Outcomes of Endovascular Management of Aortic Arch Lesion

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Objective: *Assess the outcomes of treating aortic diseases involving the transverse aortic arch with a hybrid approach in high-risk patients.*
Material and Method: *Between March 2008 and January 2010, 29 thoracic stent grafts were implanted in 15 patients with aortic arch disease (mean age, 66.9±9.34 years) for aortic arch repair of eight degenerative aneurysms, two complicated aortic dissections, and five penetrating atheromatous ulcer or pseudoaneurysm. Debranching was performed to provide an adequate proximal aortic landing zone, in five patients by a cervical approach and in four patients by a sternotomy approach.*
Results: *The technical success rates for aortic zone 0 patients (n = 4), zone 1 patients (n = 3), and zone 2 patients (n = 8) were 100%. The 30-day mortality rate was 6.7%. The actuarial survival was 80% over a mean follow-up of 11.7 months. The rate of stroke was 6.7%. There was type II endoleak in one patient.*
Conclusion: *The use of a hybrid endovascular and open surgical approach for the treatment of arch diseases is safe and effective at early follow-up, including the potential to offer therapy to patients who are not candidates for open repair.*

Keywords: *Thoracic aorta, Aortic arch, Aortic dissection, Endovascular repair, Stent graft*

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The diseases of aortic arch, especially those involving the mid to distal arch, are technically challenging to repair with conventional open techniques. These challenges relate to difficulties with exposure, need for deep hypothermic circulatory arrest, and frequent requirement for a two-stage approach to complete repair. Despite advances in surgical techniques, anesthesia, and intensive care management, reported mortality rates range between 7% and 12% and the rate of gross neurologic injury ranges from 4% to 12% with a direct correlation between advanced age and adverse outcome[1,2]. Aortic arch diseases or descending thoracic aortic with extension into the arch are often deemed unsuitable for endovascular repair owing to the close proximity of the supra-aortic vessels. A combined endovascular and open approach has therefore been adopted as a valuable alternative[3], consisting in supra-aortic debranching and revascularization followed by stent-graft deployment.

This report presents the outcomes of clinical experience with endovascular treatment of aortic arch diseases after surgical transposition of supraaortic vessels.

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Material and Method

The study protocol was approved by our institutional Clinical Research Committee and Ethics Committee on February 2, 2008. This series presents a review of a single-center experience of consecutive thoracic endovascular repair procedures involving the aortic arch between March 2008 and January 2010. Fifteen patients required stent-graft landing in the aortic arch: zone 0 to 2 (aortic arch map proposed by Ishimaru[3,4]). Among them, nine underwent a hybrid technique with supra-aortic debranching and simultaneous or staged endovascular stent grafting to treat complex aortic arch disease. There were 12 men and three women (mean age, 66.9±9.34 years; range, 53-84 years). All patients were unfit for open surgery because of serious comorbidities (ASA ≥ III, n = 13, 86.7%). One patient had a history of an endovascular

repair of aortoenteric fistula secondary to open repair of abdominal aortic aneurysm. The demographic characteristics of the study groups are outlined in Table 1. Furthermore, one (6.7%) operation was performed in an emergency setting. Indications for surgery included either fusiform (n = 8) or saccular (n = 5) aneurysms of the transverse arch (1 patient had aortobronchial fistula secondary to fusiform aneurysm). In two patients (13.3%), the aneurysm was secondary to aneurysmal formation of false lumen in aortic dissection. All 15 patients were considered to have an inadequate proximal landing zone for aortic arch stent-graft insertion, but only nine (60%) of them underwent surgical supra-aortic debranching and revascularization-via a cervical approach in five patients and through a median sternotomy in four patients. Patients were divided into three groups according to the proximal landing zone: 0, 1, or 2. Zone 0 was involved in four patients, zone 1 in three patients, and zone 2 in eight patients.

