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ENDOVASCULAR AND HYBRID PROCEDURES FOR AORTIC ARCH ANEURYSMS

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Endovascular treatment of aneurysms and aortic dissection involving the descending thoracic aorta has been shown to be an excellent alternative to open surgery. Endoluminal techniques have particular advantages for the elderly as it avoids the need for open thoracotomy, aortic cross-clamping and can be performed under local or regional anesthesia. The use of stent-grafts in the thoracic aorta has progressed to include the treatment of aneurysms of the aortic arch in patients without an adequate proximal landing zone. This requires open bypasses of the great vessels followed by endovascular aneurysm repair.

Conventional open surgical repair of aortic arch aneurysms using cardiopulmonary bypass and deep hypothermic circulatory arrest still carries a substantial mortality and morbidity, especially in the elderly. The early mortality is 8.5% to 25.2% for elective procedures and as high as 53.3% for emergencies. Even with brain protection and selective cerebral perfusion, this procedure is associated with a high incidence of permanent neurological injury.

The curvature of the aortic arch and the presence of the great vessels make the placement of a stent-graft in the aortic arch challenging. To achieve an adequate landing zone for a stent-graft in the aortic arch, it is usually necessary to cover the origins of some or all of the great vessels. The endoluminal alternative to open surgery requires either a branched stent-graft or a combination of open bypass surgery and endovascular repair. Unfortunately the positioning of a fenestration in the correct position in the aortic arch is technically challenging due to the tortuosity of the vessels and the lack of one-to-one torque at such a remote site from the access vessel.

Anatomical landing zones

To allow comparison of results from different centers an *anatomical endograft landing zone map* has been developed. The aim of the map is to classify the proximal deployment site of a thoracic stent. The ascending aorta and arch are divided into four zones (Fig. 1).

- Zone 0 ascending aorta to just beyond the origin of the innominate artery.
- Zone 1 from just beyond the origin of the innominate to just beyond the origin of the left common carotid artery.
- Zone 2 from just beyond the origin of the left common carotid artery to just beyond the origin of the left subclavian artery.
- Zone 3 from just beyond the origin of the left subclavian artery to the start of the descending thoracic aorta.

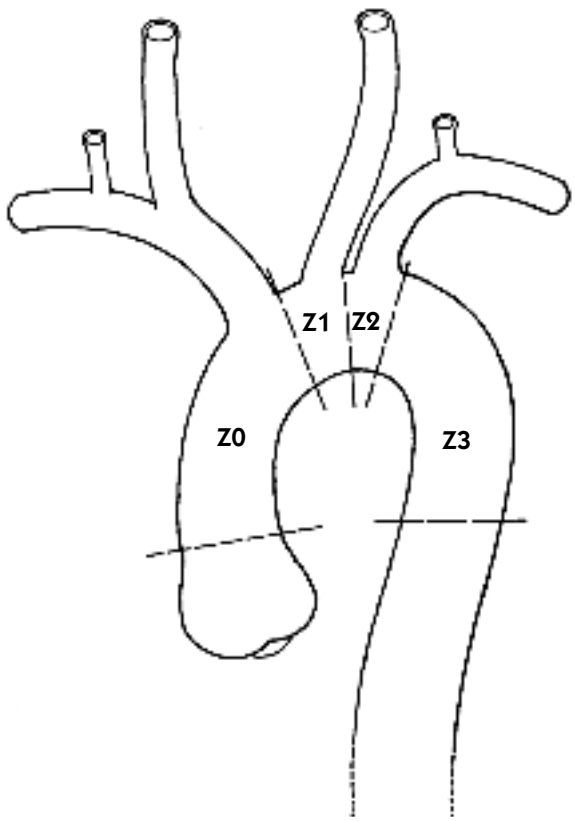

FIG. 1 Diagram of the anatomical landing zones for thoracic stents in the aortic arch.

Intentional occlusion of the origin of the left subclavian artery

Covering the origin of the left subclavian artery is often necessary with endovascular repair of aneurysms and dissections involving the proximal descending thoracic aorta and distal aortic arch. In theory covering the origin of the left subclavian artery can result in left arm ischemia, subclavian steal syndrome, posterior circulation stroke, a type II endoleak and increase the risk of spinal cord ischemia. However, covering the origin of the left subclavian artery appears to be well tolerated and pre-emptive revascularization is not usually required [1-3]. This is because the muscular arterial branches in the neck and shoulder girdle serve as collaterals to the left arm and vertebro-basilar circulation.

