Hybrid treatment for complex thoracic aortic disease: Imaging findings and interventional radiologic management.

Poster No.: C-0818
Congress: ECR 2014
Type: Educational Exhibit
Authors: S. Seitun¹, I. Budaj¹, M. Dahmane², M. Castiglione Morelli¹, S. Boccalini¹, A. Galletto¹, F. Scarano¹, G. Passerone¹, C. Ferro¹; ¹GENOVA/IT, ²Genova (GE)/IT
Keywords: Interventional vascular, Arteries / Aorta, Vascular, CT, CT-Angiography, Catheter arteriography, Arterial access, Computer Applications-Detection, diagnosis, Diagnostic procedure, Aneurysms, Dissection, Hemorrhage
DOI: 10.1594/ecr2014/C-0818

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Learning objectives

The purpose of our educational exhibit is to:

1. describe the hybrid procedures techniques
2. highlight the role of diagnostic and interventional radiology in the combined surgical and endovascular approach (hybrid treatment) of thoracic aortic diseases
3. illustrate the typical pre- and post-operative imaging findings at Multidetector Computed Tomography (MDCT). A review of the main pre- and post-operative imaging findings of 69 patients treated with hybrid approach was performed for this purpose.

Background

Hybrid treatment is a combined surgical/endovascular procedure, developed thanks to the recent improvement of new imaging, surgical, and interventional techniques and materials. For the management of complex thoracic aortic disease of the ascending aorta, aortic arch and proximal descending aorta (degenerative aneurysms, aortic dissection, penetrating atherosclerotic ulcer or aortic intramural hematoma), surgery is burdened by high rates of morbidity and mortality and hybrid surgical/radiological procedures are preferable [1-3].

Innovations in thoracic endovascular aortic repair (TEVAR) techniques have enabled its incorporation in open procedures, resulting in a hybrid approach to aortic arch repair [4-5].

A recent meta-analysis of hybrid supra-aortic debranching and stent graft repair [1] reported a pooled analysis of 275 patients showing a mean 30-day mortality rate of 15%, stroke rate of 8% and paraplegia rate of 2%.

Findings and procedure details

Type of surgery techniques preceding endovascular treatment:

*Extra-anatomic bypass*, [4-5]:

1. Carotid-subclavian bypass (Fig. 1 on page 6 and Fig. 2 on page 6)
2. Carotid-carotid bypass (Fig. 3 on page 7)
3. Carotid-carotid + carotid-subclavian bypass (Fig. 4 on page 8 and Fig. 5 on page 8)

**LSA Revascularization**

LSA is an important source of blood flow to the left arm but it also plays an important role for the collateral pathways to the cerebellum -via the left vertebral artery (VA)- and the spinal cord -via the left VA to the anterior spinal artery, and collateral perfusion to the left intercostal vessels through the internal mammary and thoracodorsal arteries.

**When revascularization of the LSA is strongly recommended, [6-10]:**

- Occluded or severely stenosed right VA
- Clearly dominant left VA
- Discontinuity of the vertebrobasilar system
- Presence of a patent left internal mammary artery to coronary artery by-pass graft
- A functioning dialysis access fistula in the left arm
- In high risk patients for spinal cord ischemia:
  - patients requiring extensive coverage of the thoracic aorta where critical intercostal arteries originate;
  - patients who have undergone infrarenal aortic surgery (ligation of lumbar and middle sacral arteries);
  - patients with compromised hypogastric blood supply

**Debranching of epiaortic vessels with sternotomy or ministernotomy [4-5; 11-14]:**

1. Partial debranching: End-to-side graft from ascending aorta to innominate artery and right common carotid artery -> left common carotid artery ± left common carotid artery -> left subclavian artery bypass (Fig. 6 on page 9)
2. Partial debranching: Bifurcated end-to-side graft from ascending aorta to innominate artery and left common carotid artery ± left common carotid artery -> left subclavian artery bypass (Fig. 7 on page 9)
3. Total debranching: Trifurcated end-to-side graft from ascending aorta to all supra-aortic vessels (Fig. 8 on page 10)

**Aortic arch replacement with sternotomy [4-5; 11-14]:**
1. En bloc total arch replacement ([Fig. 9 on page 10](#)): using an island of aortic tissue, epiaortic vessels are attached to a corresponding opening into the convex portion of the prosthetic graft.