Table 1. Demographic data

	n	%
Age (mean, year)	66.9±9.34	
Gender (male/female)	12/3	80/20
Tobacco use	10	66.7
Preoperative comorbidities		
Diabetes mellitus	3	20.0
Coronary artery disease	7	46.7
Prior coronary revascularization	1	6.7
Chronic obstructive pulmonary disease	9	60.0
Congestive heart failure	2	13.3
Hypertension	12	80.0
Dyslipidemia	6	40.0
Renal insufficiency	2	13.3
Pathology		
Degenerative aneurysm	8	53.3
Aortobronchial fistula	1	6.7
Penetrating ulcer or pseudoaneurysm	5	33.3
Complicated chronic type B dissection	2	13.3
ASA score ≥ III	13	86.7
ASA III	9	60.0
ASA IV	3	20.0
ASA V	1	6.7
Emergency and urgency repair	3	20.0
Ruptured	1	6.7
Painful aneurysm	2	13.3

TEVAR = thoracic endovascular aortic repair;
ASA = American Society of Anesthesiologists

Pre-procedural imaging

All patients underwent spiral computed tomographic angiography (CTA) scanning with three-dimensional reconstruction before stent-graft placement to determine the location, length, and diameter of the aneurysm and the possible stent-graft landing zones, as well as to evaluate the suitability of the iliac and femoral arteries for vascular access. Stent-graft dimensions were calculated from the CTA images. The preoperative characteristics of the aortic lesions are summarized in Table 2.

Table 2. Preoperative characteristics of the aortic aneurysms

	Mean±SD (mm)	Range (mm)
Aneurysm length	99.73±28.04	60-136
Aneurysm diameter	63.93±5.80	53-72
Proximal neck diameter	32.80±3.49	26-38
Distal neck diameter	30.20±4.35	22-35

Surgical procedure

All procedures took place in the surgical operating theatre, equipped with a portable digital angiographic system using a C-arm. All procedures were performed under general anesthesia. Spinal drain was routinely used in cases where the whole thoracic aorta was covered or in patients, who had their thoraco-abdominal/abdominal aorta previously repaired. Debranching procedures were performed before the deployment of the stent grafts in the same setting. Debranching and revascularization of supra-aortic trunks with a prosthetic graft was performed in all zone 0 cases through a median sternotomy, after systemic heparinization and partial crossclamping of the ascending aorta, proximal end-to-side anastomosis was performed with a prosthetic 10-mm graft, followed by two end-to-end anastomosis to the brachiocephalic trunk and the left common carotid artery (LCCA) and an end-to-end anastomosis to the LSA. In zone 1 patients, extra-anatomic revascularization of the LCCA and LSA was performed with a carotid-carotid bypass via retropharyngeal tunnel, followed by a left carotid-subclavian bypass (Fig. 1). Regarding revascularization of the left subclavian artery, in addition to debranching of the innominate and left carotid artery, was selectively performed, taking into account clinical, hemodynamic and imaging data. Specific indications for revascularising the left subclavian artery included previous coronary artery bypass grafting with patent left internal mammary artery, dominant left vertebral arterial circulation, right vertebral artery occlusion, diseased vertebro-basilar

