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Treatment of Aortic Arch Aneurysms with a Modular Transfemoral Multibranched Stent Graft: Initial Experience

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WHAT THIS PAPER ADDS

- Several methods have been proposed to limit the invasiveness of aortic arch aneurysm repair and reduce the morbidity associated with hypothermic circulatory arrest. The endovascular treatment of aortic arch aneurysms using branched stent grafts that can be introduced transfemorally is appealing for many reasons. We report our experience using a novel custom-made multibranched stent graft intended for transfemoral insertion.

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ABSTRACT

Objectives: To present initial experience with a new modular transfemoral multibranched stent graft for treating aortic arch aneurysms.
Methods: Six patients, considered high risk for open surgery, were treated with custom made branched stent grafts. All patients had a staged left carotid subclavian bypass before the endovascular procedure. Each branched graft had a 12 mm side branch for the innominate artery and an 8 mm side branch for the left common carotid artery.
Results: Four patients out of six had uneventful placement of the prostheses, with successful exclusion of their aneurysms. One patient developed a type I endoleak that was managed successfully with coiling and gluing of the aneurysm sac. In one patient, cannulation of the innominate branch was unsuccessful and an extra-anatomic bypass was necessary to perfuse the right carotid and vertebral arteries. This patient developed a stroke, while one more suffered a right cerebellar infarct.
Conclusion: We have demonstrated the technical feasibility of a modular transfemoral branched stent graft for treatment of aortic arch aneurysms. The method is relatively safe based on initial experience. More cases and long-term follow up are necessary to evaluate the efficacy and safety of this new device.

Several methods have been proposed to limit the invasiveness of aortic arch aneurysm repair and reduce the morbidity associated with hypothermic circulatory arrest. Hybrid aortic arch procedures, endovascular aortic arch repair with fenestrated stent grafts or *in situ* fenestrations and double-barrelled techniques have all been introduced as alternative treatment options for managing aortic arch pathologies. Overall, the results of hybrid aortic arch procedures are satisfactory, but the associated mortality and morbidity rates are not negligible.[1] Clear indications and the exact role of hybrid repair have not been defined.[2] An impressive experience has been developed in Japan with fenestrated stent grafts[3]; and the results of an ongoing clinical study are expected to clarify the issues of safety and efficacy of these devices. Total aortic arch debranching with *in situ* fenestrations has also been reported in case reports.[4–6] Long-term surveillance of these endografts is not available, while fenestrating an endograft *in situ* is not without potential pitfalls and loss of integrity in the long-term. Similarly, initial outcomes of chimney grafts are encouraging[7]; but long-term durability remains unknown. Until more patients and longer follow-up are available,

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chimney grafts should only be considered in emergency patients who are poor candidates for open repair or in the case of preoperative inadvertent coverage of the supra-aortic trunks.

Endovascular treatment of aortic arch aneurysms using branched stent grafts provides another attractive alternative. Initial experience was reported by Inoue and colleagues in 1999.[8] The device used consisted of a unibody graft with multiple (up to three) limbs that were snared and pulled into each of the aortic trunk vessels. The primary success was low (60%), while major complications were caused by multiple cerebral emboli. Chuter and associates have described a modular branched stent graft implanted proximally into the ascending aorta and distally into the innominate artery (IA) and descending thoracic aorta.[9,10] However, this method has fallen out of favour due to various issues, including delivery of the device through the IA, size constraints and relatively high stroke and mortality risk, approaching 30% in anecdotal series.[2] These factors, along with the success achieved in the thoraco-abdominal aorta with branched stent-graft repair of thoraco-abdominal aneurysms, led to a refinement in design and a change of thinking regarding the method of device introduction resulting in a novel, custom-made, multibranched stent graft intended for transfemoral insertion. We report our experience using this new stent graft for treating aortic arch aneurysms.

Methods

All the endovascular branched repairs of aortic arch aneurysms performed between October 2009 and May 2011 were reviewed from a prospectively maintained database. All cases were performed by one surgeon, but in different centres (Jewish General Hospital, Montreal; Toronto General Hospital, Toronto; and Vancouver General Hospital, Vancouver, Canada). Device approval under Special Access was obtained from Health Canada for each patient. These patients were all deemed high risk for conventional surgery by cardiac surgeons, and there is currently no Health Canada-approved commercially made device available to treat this anatomy. Full informed consent was obtained in all cases.

Design of the device

Planning of the procedure involves reconstruction of central flow line in a 3D workstation, which continues from the thoracic aorta into the left ventricle. Study of the proximal anatomy starts at the level of the aortic annulus and continues through the site of the origin of the coronary arteries origin, the sinotubular junction (STJ) and the first healthy part of the ascending aorta. Fundamental concepts of the planning procedure involve orientation of the supra-aortic trunk vessels and identification of sufficient sealing zones within the 'normal' ascending aorta, each supra-aortic target artery separately and the descending thoracic aorta.