The two common indications for left subclavian revascularization prior to endovascular repair are previous coronary artery bypass surgery using the left internal mammary artery [4] and renal patients with an arteriovenous fistula for hemodialysis in the left arm. Less frequent indications include occlusive disease of the innominate, right subclavian and right vertebral arteries and very rarely there may be a common origin of the left common carotid and left subclavian arteries. Routine carotid and vertebral artery imaging is advised before endovascular repair of arch aneurysms to look at vertebral artery patency and dominance. Frequently one vertebral artery has a larger diameter than the other and if this is on the left side then revascularization may be required. Occlusion or stenosis of the right vertebral artery and antegrade flow in the left vertebral would be an indication for left subclavian revascularization prior to endovascular repair, to reduce the risk of posterior circulation stroke. Bilateral severe internal carotid artery stenoses or occlusion of the right internal carotid artery and a severe stenosis of the left internal carotid artery may be an indication for left carotid endarterectomy prior to intentional coverage of the left subclavian artery.

The surgical options for left subclavian artery revascularization are left subclavian transposition or carotid-subclavian bypass. These operations have an associated mortality (1.2%), nerve injury (10%), stroke (5%), lymph leak (2%) and graft infection (1.2%) [5]. They should therefore be restricted to patients who have a definite indication for left subclavian revascularization.

There are endovascular techniques to avoid occlusion of the left subclavian artery by using branched [6] or fenestrated stent grafts [7]. The reports of these techniques are currently limited to case reports.

Intentional coverage of the left subclavian artery is tolerated very well and prophylactic transposition is not usually required (Table I). Some patients do experience exercise-induced forearm pain and symptoms of subclavian steal syndrome. If the postoperative symptoms are significant, left subclavian-carotid transposition can be performed electively. However, the majority require no further intervention.

Table I REQUIREMENT FOR REVASCULARIZATION OF THE LEFT SUBCLAVIAN ARTERY AFTER INTENTIONAL OCCLUSION WITH THORACIC STENT

First author	*Ref.*	*Year of publication*	*Number*		
			Left subclavian artery covered	*In-hospital revascularization*	*Late surgery*
Görich	2	2002	23	3	0
Palma	8	2002	14	0	1
Rehders	1	2004	22	0	0
Melissano	9	2005	18	3	0
Personal experience		2005	40	1	0

Intentional occlusion of the left subclavian and left common carotid arteries

To create a satisfactory landing zone for distal arch aneurysms, it can be necessary to cover both the origins of the left common carotid and left subclavian arteries. In contrast to the left subclavian artery, the left common carotid should always be bypassed prior to endovascular repair to prevent stroke. The simplest method for left common carotid revascularization is a right-to-left carotid bypass. This requires a prosthetic graft and end-to-side anastomosis on the right common carotid and end-to-end anastomosis on the left common carotid with ligation or oversew of the proximal left common carotid artery (Fig. 2). The graft can easily be tunnelled around the front of the trachea underneath the strap muscles, although some authorities recommend the more direct retropharyngeal route passing behind the pharynx and the esophagus.

Intentional coverage of the left subclavian, left common carotid and innominate origins

Endovascular repair of aneurysms involving the whole aortic arch is possible if the patients have pre-emptive revascularization of the innominate and left common carotid arteries. Some authors also suggest that left subclavian artery revascularization should also be included. There are several options for surgical bypass.

1-Inverted bifurcated graft from the ascending aorta to the innominate and left common carotid arteries (Fig. 3).