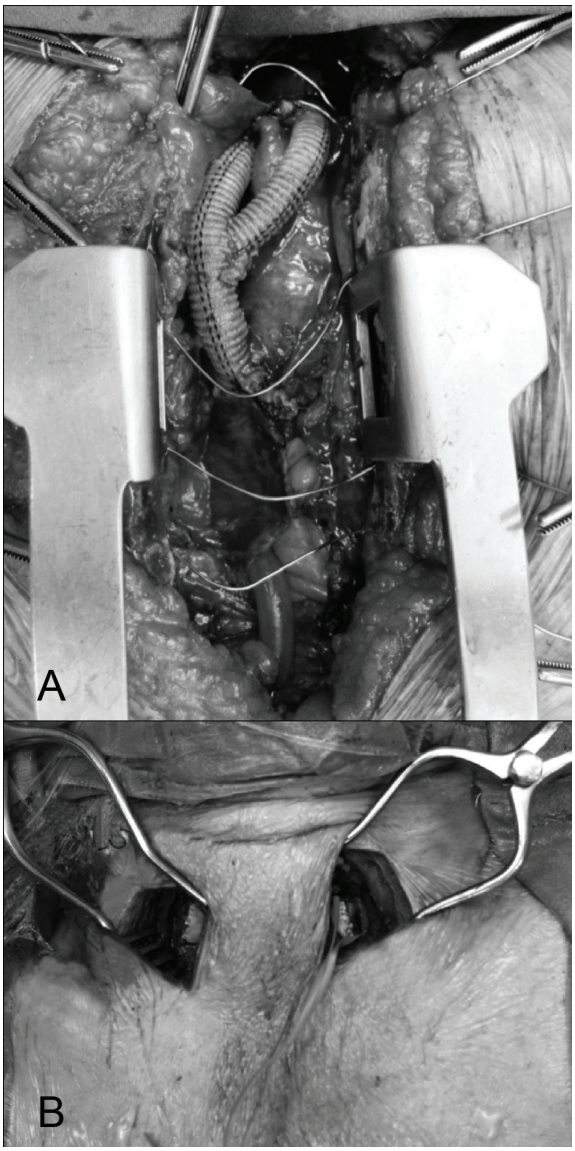

Fig. 1 Intraoperative photograph of a patient demonstrating. (A) Debranching of the supra-aortic vessels and (B) carotid-carotid-subclavian artery bypass.

system, anticipated extensive thoracic intercostal vessels coverage, previous thoraco-abdominal aortic surgery, the patient with left arm dialysis dependent or when the potential exists for retrograde perfusion of a type B dissection via a patent subclavian artery. The second part of the procedure consisted of stent-graft deployment to exclude aortic pathology. In zone 0 patients, stent-graft access was through ascending aortic conduit except one patient was accessed via transfemoral. The transfemoral approach for endovascular access was used in all zone 1 and 2 but one case, where stent-graft access was through retroperitoneal conduit due to severe stenosis of external iliac artery. Several commercially available stent-graft systems were employed. Balloon dilatation was selectively performed when a residual endoleak was noticed.

Intravascular device details, stent graft placement, and postoperative care

All intravascular devices used were covered stent grafts, 16 Zenith TX2 devices (Cook Endovascular, Bloomington, IN), 12 Valiant devices (Medtronic, Inc., Minneapolis, MN), and one Excluder device (W. L. Gore & Associates, Elkton, MD). Stent graft dimensions were oversized by 10% to 20% compared with the landing zone diameters and were at least 25 to 35 mm longer than the aortic lesion to be treated. All the patients received an intravenous bolus of heparin at the dose of 75 UI/kg. Anticoagulation was maintained for 48 hours (preventive doses of low-weight heparin or calcic heparin according to the blood creatinin level) and then followed by aspirin (120 mg/d).

The mean number of stent graft used was two (range 1 to 4).

Follow-up

Follow-up consisted of standard chest roentgenography and injected spiral scanner or magnetic resonance before discharge and on the first or third, sixth, and twelfth months. Standard chest roentgenography and injected spiral scanner or magnetic resonance was performed every subsequent year. One patient was lost from follow-up. Mean follow-up was 11.7±8.18 months (range, 5.7 months-2.1 years).

Definitions

Outcome criteria and definitions, including technical success, significant inpatient morbidity and death, were based on recommended reporting standards for endovascular aortic aneurysm repair, published by the Society for Vascular Surgery Ad Hoc Committee on TEVAR Reporting Standards[5]. Primary technical success was defined on an intent-to-treat basis that begins with the implantation procedure and requires the successful introduction and deployment of the device in the absence of surgical conversion to open repair, death ≤24 hours, type I or III endoleaks as evidenced by procedural angiography, or graft obstruction. Endoleak was defined by the persistence of blood flow outside the lumen of the endoluminal

graft but within the aneurysm sac as determined by an imaging study. Endoleaks were then classified according to the literature. Paraplegia or paraparesis observed immediately or upon awakening was defined as immediate neurologic deficits. Those occurring after a period of normal neurologic function were classified as delayed deficits. Any perioperative deaths, any primary or secondary endoleaks, any failures of the endovascular device, any reinterventions, and any deaths related to an aortic rupture or any sudden unexplained late deaths were considered as failures of the treatment.

Results

Perioperative outcome

The stent-graft was deployed successfully in all patients, with no surgical conversions. Primary technical success was achieved 100%. In eleven patients, the distal landing zone was at the mid-thoracic level (distal landing zone 4, thoracic segments T6-T8), whereas the rest of the patients had their entire thoracic aorta stented (distal landing zone 4, thoracic segments T11-T12). One death occurred within 30 days (6.7%) in the patient who had aneurysmal formation of aortic dissection with right aberrant subclavian artery. He underwent stent-graft deployment in zone 1 after extra-anatomic carotid-carotid bypass with left carotid-subclavian transposition and developed brainstem infarction.