The branched stent graft is custom-made and is manufactured by COOK (Cook Medical, Brisbane, Australia). It is loaded into a Flexor sheath with a diameter of 20–24 French. The introducer has an inner nitinol cannula and is precurved. A notch in the dilator tip is aligned with the outer curve of the introducer and graft. The advantage of this novel introducer is that it orientates itself properly during placement into the arch without any rotational manipulation. In addition, a shorter introducer tip (60 mm) is used; however, even with this modification, crossing of the aortic valve is inevitable.

The graft is made of polyester, supported by stainless steel sealing Gianturco Z-stents at both ends and a combination of nitinol and stainless steel stents throughout its body (Fig. 1(a)). The use of low profile polyester has since been introduced to reduce the profile of the device. There are no uncovered stents. The stents at the arterial implantation sites are sutured to the inside of the polyester graft while, elsewhere they are sutured to the outside. The proximal stent has caudally oriented barbs projecting out through the overlying graft to help prevent migration. As a result, the ability to withdraw or advance the device is limited once the sheath is withdrawn. The graft has a spiral stabilising wire attaching the graft to the inner cannula at 12 o'clock (greater curve line) (Fig. 1(a)). It is also attached to the introducer at its proximal and distal ends at a single point, on the line of the outer curve. Spiral stabilising wires, proximal and distal attachments and diameter reducing ties have been extensively used before, in construction of fenestrated and branched stent grafts for treating thoraco-abdominal aortic aneurysms.[11,12]

The graft is constructed with two side-branches. Theoretically, a third branch could be added for the left subclavian artery (LSA). Usually, the branch for the left common carotid artery (LCCA) is an 8-mm side-branch sited most distally at 11.30 o'clock, and the branch for the IA is a 12-mm branch sited most proximal at 12.30 o'clock. The first case performed worldwide in 2009 at McGill University involved a branched graft with external funnel-shaped branches to facilitate their cannulation (Fig. 1(b)). Concerns were

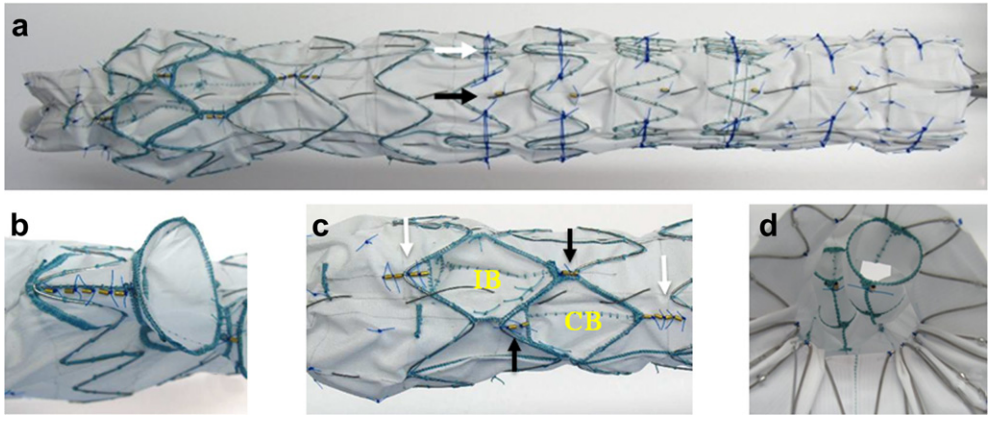

Figure 1. (a) Aortic-branched stent graft with double diameter reducing ties (white arrow) and a spiral stabilizing wire (black arrow) attaching the graft to the inner cannula at the greater curve line (12.00 o'clock), (b) funnel-shaped external components designed at the orifice of the branches to facilitate their cannulation; this was abandoned after the first patient, (c) diamond-shaped outer openings, slightly sunken to facilitate cannulation of the branches. Two sets of gold markers are placed to the branch entries: "quadruple" linear markers at the proximal edge of the innominate branch and the distal edge of the carotid branch diamonds (white arrows) and "double" markers at the distal edge of the innominate branch and the proximal edge of the carotid branch diamonds (black arrows), and (d) internal low profile side-branches. IB: Innominate Branch, CB: Carotid Branch.

raised about the possibility of compressing these branches onto the greater curvature of the aortic arch, and subsequent cases were performed with branched grafts having fully internal branches with slightly sunken 'shelf-like' entry points to facilitate their cannulation (Fig. 1(c)). In addition, the proximal stent was modified to incorporate the Cook Medical Pro-Form technology, so that proximal wall apposition was ensured. Gold markers indicate the location of side-branches and the aspect of the graft that is to be aligned to the greater curve of the arch (Fig. 1(c)). Two sets of gold markers are placed at the branch entries: 'quadruple' linear markers at the proximal edge of the innominate branch and the distal edge of the carotid branch entries and 'double' markers at the distal edge of the innominate branch and the proximal edge of the carotid branch entries. The stent graft tapers at the site of the side-branch openings to provide more space for branches' accommodation. Positioning of double diameter reducing ties further lessens the diameter of the stent graft following sheath retrieval (Fig. 1(a)).

