Transposition of the supraaortic branches for extended endovascular arch repair

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Abstract

Background: Supraaortic branches limit extended application of endovascular aortic repair. For this purpose, we applied extensive reconstructions.

Methods: Between October 2002 and March 2005, 11 patients (mean age 72.3 years) presented with acute or chronic aortic diseases originating from the aortic arch (arch aneurysms n = 8, type B dissections n = 3). Treatment was by autologous sequential transposition of the left carotid artery into the brachiocephalic trunk and of the left subclavian artery into the already transposed left common carotid artery in nine patients and by additional reconstruction of the brachiocephalic trunk in two patients. Endovascular stent-graft placement was successfully performed thereafter.

Results: Procedure-related mortality was 0%. At completion angiography, all reconstructions were fully patent. One patient had a small type Ia endoleak that resolved spontaneously within one week. Mean follow-up was 18 months (1—29 months). One patient underwent redo stent-graft placement after 25 months due to a type III endoleak. The remaining patients had normal follow-up CT scans with regular perfusion of the supraaortic branches without any signs of endoleaks.

Conclusions: Extended application of this technique will enable safe and effective treatment of a highly selected group of patients by avoiding conventional repair.

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1. Introduction

Endovascular stent-graft placement has been developed as a safe and effective treatment modality in various diseases of the descending aorta [1—4]. In case of involvement of the aortic arch, innovative vascular surgical approaches to maintain cerebral perfusion have been developed to enable safe and effective endovascular repair [5—12]. Depending onto the extent within the arch, autologous approaches or approaches using alloplastic graft material to maintaining cerebral perfusion may be used [5,11].

The aim of this study was to evaluate the safety and efficacy of combined repair of acute dissections as well as chronic atherosclerotic aortic aneurysms by extensive supraaortic rerouting and endovascular stent-graft placement.

2. Patients and methods

Between October 2002 and March 2005, 11 patients were submitted to our department with acute dissections as well as chronic atherosclerotic aortic aneurysms. There were seven men and four women with a mean age of 72.3 years. All patients had significant comorbidities such as diffuse coronary artery disease with consecutively low left ventricular ejection fraction, diabetes mellitus, hypertension, chronic renal insufficiency as well as obesity. One patient suffered from multiple organ ischemia due to diffuse peripheral embolization originating from a local dissection at the concavity of the aortic arch. Mean EuroSCORE in these patients was 9. Therefore, conventional surgical repair was deemed not suitable.

2.1. Preoperative evaluation and surgical approach

Preoperative evaluation was done by multislice CT scans in order to exclude major occlusive disease of the supraaortic branches as well as of the aortoiliac axis — for later arterial access for stent-graft insertion — and to reassure that a sufficient proximal neck of at least 2 cm along the lesser
curvature of the aortic arch would become available after rerouting. In patients undergoing autologous transposition of the supraaortic branches, an upper hemisternotomy was chosen and the skin incision was extended parallel to the upper margin of the left clavicle in order to achieve sufficient mobilization of the left common carotid and the left subclavian artery up to an extrathoracic level. In patients undergoing total arch rerouting, a full median sternotomy approach was chosen. We did not in particular focus upon the competence of the circle of Willis. Intraoperative neuromonitoring was not applied in these patients. Cerebral perfusion control was by the arterial line in the right radial artery.

2.2. Autologous double transposition

The original method has been described in detail previously [10]. After systemical heparinization with 80 IU/kg bodyweight, the left common carotid artery was dissected free and clamped. The vessel was transversely divided. Consecutively, the brachiocephalic trunk was partially clamped, longitudinally opened and a side-to-end anastomosis was performed. An analogous procedure was carried out between the left subclavian artery and the already transposed left common carotid artery (Fig. 1).

2.3. Total arch rerouting

After median sternotomy, the pericardium was opened and the ascending aorta was exposed in usual fashion. Afterwards, the anonymous vein was circumferentially dissected beginning from the left confluence of the internal jugular vein and the left subclavian vein up to the superior caval vein. Then, the brachiocephalic trunk, the left common carotid as well as the left subclavian artery were circumferentially dissected and encircled with silastic tapes. After systemical heparinization with 80 IU/kg bodyweight, the ascending aorta was tangentially clamped and a longitudinal arteriotomy was performed. An anastomosis between the proximal portion of the inverted bifurcated Dacron prosthesis (Braun Unigraft, Melsungen) and the ascending aorta was performed with reinforcement of Teflon felt strips with a 4-0 Prolene running suture (Ethicon Inc., Somerville, NJ, USA). Consecutively, the left subclavian artery was clamped, transversely divided at its origin and an end-to-end anastomosis was performed with the initial branch of the bifurcated prosthesis with a 5.0 Prolene running suture. The branch was guided inferior to the anonymous vein to avoid venous compression.