Five patients (33.3%) had non-fatal morbid adverse events <30 days. The most common complications in order of frequency were pulmonary complications (26.7%), GI bleed (13.3%), recurrent laryngeal nerve injury (6.7%), sternal dehiscence (6.7%), and femoral emboli (6.7%).

Endoleak occurring either intra-operatively or within 30 days of intervention developed in one patient (6.7%).

Outcome on follow-up

The mean follow-up period for the whole study population was 11.7 months (range, 5.5-25.2 months). One patient was lost to follow-up. All endografts and supra-aortic bypass grafts remained patent during follow-up. No device failure, no migration, no kink or twist, and no secondary endoleak were observed beyond the thirtieth day after the procedure. No endovascular reinterventions were needed during the follow-up period. Late (up to the end of follow-up) mortality occurred in 13.3% of patients. None of the late deaths was associated with the aortic pathology or previous intervention. One patient died two months after the procedure from the 2009 influenza A (H1N1) infection, which was proved by positive throat swab culture. Another patient who underwent aortic valve replacement one year later died after the operation from ARDS secondary to aspirated pneumonia. During the follow-up, four complications were encountered in three patients. Morbidity was due to transient cerebrovascular episode and pulmonary complication in one patient, cardiac complication in one patient, and one patient with ischemia of the left upper limb, which was successfully treated by left carotid-subclavian bypass three months after the procedure. The patient with type II endoleak was managed conservatively. In all patients, follow-up CT scans showed mean progressive regression of aneurysm diameter size of 5.04±3.27 mm, 13.96±4.49 mm, and 16.83±4.88 mm after one month, six months, and one year respectively.

Discussion

Endovascular therapies are considered an evolutionary step toward less-invasive treatments for thoracic aortic diseases. Even though open surgical repair is considered the treatment of choice for aortic arch disease in low-risk patients, such invasive surgery is accompanied by significant in-hospital mortality rates, which, in a large study, exceed 20%[6]. Despite recent improvements in surgical outcomes, even in expert high-volume centers, it carries a perioperative mortality ranging from 7% to 17% and an adverse neurologic event rate ranging from 4% to 12%[1,2]. Hybrid repair of the aortic arch with supra-aortic debranching prior to stent-graft deployment provides the advantage of reducing invasiveness by avoiding aortic crossclamping and circulatory arrest[7]. However, there are still many specific concerns about the durability of this approach as long-term follow-up data is still lacking. In addition, there are difficulties with the application of endovascular techniques in this area that are related to arch angulation, high blood flow, and substantial pulsatile movement of this portion of the aorta.

The reported incidence of endoleak ranges from 5% to 30%, particularly for type I[8,9]. However, our rate of type I and III endoleaks is 0%. We think that our good results are due to the preference in planning for the proximal landing zone. In zone 0 patient, we prefer to deploy the stent-graft in mid-portion of aorta, which allows stent-graft deployment in a straight vessel. Thus, stent-graft will have a longer landing zone and achieving a better seal than in a

curved aortic arch. However, there is a difficulty with making proximal anastomosis of aortocarotid bypass. Our preference to perform end-to-end anastomosis in distal site may also help to avoid the possibility of a type 2 endoleak and prevents the possibility of cerebral embolization during stent-graft navigation through the aortic arch and deployment.

Most of the early reports on the use of stent grafts in the aortic arch suggested that the LSA need not be revascularized in most patients and that this might avoid the operative morbidity of a hybrid procedure[10-12]. More recent data, however, have been contradictory, with most studies supporting LSA revascularization[13-15]. In our institution, we chose to selectively revascularize the left subclavian artery in cases where previous coronary artery bypass grafting with patent left internal mammary artery, dominant left vertebral arterial circulation, right vertebral artery occlusion, diseased vertebro-basilar system, anticipated extensive thoracic intercostal vessels coverage, previous thoraco-abdominal aortic surgery, the patient with left arm dialysis dependent or when the potential exists for retrograde perfusion of a type B dissection via a patent subclavian artery. We identified one patient with ischemic symptom of left upper limb who had endograft coverage of the subclavian artery. However, this patient was successfully treated with carotid to subclavian bypass. We also had fatal stroke in right aberrant subclavian patient with aneurysmal dilatation of type B chronic dissection of aorta. Despite we had performed left carotid and subclavian arteries before the stent-graft was deployed as recommended by some authors[16,17]. As a result, we now routinely perform preoperative evaluation of the cerebral circulation and subclavian artery transposition or carotid to subclavian bypass in all patients with aortic arch disease. In the patient with aberrant right subclavian artery, we advocate routinely performing bilateral carotid-subclavian bypass. We suspect that this aggressive policy of arch branch reconstruction has contributed to an improvement in stroke rate over time and may contribute to optimal spinal cord perfusion.