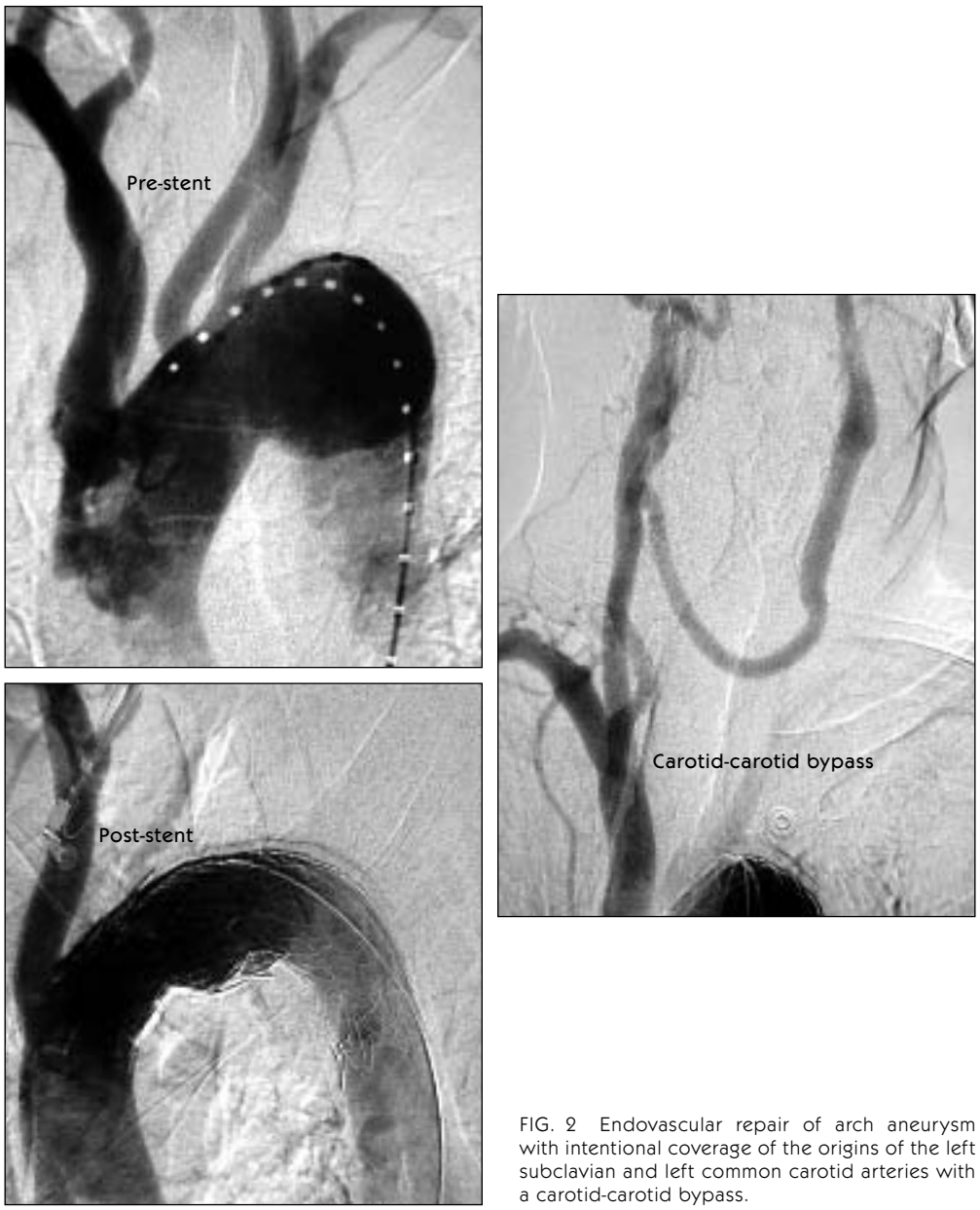

FIG. 2 Endovascular repair of arch aneurysm with intentional coverage of the origins of the left subclavian and left common carotid arteries with a carotid-carotid bypass.

2-Graft from the ascending aorta to the innominate (end-side anastomosis) and left common carotid arteries (end-to-end anastomosis) (Fig. 4).

3-Graft from the ascending aorta to the innominate (or proximal right subclavian artery) and separate right-to-left carotid-carotid bypass (Figs. 5, 6).

4-Bypass from the right common femoral artery to the right axillary artery and then to the right common carotid artery followed by a right-to-left carotid-carotid bypass.

5-Bypass from the right common femoral artery to the innominate artery, followed by a right-to-left carotid-carotid bypass.

In the first three options, where the ascending aorta is exposed, a polyester wrap around ascending aorta at the site of the proximal landing zone can help secure fixation of the *stent-graft.*