Bridging from the LCC side-branch to the LCCA requires a suitable stent graft (Fluency Plus© stent graft (Bard Peripheral Vascular, Tempe, AZ, USA) or Viabahn (W.L. Gore & Associates, Flagstaff, AZ, USA)), supported with self-expanding stents. Due to the large diameter of the IA, custom-made bridging limbs (Cook Medical, Brisbane, Australia) are used to bridge from the IA to its branch. These bridging limbs also use 'low profile' fabric and nitinol stents to ensure that the grafts could be loaded into a 14-French flexor sheath.

During the course of our series, modifications were made to the deployment system to optimise deployment accuracy and proximal conformance of the graft. The latest deployment system includes four release mechanisms that control wires attaching the graft to the central shaft of the delivery system. The first release removes a spiral stabilising wire, the second releases the inner proximal attachment, the third releases the proximal diameter reducing ties that give the Pro-Form effect and the outer curvature proximal attachment and the fourth releases the distal diameter reducing ties and the distal end of the stent graft from the central shaft of the delivery system.

A distal thoracic graft extension was planned when the landing zone was further distal in the descending thoracic aorta. This device was introduced second, achieving overlap of at least two stents with the proximal stent graft.

Placement of the device

The first stage of the procedure involved creation of a left carotid–subclavian bypass with occlusion of the proximal LSA (ligation or placement of vascular plug). The second stage involved insertion of the branched stent graft through femoral or aorto-iliac access. Procedures were performed in a GE Innova 3131^{IQ} fixed ceiling-mounted angiosuite in four cases and with a mobile C-arm (GE OEC 9900) in two cases. Initially, a 6-Fr sheath was placed at the origin of the IA through the right axillary artery that had been surgically exposed, with our preference being an infraclavicular approach. Similarly, a 6-Fr sheath is placed at the origin of the LCCA through the surgically exposed left brachial or axillary artery – depending on the size – and via the previously constructed carotid–subclavian bypass. Transfemoral access to the left ventricle through the aortic valve was also achieved with a careful, interventional technique eventually leaving a double curved stiff Lunderquist wire buried into the left ventricle (Cook Inc., Bloomington, IL, USA). Intravenous heparin was administered to maintain an activated clotting time (ACT) time >250 s. The graft was advanced over the stiff wire and confirmed to be in correct position, with its proximal edge of fabric lying distal to the coronary ostia and the distal markers of the innominate and carotid branches lying proximal to their respective ostia. At this position, the tapered tip of the device is generally through the valve into the left ventricle (Fig. 2).

The deployment sequence has been modified and simplified through the evolution of the stent-graft design. Currently, the sheath is withdrawn completely to expose the graft under rapid pacing and then, the first three release rings are pulled on the control handle to sequentially deploy it. At this point, the rapid pacing is discontinued, normal rhythm is restored and the tapered tip of the introducer together with the stiff guidewire are removed from the left ventricle. The branches for the IA and LCCA are then cannulated through the right- and the left-sided sheaths, respectively; while the fourth release ring remains in place to retain the distal attachment and stabilise the graft. Bridging of the IA is usually accomplished with a custom-made limb; this can be introduced through the right axillary artery or through a conduit sewn on to it, and it usually requires a stiff wire to be placed into the left ventricle for support. A covered stent is used for bridging of the LCCA, and this may be further supported with a bare self-expanding stent. Direct flow to the IA and LCCA does not cease for any significant time during the procedure.

When a second distal thoracic stent graft is planned, the introducer of the branched stent graft is not removed and the fourth release ring remains in place. The second endograft is inserted through the contralateral femoral artery and is advanced into the branched stent graft, so that at least two stents overlap exists between the two devices (additional stent overlap is preferable). The fourth release ring stabilises the branched stent graft during advancement of the second distal thoracic extension, preventing any infolding or displacement. With the distal thoracic part in place, deployment of the branched graft is completed and its