2. When the arch is heavily calcified, separated anastomoses of individual grafts to the arch vessels are performed ([Fig. 10 on page 11](#))

3. Dacron branched grafts designed for total aortic arch replacement may be used for this purpose ([Fig. 11 on page 11](#))

**Elephant-trunk and Frozen Elephant-trunk techniques [15-17]:**

1. Aortic arch replacement (± replacement of ascending tract) with elephant trunk technique ([Fig. 12 on page 12](#)): a free-floating extension of the arch prosthesis, the so-called "elephant trunk" (usually 5- to 7-cm long), is left behind in the proximal descending aorta. This technique facilitates subsequent endovascular treatment (TEVAR) on the downstream aorta which, in our experience, could be performed in the same stage, avoiding the requisite thoracotomy or thoracoabdominal incision, mandatory in the traditional second surgical stage.

2. Aortic arch replacement (± replacement of ascending tract) with frozen technique ([Fig. 13 on page 12](#)). This procedure is adapted from the previous technique, with E®-vita prosthesis placement (Jotec, Hechingen, Germany). E®-vita is a hybrid vascular graft consisting of a conventional tube graft with an endovascular stented graft in the distal end ([http://www.jotec.com/english/produkte-hybrid.pml](http://www.jotec.com/english/produkte-hybrid.pml)).

**Role of Imaging**

MDCT technology with ECG-gating for thoracic aorta improves spatial/temporal resolution and minimizes motion artifacts and examination time, thus:

1. allowing optimal one-step assessment of entire aorta, mediastinal structures, and lungs
2. providing optimal visualization of the coronary arteries
3. including in the same session also the intracranial vasculature and the iliac-femoral arteries.

**Treatment planning**
According to the classification that was initially described by Balm et al. [18], then modified by Mitchell et al.[19], and used in published reports by Criado et al.[20], the level and extension of aortic involvement are defined by using an "arch zone map" (Fig. 14 on page 13) that has since been embraced by many around the world and incorporated in several clinical trial protocols. The classification divides the arch into actual four zones that could be used to define precisely the site of proximal fixation of a thoracic stent-graft. On this basis, the operative strategy is decided and procedure planning and materials are defined.

Role of the Diagnostic/Interventional Radiologist - Patient and pathology management - (Fig. 15 on page 13)

- Choice of the type of endovascular procedure
- Choice of the vascular accesses
- Patient evaluation
- MDCT scan review (site and extension of the pathology) and stent-graft planning
- Choice of the devices
- Imaging follow-up, which allows prompt recognition of complications, which is crucial for immediate management

Role of the Interventional Radiologist - Technical issues -

- Positioning of aortic endograft
- Other related procedures (before or after endograft)
- LSA occlusion (possible use of vascular plug)
- Possible PTA/stenting of iliac arteries
- Aortic fenestration
- Management of complications (e.g. vascular thrombosis, iliac dissection, embolism)

Pre- and post-operative imaging findings at MDCT

Fig. 16 on page 14 and Fig. 17 on page 14 illustrate a case of an aortic arch aneurysm treated with sequential extra-anatomic by-pass followed by endograft repair.

Fig. 18 on page 15, Fig. 19 on page 15 and Fig. 20 on page 16 illustrate a case of a chronic type-B aortic dissection managed with epiaortic vessels debranching with bifurcated graft and left common carotid -> left subclavian artery by-pass followed by endograft repair.
Fig. 21 on page 16 illustrates a case of an aortic arch aneurysm treated with total debranching using a trifurcated graft followed by endograft repair.

Fig. 22 on page 17 illustrates steps of the surgical part of the hybrid procedure (total debranching using a trifurcated grafts to all supra-aortic vessels) and the MDCT correlation for the treatment of extensive thoracic aortic disease.

Fig. 23 on page 17 and Fig. 24 on page 18 illustrates a case of an aortic aneurysm involving the aortic arch and the descending thoracic aorta, managed with total debranching using three separated graft anastomoses followed by stent-graft repair.

Fig. 25 on page 18 and Fig. 26 on page 19 illustrate a case of a huge aneurysm of the aortic arch and descending thoracic aorta with extensive wall thrombosis treated with elephant-trunk technique followed by stent-graft repair.

Fig. 27 on page 19 and Fig. 28 on page 20 illustrate a case of a huge aneurysm of the aortic arch and descending thoracic aorta with extensive wall thrombosis managed with frozen elephant-trunk technique followed by stent-graft repair.

