomy may suffice, or suturing a graft to the side of the iliac artery. Antegrade deployment of the ESG has been performed just after debranching. A danger associated with this is partial disruption of the proximal graft due to undue forces, and if this occurs a side-biting clamp should not be placed over the ESG, and the graft should be repaired without clamping.[1] It may be difficult to negotiate the graft around the aortic arch. We have found that a super stiff Amplatzer guidewire facilitates this process. Unexpected problems may be encountered as we found in case 3 where we unknowingly entered the false lumen of the dissection, and the stent kept ending up in the aneurysm. The false lumen was the larger and we could not get the guidewire or stent across the arch. This problem was solved by placing a balloon in the false lumen, and this helped us to pass the guidewire into the true lumen (Figure 8).

Prior to deployment of the ESG, great care should be taken to prevent migration during deployment. The mechanism should be firmly held. Blood pressure is lowered to about 60 to 70 systolic. A bolus of adenosine is given just before deployment. Others prefer to use rapid cardiac pacing.[1]

The procedure is not without its hazards, and fatal complications may be catheter related (iliac rupture, and left ventricular perforation).[5] Our patient number 4 was a female with smallish femoral arteries, requiring a large (45mm) Gore Tag stent, which requires a 24 French sheath. The femoral artery would only accept a 22F sheath. This sheath was then dilated with a 24F introducer, and we were then able to advance the stent through the sheath. We were able to detect dissection of the iliac artery (the whole intima was stripped), and repair it with stents down to the arteriotomy site, therefore preventing rupture. CT angiogram of the entire aorta, with assessment of the femoral arteries for disease and size is mandatory to prevent these kind of complications (which incidentally have a 10% incidence in transcatheter aortic valve insertion). In this patient (who was of small size) the vessels looked adequate, however a larger than usual sheath is required for the

45mm diameter stent. The complication could possibly have been avoided by sewing a graft onto the iliac artery and inserting the stent through this graft. However, this involves a more invasive incision. The complication was instantly recognised and managed with endovascular repair, thus avoiding a major vascular disaster. Not only is pre-operative planning important, but also recognising problems immediately as this applies to percutaneous valve repair, which has a similar sheath.

Other procedural complications include intra-operative proximal bare stent perforation and embolic stroke. In high risk patients turned down for conventional repair morbidity is high and includes pneumonia, cardiac failure, prolonged ventilation, renal failure and bypass infection.[13]

Type I endoleaks are reported to be from zero[6] to 23%.[4] This may be prevented by balloon dilatation of the inserted stent. Completion angiography should be performed at the end of the procedure to exclude any signs of an early leak which can be attended to. Early residual endoleaks usually resolve spontaneously in the first 6 months.[3] Others recommend treatment with extended stents and balloon angioplasty.[4] Type I endoleaks are an independent risk for later mortality so we stress the importance of completion angiography and repair with extended stents.

Replacement of the entire thoracic aorta with ESG is feasible, and case 4 has been included for demonstration. The entire aorta was dilated at presentation, although at this stage only the ascending and innominate were large enough to indicate replacement. The innominate artery had already been debranched during the ascending repair. The 10mm graft was attached lower down on the ascending aortic graft than usual, in order to allow an adequate landing zone should the aortic arch require stenting later on. The proximal descending aorta can still be grafted with ESG, then the arch, after performing a cervical carotid-to-carotid graft.

Other groups have shown that transfemoral stenting of the entire thoraco-abdominal aorta is possible after debranching the visceral and renal vessels onto the ascending aorta.[21] To take it one step further, simultaneous debranching of the arch and viscero-renal vessels onto the ascending aorta has been performed in the same patient, replacing the aorta from the arch to the iliac arteries.[22]

CONCLUSION

In selected cases, this hybrid approach using the ascending aorta for translocation of the cerebral arteries combined with endovascular stent grafting is feasible, with decreased operative morbidity. The combination decreases the operative burden on the patient, especially where several segments of the aorta are involved. Longer follow-up is needed to determine durability.

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