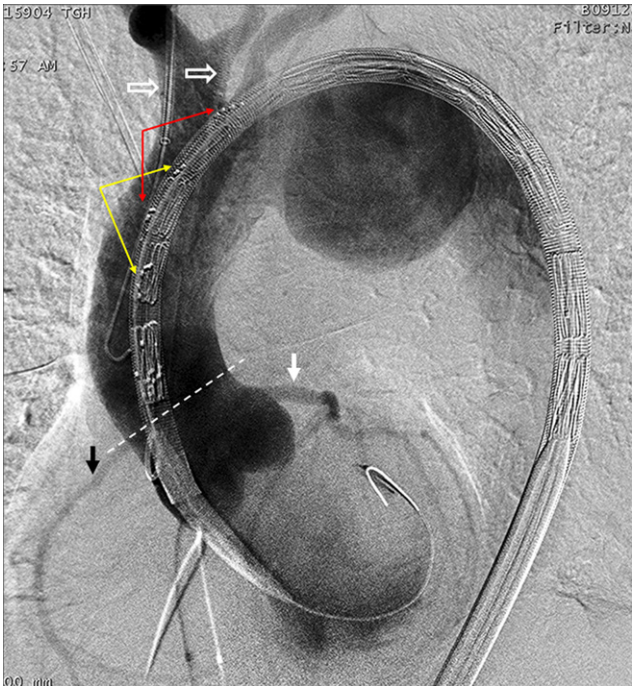

Figure 2. Positioning of the branched stent graft: a double curved stiff Lunderquist guidewire has been placed into the left ventricle. The tapered tip of the graft has been advanced through the aortic valve into the left ventricle. The proximal edge of the branched graft lies distal to the left coronary artery (white arrow) and the right aortocoronary bypass (black arrow); the dotted line indicates this level. The marker of the proximal (yellow arrows) and distal (red arrows) internal branches must lie proximal to the IA and LCCA ostia (in this case common bovine origin). The transparent white arrows indicate the two 6-Fr sheaths placed close to the ostiae of the IA and LCCA.

Table 1
Patient characteristics.

Patient Characteristics	$N = 6$
Age, mean ± SD	73.5 ± 11.9
Male gender	6/6
Smoking	1/6
Diabetes mellitus	1/6
History of CAD	5/6
History of COPD	3/6
History of cancer	2/6
e-GFR < 60	3/6
History of aortic surgery	1/6
ASA score ≥ 4	5/6

introducer is removed, followed by deployment and release of the distal stent graft.

Patient sample

All treated patients were considered high risk for open surgery. From October 2009 to May 2011, six patients were treated with branched endografts (all men; mean age 73.5 years). Four patients were treated at the Montreal Jewish General Hospital (McGill University), one patient at Toronto General Hospital (University of Toronto) and one at Vancouver General Hospital (University of British Columbia). All procedures were performed by a team led by the senior author of this report (Dr C.Z. Abraham). Patient characteristics are shown in Table 1. Fully informed consent was obtained from all patients. Two patients had aortic arch aneurysms, three had descending thoracic aortic aneurysms involving the distal arch and one patient had a saccular aneurysm of the arch adjacent to the origin of the IA (Table 2). All patients had a left carotid–subclavian bypass with an 8-mm synthetic graft 1–2 weeks before the endovascular procedure. Anatomical criteria for patients to be considered a candidate for an endovascular approach are shown in Table 3.

Results

Four patients out of six had uneventful placement of the prostheses, with successful exclusion of their aneurysms. One patient (1/6) developed a type I endoleak that was managed successfully. Aneurysm exclusion without endoleak was therefore achieved in 5 of the 6 patients (one of which who had a secondary procedure to exclude the aneurysm). Eleven of the 12 target vessels were successfully cannulated and preserved (Table 4); in one patient, cannulation of the innominate branch was unsuccessful and an extra-anatomic bypass was necessary to perfuse the right carotid and vertebral arteries. Median procedure time was 330 min (range, 265–360), median fluoroscopy time was 117.5 min (range, 55–170) and median contrast infusion was 215 ml (range, 150–250). The median proximal diameter of the graft was 40 mm (range, 38–46), the median distal diameter was 37 mm (range, 30–40) and the median length of the branched device was 253 mm (range, 231–291). In four patients, a distal thoracic part was used.

Table 3
Anatomical criteria for patients to be considered a candidate for an endovascular approach.

- Ascending aortic diameter ≤ 38 mm,
- Proximal and distal landing zones length ≥ 20 mm,
- IA diameter > 8 mm, LCCA diameter > 6 mm,
- Acceptable tortuosity of the aortic arch, descending thoracic aorta, abdominal aorta and iliac arteries,
- Minimal calcification of the aortic arch,
- Diameter of iliac arteries > 8 mm (appropriate for inserting a 24-Fr size delivery system).

IA: Innominate artery, LCCA: Left Common Carotid Artery.

This is the first reported series for this technology in the literature, and discussion of case-specific difficulties is warranted. Patient 1 had a distal arch aneurysm; however, the arch vessels were very closely spaced so as to preclude a proximal seal without covering the LCCA, and possibly the IA. The custom-made branched stent graft was placed successfully. Postoperative computed tomographic angiography (CTA) at 6 weeks demonstrated a significant endoleak (Fig. 3(a)). Subsequent digital subtraction angiography confirmed a late-filling type Ia endoleak, due to inadequate apposition of the proximal edge of the endograft at the inner curvature of the aortic arch (bird beak configuration) (Fig. 3(b)). The patient underwent elective coiling (eight 12 mm Nester© embolisation coils, Cook Medical, Bloomington, IL, USA) and gluing (Indermil© Tissue adhesive, Covidien, Mansfield, MA, USA) of the aortic aneurysm sac via retrograde femoral percutaneous access with catheter entry into the aneurysm sac between the proximal stent and the aorta. Intraoperative angiography and postoperative CTA confirmed the presence of the contrast-mixed bio-glue within the aneurysm sac, yet no evidence of obvious, ongoing endoleak (Fig. 3(c)). The patient refused follow-up CTA after discharge and was later lost to follow-up.