Afterwards, the left common carotid artery was transversely divided at its origin. An end-to-side anastomosis between the initial branch of the bifurcated prosthesis and the left common carotid artery was performed with a 5.0 Prolene running suture. Blood flow was reinstalled in a usual fashion. In one patient the brachiocephalic trunk was transversely divided and an end-to-end anastomosis was performed, in the remaining patients, a side-to-end anastomosis between the second branch of the bifurcated prosthesis and the brachiocephalic trunk was performed (Fig. 2).

2.4. Stent-graft systems used

Three different commercially available stent-graft systems were used. The Talent endovascular stent-graft (Medtronic, Santa Rosa, CA, USA) was used in six patients. The Excluder stent-graft (WL GORE, Flagstaff, AZ, USA) was used in four patients. The Endofit stent-graft (LeMaitre Vascular, Burlington, MA, USA) was used in one patient. For all systems, the diameter of the stent-graft was calculated from the largest diameter of the proximal or distal neck and an oversizing factor of 10–20% was added.
2.5. Stent-graft placement

Stent-graft placement was performed during general anesthesia. In nine patients, a right common femoral artery access was chosen, in two other patients, the right common iliac artery was used. Initially, a 5-French pigtail catheter was advanced via the right brachial artery into the aortic arch to reconfirm characterization of the morphology and extent of the aneurysm. After systemic heparinization with 80 IU/kg bodyweight, an arteriotomy was performed and the system was advanced under fluoroscopic guidance. Afterwards, stent-grafts were deployed during systemic hypotension with a systolic pressure of 60 mmHg.

3. Results

3.1. Surgical procedure

All patients recovered uneventfully without any signs of transient or permanent neurologic injury after rerouting of the supraaortic branches. One patient had to undergo sternal revision due to mechanical sternal dehiscence because of therapy-refractory cough.

3.2. Stent-graft placement

Stent-graft placement was carried out metachronously after a mean time interval of 15 days. All 11 endovascular procedures were completed uneventfully. Mean number of stent-grafts used was 2.5. In one patient, a small type Ia endoleak could be detected after stent-graft placement. After one week, the patient was readmitted for completion angiography. The endoleak had already closed spontaneously. One patient experienced postoperative bleeding from the right common iliac artery cannulation site and subsequently underwent reexploration.

Mean hospital stay for both procedures — surgical and endovascular — was 18 days. Fig. 3 depicts a three-dimensional CT scan after stent-graft insertion in a patient after double transposition. Fig. 4 depicts a three-dimensional CT scan after stent-graft insertion after total arch rerouting.

3.3. Follow-up period

The mean follow-up period was 18 months (range 1–29 months). Patients were readmitted for completion CT scans after three months and biannually, thereafter. The patient suffering from multiple organ ischemia due to diffuse peripheral embolization originating from a local dissection at the concavity of the aortic arch died after four months due to mesenteric venous thrombosis. One patient underwent redo stent-graft placement after 25 months due to a type III endoleak. The remaining patients had normal CT scans with regular perfusion of the supraaortic branches without any signs of endoleaks.

4. Comment

Extended application of supraaortic rerouting with consecutive endovascular stent-graft placement is a safe and effective treatment modality designed for a highly selected subgroup of patients by avoiding conventional repair with excellent mid-term results.
The main advantage of this approach is its less invasiveness. All reports available in the literature to date confirm safety and efficacy of supraaortic reconstructions, both autologous as well as alloplastic, with consecutive stent-graft placement to treat aortic arch diseases in patients not suitable for conventional surgical repair.

Despite recent improvements in surgical technique and cerebral protection, surgical repair of the aortic arch still is an invasive procedure with a substantial rate of mortality and permanent neurologic injury [13—15]. Drawn from the experience after coronary artery bypass grafting (CABG), age remains an independent predictor of early mortality and permanent neurologic injury [16,17]. Recent work supported that deep hypothermic circulatory arrest (DHCA) is associated with an increased incidence of postoperative permanent neurologic dysfunction [18]. In this series, all patients recovered uneventfully without any signs of neurologic injury thereby supporting the hypothesis that avoidance of extracorporeal circulation and DHCA are substantial parts in preventing neurologic adverse events.