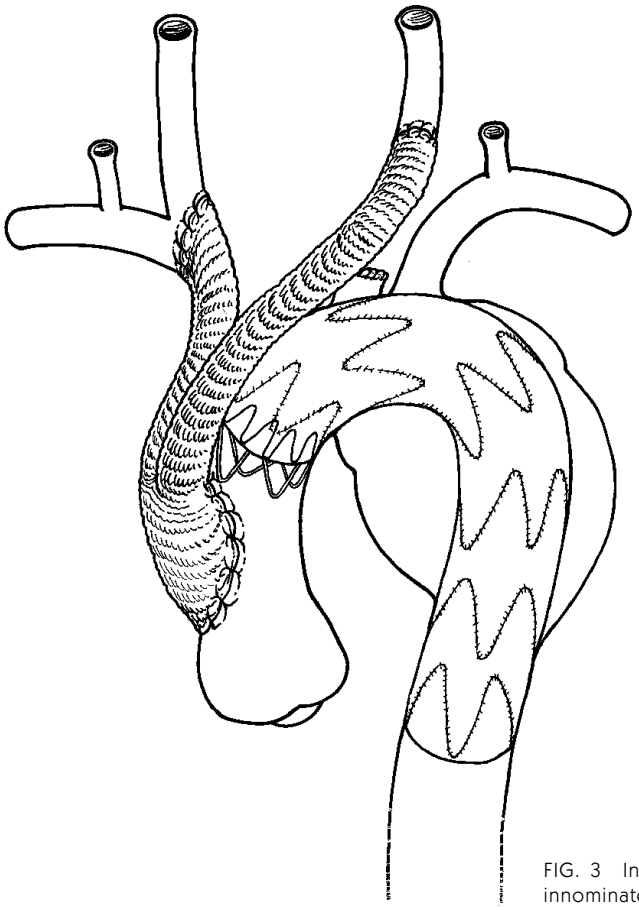

FIG. 3 Inverted bifurcated graft from the ascending aorta to the innominate and left common carotid arteries.

FIG. 4 Arteriogram showing endovascular repair of an aortic arch aneurysm with a bypass from the ascending aorta to the innominate artery.

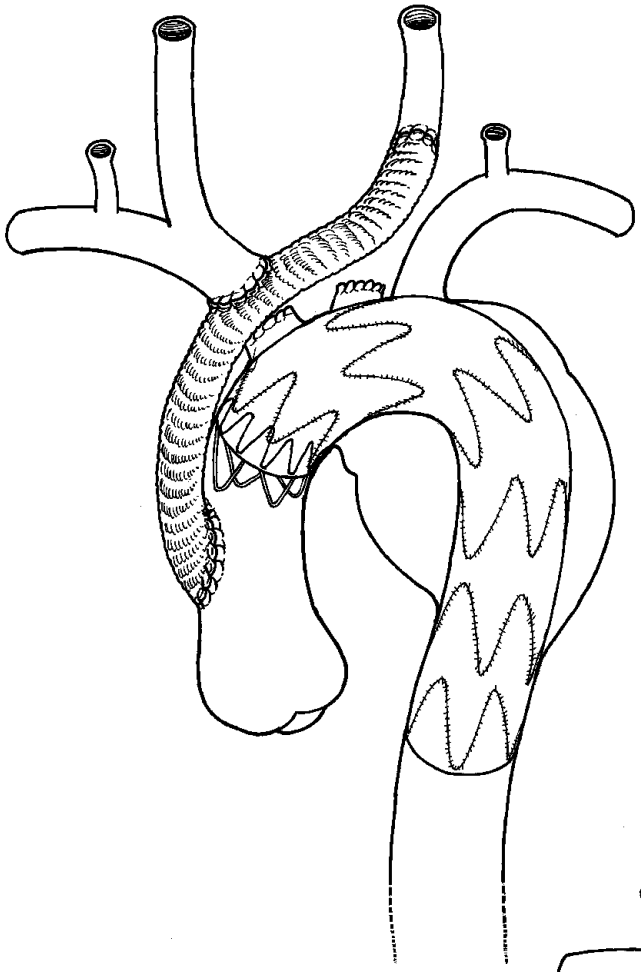

FIG. 5 Graft from the ascending aorta to the innominate and left common carotid arteries.