Patients 2, 3, 5 and 6 had uneventful placement of the endografts with successful exclusion of the aneurysms. Patient 3 had an innominate origin of the LCCA and the orientation of the branches was modified to accommodate easier cannulation of the branches (Fig. 4). Cannulation of the left carotid branch was difficult but successful. The pre-discharge CTA showed compression of the stent grafts placed into the LCCA (9 × 10 mm and 9 × 5 mm Viabahn (W.L. Gore & Associates, Flagstaff, AZ, USA)). This was most certainly caused by crossing of the two branches, which resulted in compression of the carotid branch. A balloon-expandable stent was inserted (7 × 51 mm Express stent (Boston Scientific, Natick, MA, USA)) with good expansion of the covered stent. This remains patent, and the aneurysm remains excluded after 12 months follow-up. This patient had a mild ataxia noted postoperatively, which resolved. Postoperative CT head demonstrated a right

Table 2
Morphological features of the ascending aorta and aortic arch.

Patient	Aneurysm type	Diameter (cm)	Target vessels origin	Diameter of aorta at STJ (cm)	Diameter of aorta at the IA, (cm)	Length of ascending aorta,[a] (cm)	Clock face orientation of LCCA,[b] (°)
1	Distal arch/ DTA	6.4	Separate	3.9	4.1	8.5	60
2	Aortic arch	6.5	Separate	3.2	3.2	6.7	37
3	Aortic arch	5.7	Bovine	3.7	3.7	6.7	Bovine
4	Aortic arch/saccular	3.2	Bovine	3.1	3.1	6.6	Bovine
5	Distal arch/ DTA	6.2	Separate	3.8	3.8	6.7	67
6	Distal arch/ DTA	5.6	Separate	3.4	3.7	5.6	52

DTA: Descending thoracic aorta, IA: Innominate artery, LCCA: Left Common Carotid Artery, STJ: sinotubular junction.
[a] From STJ to IA.
[b] Innominate artery is considered at 0°.

Table 4
Intraoperative parameters and follow-up.

Patient	Target vessels accessed	Exclusion of the aneurysm	Postoperative complications	In hospital stay (days)	Follow-up (months
1	2/2	No-type I endoleak	Renal failure	12	16
2	2/2	Yes	–	8	12
3	2/2	Yes	Minor stroke	9	12
4	1/2	No	Stroke	15	9
5	2/2	Yes	–	6	6
6	2/2	Yes	Cardiac ischemia, c.dif. infection	48	3

cerebellar infarct. The patient was in atrial fibrillation before surgery, and restoration of anticoagulation was delayed because of postoperative thrombocytopaenia. Although the stroke is considered to be procedure related, a cardiac source of the embolus cannot be excluded. The patient fully recovered and was discharged home 10 days postoperatively.

Patient 4 had a saccular aneurysm of the proximal aortic arch, close to the origin of the IA. The ostium of this saccular aneurysm was considered to be too wide to be treated with coil embolisation. The orientation of the branches was modified as a result of attempting to predict the straighter path of access from the supra-aortic vessels into their respective branches (Fig. 5). In hindsight, this was a poor choice; although the carotid branch was easily catheterised, cannulation of the diamond-shaped opening for the innominate branch was not possible, even after prolonged attempts with different combinations of catheters and wires. The small diameter of the aorta at the level of the IA (31 mm, the narrowest in this group of patients) and the modification of the orientation of the branches resulted in firm apposition of the entrance of the innominate branch to the aortic wall and failure to cannulate it. Transfemoral retrograde cannulation of the IA branch using a reversed curve catheter was also attempted but again, propagation of the wire through its opening was not possible. Further attempts of IA cannulation were abandoned, because an antegrade angiography showed diminished flow in the IA and arterial waveforms in the right radial artery were clearly reduced. Due to the length of the procedure at this point, we elected to terminate the procedure and planned to return to the operating theatre for exclusion of the sac later. As both right subclavian and right femoral arteries were exposed, creation of a right femoral–axillary bypass was advocated as the most expedient and simple procedure to perfuse the right carotid and vertebral arteries. This patient, who had significant comorbidities with ischaemic heart disease and multiple myeloma, developed right cerebral stroke with left-sided hemiplegia. However, he had a good recovery and he was discharged home 15 days later. At a second stage, a 16-mm AMPLATZER® Vascular Plugs II (AVP; AGA Medical, Golden Valley, MN, USA) was placed into the IA to occlude retrograde flow. The patient was clinically well at 6 months follow-up but CTA continues to demonstrate a blush of contrast in the aneurysm sac, although the size remains stable.