With regard to the rerouting procedures, some vascular surgical aspects have to be considered. In patients with aortic arch aneurysms located at the convexity of the aortic arch, the autologous surgical procedure is rather uncomplex. The aneurysm itself due to its large size approximates supraaortic branches thereby facilitating vascular anastomoses. Additionally, the supraclavicular extension of the incision enables mobilization of the supraaortic branches up to an extra-thoracic level thereby enabling tension free accomplishment of vascular transposition [10]. However, circumferential dissection of the left subclavian artery is challenging as the vessel adheres to the aneurysmal wall with more or less severe components of vessel wall inflammation resulting from the mechanical pressure arising from the aneurysm.

In patients with aneurysms mainly located at the concavity of the aortic arch and in patients with dissections, distances between the arch vessels are longer. Therefore, attention has to be paid during the autologous procedure to accomplish tension-free anastomoses. With regard to the alloplastic procedure, things are easier as the operative procedure is not limited by the length of the native vessels.

Cerebral monitoring was not performed in these patients, as it would have been without any consequence. The only reliable means to trying to avoid cerebral malperfusion remains the arterial line within the right radial artery by avoiding any depression in the pressure curve during partial clamping. Additionally, antegrade perfusion via both vertebral arteries is still present despite dividing the left common carotid artery as well as partially clamping the brachiocephalic trunk. However, this particular situation may have significant morbidity if the duration of the anastomosis exceeds the time frame of cerebral ischemic tolerance. We routinely perform subclavian-to-carotid artery transposition in any kind of chronic disease of the distal arch prior to stent-graft placement with the primary intention of preserving posterior cerebral circulation and not to maintain antegrade perfusion of the left upper extremity as it is well known that collaterals blood supply usually is sufficient. Furthermore, retrograde perfusion of the aneurysmal sac via the left subclavian artery may result in type II endoleak formation [19].

A mural thrombus was detectable in all patients with arch aneurysms. Without doubt, central manipulation of supraaortic vessels may cause cerebral injury by embolization of atherosclerotic debris. Therefore, a non-touch technique has to be applied whenever feasible. Additionally, the entire arch itself is not exposed, as it is not necessary for this very surgical procedure. Furthermore, brisk manipulation of the stent-graft introducer within the aortic arch may lead to detachment of soft plaques or parietal thrombi with consecutive cerebral embolization and has to be avoided.

Two commercially available endovascular stent-graft systems have been used. The first generation stent-grafts, which have been used at the very beginning of this series, had several technical drawbacks, mainly their rigid behavior. Therefore, passing the curve of the aortic arch was the main limitation of these devices. With the second generation stent-grafts, these problems have been partially solved and handling was facilitated. With regard to the mechanism of deployment, it remains to be shown if stepwise deployment with the possibility to readjusting or immediate deployment will be the method of choice. Recently, branched stent-grafts have become available to treat aortic arch diseases [20]. However, the procedure is complex and initial results are not encouraging. Due to the ease of aortic arch rerouting, branched stent-grafts may become obsolete in the future.

To our knowledge, this is the largest series with the longest follow-up to date. However, due to the novelty of these procedures, experience of the scientific community with regard to long-term durability of this procedure is limited. Several aspects have to be considered. Endoleak formation of any kind in this highly shear-stress exposed area has to be closely monitored as radial forces and severely curved pathways of vessels in combination with constant friction between the stent-skeleton and the graft are more pronounced within the aortic arch than within the descending thoracic aorta [10].

By extending endovascular stent-graft placement up to the ascending aorta, reconsideration of deployment modalities may become necessary due to the proximity of supraaortic reconstructions as well as to the aortic root. Stent-graft deployment during systemic hypotension with a systolic pressure of 60 mmHg has been our method of first choice within the last years. Recently, we have been using overpacing up to 180 beats per minute by a temporary ventricular pacemaker placed via the right subclavian vein in order to decrease cardiac output, thereby minimizing the risk of dislodging the stent-graft during deployment.

4.1. Limitations of the study

Patient number is small. However, the main issues for this entity are the selection criteria. These patients represent a subgroup of patients with aortic pathologies nobody would have looked upon 10 years ago due to lack of knowledge and lack of commercially available devices for dealing with this complex entity. We believe that when common acceptance for these hybrid procedures will rise by reaching a broad community of interest, numbers and consecutively, knowledge with regard to mid- and long-term durability will rise.

In summary, extended application of supraaortic rerouting with consecutive endovascular stent-graft placement is a
safe and effective treatment modality designed for a highly selected subgroup of patients with excellent mid-term results.

References