Images for this section:
Carotid-subclavian bypass

LCC = left common carotid artery
LSA = left subclavian artery

1. LCC → LSA bypass
   + endovascular embolization of proximal LSA

Fig. 2

Carotid-carotid bypass

2. Carotid-carotid bypass
   + surgical ligation of LCC artery

Fig. 3
Revascularization of epiaortic vessels using bypass grafts

RCC = right common carotid artery
LCC = left common carotid artery;
LSA = left subclavian artery;

3. RCC→LCC + LCC→LSA bypass
direct bypass + surgical ligation of LCC artery and proximal LSA

Fig. 4

Revascularization of epiaortic vessels using bypass grafts

RCC = right common carotid artery
LCC = left common carotid artery;
LSA = left subclavian artery;

3. RCC→LCC + LCC→LSA bypass
sequential bypass + surgical ligation of LCC artery and proximal LSA

Fig. 5
1. Partial debranching
   *End-to-side graft from ascending aorta to IA and RCC → LCC ± LCC → LSA bypass*

2. Partial debranching
   *Bifurcated end-to-side graft from ascending aorta to IA and LCC ± LCC → LSA bypass*

In all procedures ligation of the proximal stump of epiaortic vessels is performed to prevent type-2 endoleak.
Type of debranching of epiaortic vessels

IA = innominate artery
RCC = right common carotid artery
LCC = left common carotid artery
LSA = left subclavian artery

3. Total debranching
Trifurcated end-to-side graft from ascending aorta to all supra-aortic vessels

In all procedures ligation of the proximal stump of epiaortic vessels is performed to prevent type-2 endoleak

Fig. 8

Type of aortic arch replacement

1. En bloc total arch replacement

Fig. 9
2. Aortic arch replacement using separated anastomoses of individual grafts to the arch vessels

3. Aortic arch replacement using Dacron branched grafts for the separated anastomoses to the arch vessels
“Elephant-trunk” Technique

A free-floating extension of the arch prosthesis, the so-called “elephant trunk” (usually 5- to 7-cm long), is left behind in the proximal descending aorta. This technique facilitates subsequent endovascular treatment (TEVAR) on the downstream aorta.

Fig. 12

Frozen “Elephant-trunk” Technique

Frozen elephant trunk technique is adapted from the previous technique, with E®-vita placement.

E®-vita is a hybrid vascular graft consisting of a conventional tube graft with an endovascular stented graft in the distal end

http://www.jotec.com/english/produkte-hybrid.pml

Fig. 13
The aortic arch is divided into four zones. The position of the proximal end of the endograft is classified according to this system.

**Fig. 14**

**Stent graft Planning**

**Treatment planning**
(from the radiological point of view)

**Vessel analysis**

The report:
- Diameters and length of diseased aorta
- Extension of aortic wall disease
- Proximal and distal neck
- Diameters and disease burden on
  - Iliac and femoral vessels
  - Supraaortic and intracranial branches
  - Visceral arteries

**Fig. 15**
**Fig. 16**

a. MDCT before hybrid procedure. Arch aneurysm with eccentric wall thrombosis. The origin of the left subclavian artery (LSA) is included into the aneurysm. b. MDCT after sequential right common carotid - left common carotid (CC) bypass (arrows) and left CC to LSA bypass (arrowheads).

**Fig. 17**

In this patient thight stenosis of the left common iliac artery was found on MDCT. PTA + stenting (c, d) were performed in order to provide vascular patency for the following passage of the aortic graft. e. Aortography shows patency of sequential bypasses and deployment of aortic stent graft. f. Volume rendering image of the thoracic aorta confirms correct position of the stent-graft and bypasses patency; note the stump of the left CC (arrowhead).
Chronic type-B Aortic Dissection (AD) - Total debranching -
M 57 y/o, uncomplicated acute type-B AD with entry site just distal to the LSA → management with medical therapy

Progressive false lumen expansion (>5 mm / 1 month)

Fig. 18

Fig. 19
Fig. 20

Chronic type-B Aortic Dissection (AD) - Total debranching -

a. Chronic type B dissection with progressive diameter enlargement (> 5.5 cm) due to false lumen expansion. Supra-aortic debranching was performed with bifurcated graft. b. Stent-graft deployment. Note the left CC-LSA bypass (arrows). c. Proximal occlusion of LSA through ipsilateral brachial approach. d, e. MIP and VR image demonstrating correct positioning of graft with patency of bypass (arrows); see also plug occlusion of the LSA (circle).