The postoperative course of Patient 6 was complicated by cardiac ischaemia and a *Clostridium difficile* infection that prolonged his hospital stay to 48 days. The patient remains clinically well and with his aneurysm excluded at 3 months follow-up.

Discussion

Aneurysms that involve the aortic arch extend more commonly to the ascending and/or descending thoracic aorta, while isolated aortic arch aneurysms represent only 4% of all the aortic aneurysms.[13] The natural history of isolated aortic arch aneurysms is poorly defined, and their surgical treatment requires specific expertise. The endovascular treatment of arch aneurysms using branched stent grafts that can be introduced transfemorally is appealing for many reasons. This method is minimally invasive, avoids the need for creating a carotid–carotid bypass, as well as inserting a bulky component through the innominate bifurcation that was often the issue with previous modular arch devices. The theoretical but inherent risk of disassembly of modular devices is also diminished with the integrated design of the transfemoral branched endografts.

Technical considerations for successful insertion of the device involve transfemoral device delivery or aortic/iliac introduction through an arterial conduit, if necessary. Anomalous arch anatomy, dissections, previous ascending aortic repair or large diameter fixation sites may increase complexity or pose a contraindication to the procedure. Increased tortuosity of the aortic arch may make passage of the device and lining up of the branches difficult.

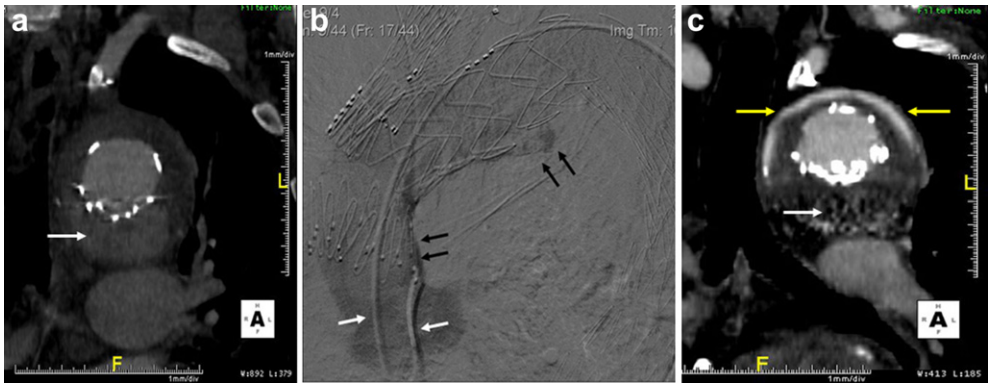

Figure 3. (a) Postoperative CT angiography at 6 weeks showing a significant type Ia endoleak (white arrow) (b)Type Ia endoleak due to protrusion of proximal stent into the aortic lumen at the minor curve. A reversed curve catheter has been placed in the stent graft (white arrows). Contrast infusion through the catheter demonstrates the endoleak (black attows), (c) postoperative day one CT angiography, following coiling and gluing of the aortic aneurysm sac. The white arrows indicate some contrast-mixed glue within the aneurysm sac, yet no evidence of obvious ongoing endoleak.