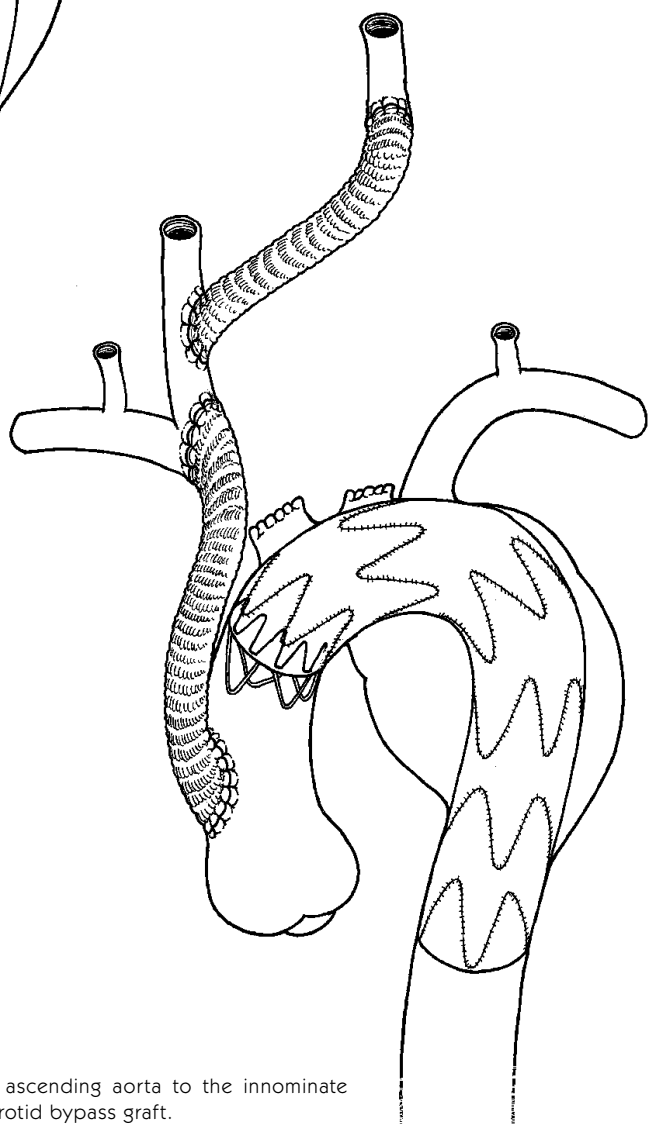

FIG. 6 Graft from the ascending aorta to the innominate and separate carotid-carotid bypass graft.

Published experience of endovascular repair of aortic arch aneurysm is limited (Table II). Revascularization of the innominate and left common carotid arteries can be performed without cardiopulmonary bypass through a partial sternotomy. It is not normally necessary to cross-clamp the ascending aorta as the proximal anastomosis can be performed with a side –biting clamp on the aorta. Most patients well tolerate this procedure but it does involve opening the chest and general anesthesia. For patients who are too unfit to have a sternotomy it is possible to perform an extra-anatomical bypass from the common femoral or iliac artery to the innominate and left common carotid arteries. One problem with a bifurcated graft originating from the ascending aorta (example 1) is that one limb can thrombose with disastrous results. To avoid this a single large graft (10 to 12 millimeter diameter) is recommended from the ascending aorta to the innominate artery and then a separate graft can be taken for the carotid-carotid bypass (example 2). The latter example is our preferred option.

The largest published experience comes from Bergeron et al. [16] comprising 29 patients who required hybrid procedures for a variety of aortic pathologies including aneurysms (n = 15), type A dissection (n = 6), type B dissection (n = 7) and one false aneurysm. Eleven patients had a median sternotomy and sixteen patients had a carotid-carotid bypass. Two patients died (mortality 7.7%) and one patient suffered a major stroke. Another patient suffered a delayed minor stroke. One patient developed unilateral limb weakness which improved with CSF drainage. The follow-up was an average of 15.7 months and one further patient had a late stroke. Two out of 15 aneurysms had endoleaks at follow-up and 27.3% of dissections had patent false lumens.

Although the overall published experience is small (49 patients), the results are reasonable although there is a significant mortality and risk of stroke (Table II).

Table II REVIEW OF PUBLISHED DATA FOR HYBRID PROCEDURES FOR AORTIC ARCH ANEURYSMS

First author [ref]	*Year of publication*	*N of cases*	*Whole arch (Innominate, LCCA & LSA)*	*LCCA & LSA*	*LSA*	*Mortality*	*Neurological complications*	*Follow-up Months*
Criado [11]	2002	13	-	3	10	-	-	
Kato [10]	2002	3	2	-	1	-	1/3	
Schumacher [12]	2003	28	3	5	20	1/8	-	16
Czerny [13]	2004	5	-	5	-	-	-	10
Czerny [14]	2004	19	-	2	17	-	-	
Kieffer [15]	2004	16	8	8	-	3/16	2/16	
Bergeron [16]	2005	29	11	16	29	2/29	3/29	15.7
Melissano [9]	2005	30	6	6	18 (3•)	2/30	1/30	23
Personal experience	2005	49	1	8	40 (1•)	2/49	2/49	

LCCA: left common carotid artery
LSA: left subclavian artery
• Number of patients who had pre-emptive subclavian revascularization

Conclusion

The role of endovascular treatment of thoracic aortic disease has been extended to the treatment of aortic arch aneurysms. For the elderly and those unfit for major surgery, this hybrid technique is preferable to open surgery as it avoids aortic cross-clamping and deep hypothermic arrest. The initial results of hybrid procedures to the aortic arch are promising. However, there is a risk of stroke and death associated with the procedure, particularly when the entire arch is involved.

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