Fig. 21

Aortic Arch Aneurysm - Total debranching -

a. Huge aneurysm (75 mm) of the lesser curvature of the aortic arch. The aortography was acquired after total debranching with placement of a trifurcated graft (arrowheads). b. Graft deployment. c. Aortography demonstrating correct position of the stent-graft, that excludes completely the aneurysm but mildly protrudes into the sac (arrow). MIP (d) and VR (e) MDCT images at 1 month follow-up confirm aneurysm exclusion and patency of the surgical grafts.
**Type of debranching of epiaortic vessels**

**Fig. 22**

a, b and c. Trifurcated grafts. Note external radio-opaque thread landmarks in surgical sponges in the ascending aorta (arrows in a) for stent-graft placement without pre-deployment angiography.

In b and c, radiographic markers placed around proximal anastomosis to facilitate identification of the graft origin under fluoroscopy.

**Thoracic Aortic Aneurysm (TAA)**

**Fig. 23**

a. Perpendicular cross-section image shows huge aneurysm of the aortic arch without neck from the left CC (arrow).

b, c. Sagittal oblique MPR and corresponding cross-section image show a second large aneurysm of the descending thoracic aorta. The sagittal oblique MPR (b) and VR (d) images confirm the two aneurysms with angulation of the aorta at the thoraco-abdominal gate. A saccular dilatation at the medio-toracic level is demonstrated too (arrow in b).
Fig. 24

a, b. Oblique MPR and VR images: the entire aneurysmal aorta is displayed. Complete debranching was done but, due to the badly diseased wall of the ascending aorta the surgeon decided to perform three separated graft anastomoses (arrowheads in b). In this patient, due to concerns on procedure duration and patient’s clinical conditions, endovascular procedure was done 1 week after surgery. c. VR image acquired 1 week after the endovascular step, shows correct stent-graft position with exclusion of the three aneurysms and patency of surgical grafts.

Fig. 25

a. Sagittal oblique MPR image shows huge aneurysm of the arch and descending thoracic aorta with extensive wall thrombosis. b. Sagittal oblique MPR image after elephant trunk («free floating» prosthesis, arrows) procedure. c. VR reconstruction well displays elephant trunk and supraaortic vessels implantation using an island of aortic tissue.
**Fig. 26**

Aortography of the elephant trunk before (d) and after (e) endograft deployment. f. VR image acquired 1 week after the intervention shows correct graft position and patency of supraaortic vessels.

**Fig. 27**

a, b, c. Sagittal and coronal oblique MPR images show huge aneurysm of the arch and descending thoracic aorta with extensive wall thrombosis.
**d, e.** Stent-graft deployment into the E-vita prosthesis and subsequent ballooning at the stent-graft overlap to ensure endograft expansion. **f.** Sagittal oblique MIP images shows complete exclusion and thrombosis of the aneurysm, without endoleak. Patient underwent previously abdominal stent-graft repair (arrow).

Fig. 28
Conclusion

Hybrid technique is a safe, effective and less invasive alternative to open surgery, especially in high-risk patients with multiple comorbidities.

The diagnostic and interventional radiologists play a key role for the treatment planning, for the selection of the most appropriate hybrid approach and for the imaging follow-up.

Personal information

S. Seitun Department of Radiology and Interventional Radiology, IRCCS-University Hospital San Martino-IST, Genova, Italy saraseitun@yahoo.com

I. Budaj Department of Radiology and Interventional Radiology, IRCCS-University Hospital San Martino-IST, Genova, Italy.

M. Dahmane Department of Radiology and Interventional Radiology, IRCCS-University Hospital San Martino-IST, Genova, Italy.

M. Castiglione Morelli Department of Radiology and Interventional Radiology, IRCCS-University Hospital San Martino-IST, Genova, Italy.

S. Boccalini Department of Radiology and Interventional Radiology, IRCCS-University Hospital San Martino-IST, Genova, Italy.

A. Galletto Department of Radiology and Interventional Radiology, IRCCS-University Hospital San Martino-IST, Genova, Italy.

F. Scarano Department of Cardiac Surgery, IRCCS-University Hospital San Martino-IST, Genova, Italy.

G. Passerone Department of Cardiac Surgery, IRCCS-University Hospital San Martino-IST, Genova, Italy.

C. Ferro Department of Radiology and Interventional Radiology, IRCCS-University Hospital San Martino-IST, Genova, Italy.
References