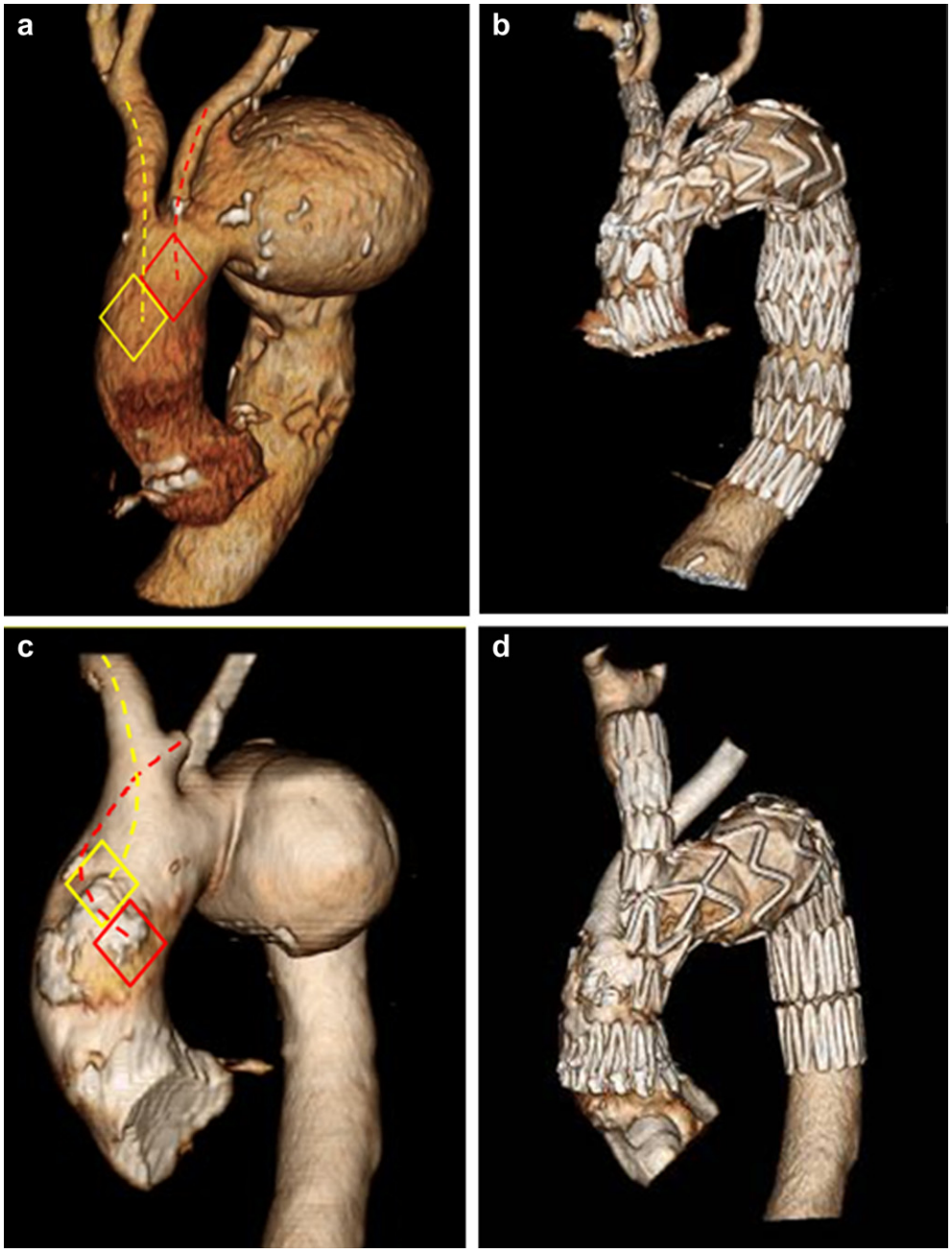

Figure 4. Different positions of branches: (a,b) The branch for the innominate artery is usually the most proximal and the branch for the left carotid artery is the most distal, (c,d) Common origin of the innominate and left carotid arteries ("bovine arch") and design of "crossed-over branches" following the natural direction that the catheters and wires take from the "bovine" vessel origins.

Rotation of the device in the arch is not advised as this can end up with infolding or twisting of the graft. For managing extreme aortic tortuosity, trans-septal techniques with a through and through wire have been described.[14] Characteristics of the IA may challenge the procedure because of its large diameter, short length and occasionally tortuosity. The status of the aortic valve is important because prosthetic or diseased valves are at higher risk of injury or may not be amenable to crossing with the device cone. The use of rapid pacing techniques is essential for accurate deployment of the device.

Endovascular occlusion of the proximal LSA is recommended by the authors during the first stage procedure to prevent thrombosis of the bypass graft between the stages of the operation from competitive flow. However, others prefer to defer this to the second stage procedure, to keep endovascular options open for salvage, should there be a problem with distal maldeployment of the arch-branched graft (personal communication with T. Chuter).

Procedural risks involve injuries of the left ventricle from stiff wire instrumentation and delivery system insertion. Significant challenges exist with respect to the health of the ascending aorta-fixation site and the potential for retrograde dissection. This potential complication may be better characterised in the future as more cases are performed worldwide. The primary concern with this procedure appears to be the potential for stroke (thrombotic/embolic vs. low flow). The incidence of stroke in this series was 2/6 cases. Catheter and wire manipulation on the arch is unavoidable,

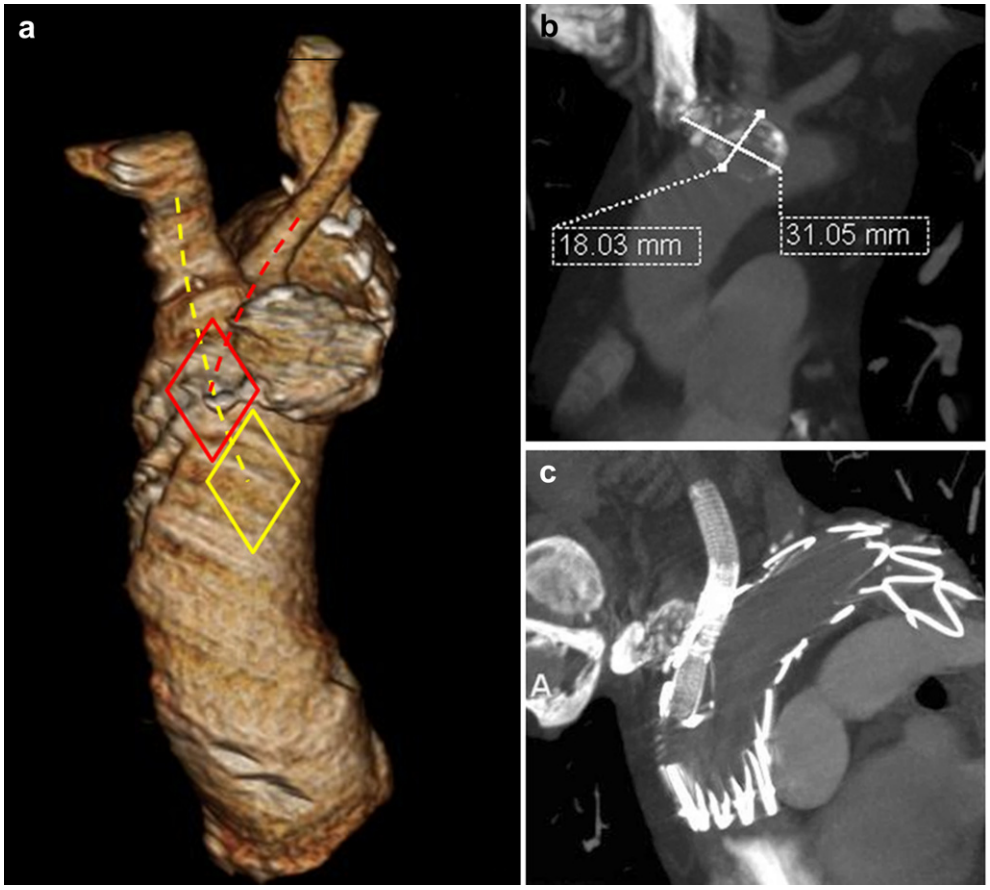

Figure 5. (a,b) Saccular aneurysm of the proximal aortic arch of 3.1 cm diameter, (c) successful exclusion of the aneurysm. The innominate branch was not possible to be cannulated.

and stroke may prove to be the Achilles heel of the procedure. The use of filters to the internal carotid arteries during advancement and deployment of the device into the aortic arch and while cannulating the branches could theoretically reduce the risk of stroke. However, this addition would increase even more the complexity of the procedure, while protection would be incomplete as the posterior circulation would remain at risk of embolism through the right vertebral artery. Indeed, one of the two patients in our series who suffered a stroke had a cerebellar infarct.

In the current report, we have demonstrated the technical feasibility of the endovascular treatment of aortic arch aneurysms with a simplified branched stent graft in a small group of patients. With aortic-branched stent grafts, absolute accuracy in design and placement is necessary. The importance of using a 3-D workstation for planning and a state-of–the-art modern angiosuite for placement of the device cannot be underestimated. Our small series has identified two major concerns. The risk of stroke in these patients remains high. Complex arch anatomy may necessitate extensive instrumentation within the arch during positioning of the stent graft or during cannulation of branches. Strokes may be embolic or result from inadequate cerebral perfusion, as might have been the case in Patient 4. Therefore, hostile anatomy together with excessive arch calcification should be considered contraindications for the endovascular approach. Increased case volume and longer follow-up will better characterise this feared complication. Modification of the orientation of the branches from the usual proximal innominate and distal carotid branch at 12:30 and 11:30 clock positions respectively, proved to be unsuccessful in two of our patients. Future planning of these procedures must take this potential problem into account.

The long-term durability of the branched stent grafts in the aortic arch is unknown. Endografts placed in the ascending aorta and the aortic arch are subject to high, pulsatile forces that may affect the integrity of their structure. Remodelling of the aortic arch over time may also affect their stability, while long-term patency of the branches is another concern. The question also remains regarding the use of these devices for treating type A aortic dissections. Only few case reports or small series are available in the literature regarding endovascular treatment of type A dissections, using different devices.[13–17] Two recent studies tried to delineate the baseline anatomy of patients with type A dissections and their suitability for endovascular repair. According to these studies, one-third to one-half of the patients with type A dissection may be suitable for endoluminar repair.[15,18] In general, the primary objectives of endovascular treatment of type A dissections are sealing of primary fenestration and prevention of retrograde propagation of the dissection, and possibly these objectives can be accomplished with some kind of tubular devices landing distally to the STJ and proximally to the IA or LCCA. In cases that the entry tear approaches the LCCA ostium, the use of branched aortic arch stent grafts could be considered. Certainly, several morphologic characteristics must be met to even consider such a treatment, and even then, applicability of method is questionable.

Owing to the small size of this series and the short follow-up, a comparison with reported outcomes for standard open repair or aortic arch debranching procedures is not possible.[19–24] The present series demonstrates the technical feasibility of the method. Safety and efficacy will be better defined with longer follow-up and increased worldwide experience. The method is

relatively safe based on initial experience, and we currently recommend it to high-risk patients with aneurysms involving the aortic arch and suitable anatomy. The need for intervention should be balanced against the risk for complications or death resulting from it.

Conflict of Interest

Dr C. Abraham is a paid consultant for review of cases and case proctoring for Cook Medical. The other authors have no conflict to report related to this publication.

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