Paraplegia is one of the most feared complications after repair of thoracic aneurysms. Although the endovascular repair of thoracic aortic aneurysms shows a promising reduction in operative morbidity compared with open surgery, the risk of spinal cord ischemia still exists. According to the literature, paraplegia occurs in 0% to 6% of cases[18,19]. Our experience is in line with the literature, reporting a perioperative mortality of 0%.Mechanisms of spinal cord injury include the length of aortic coverage and peri/postoperative hypotension, as spinal cord perfusion pressure is directly related to systemic blood pressure and inversely proportional to cerebro-spinal fluid pressure[20].Units must have robust policies in place for lumbar CSF drainage and postoperative blood pressure manipulation. The number of adverse events in this study was too small to assess an association between spinal drainage and the incidence of spinal cord injury.

Conclusion

The use of a hybrid endovascular and open surgical approach to the treatment of arch diseases appears safe and effective at early midterm follow-up and offers several advantages over conventional repair, including the potential to offer therapy to patients who are not candidates for open repair. To date, they have proven to be safe and highly effective when they are utilized in higher risk patients with a variety of aortic disorders. Careful selection of patients and consideration of anatomical features are required to achieve satisfactory results.

Limitations of the study

This study is limited by a small number of patients that affect the power of the study, and the few observation endpoints limited the statistical analysis. It is also series represents a single center limited experience with a retrospective analysis although data were prospectively collected. The relatively short follow-up does not allow making definite inference regarding the durability of this approach.

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Potential conflicts of interest

None.

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ผลการรักษาโรคหลอดเลือดแดงใหญ่เอออร์ตาในบริเวณอาร์คด้วยหลอดเลือดเทียมแบบมีขดลวด

อรรถภูมิ สู่ศุภอรรถ, วิทวัส พิบูลย์, รักฝัน สวัสดิพาณิชย์, เสกสรร จิตวิเศษ

วัตถุประสงค์: เพื่อศึกษาผลของการรักษาและประเมินความเสี่ยงของการรักษาโรคหลอดเลือดแดงใหญ่เอออร์ตาในบริเวณอาร์คด้วยการผ่าตัดร่วมกับการใส่หลอดเลือดเทียมชนิดมีขดลวด ในผู้ป่วยที่มีความเสี่ยงสูง

วัสดุและวิธีการ: การศึกษาครั้งนี้ได้ทำระหว่างปี พ.ศ. 2551-2553 โดยการรักษาโรคหลอดเลือดแดงใหญ่เอออร์ตาในบริเวณอาร์คด้วยการผ่าตัดร่วมกับการใส่หลอดเลือดเทียมชนิดมีขดลวดรวมทั้งสิ้น 29 ชิ้น ในผู้ป่วยที่มีความเสี่ยงสูง 15 ราย อายุเฉลี่ย 66±9.34 ปี ซึ่งได้รับการวินิจฉัยเป็นโรคหลอดเลือดโป่งพอง 8 ราย โรคหลอดเลือดเซาะฉีกที่มีภาวะแทรกซ้อน 2 ราย และโรคหลอดเลือดโป่งพองเทียม (pseudoaneurysm) 5 ราย มีผู้ป่วยจำเป็นต้องได้รับการผ่าตัดต่าง ๆ ร่วมด้วย เพื่อขยายตำแหน่งที่เหมาะสมในการวางหลอดเลือดเทียมทั้งสิ้น 9 ราย โดยทำผ่าน median sternotomy 4 ราย และผ่านบริเวณคอ (cervical approach) 5 ราย

ผลการศึกษา: พบว่าผู้ป่วยทุกรายประสบความสำเร็จในการวางหลอดเลือดเทียมในตำแหน่งที่ต้องการ โดยวางในตำแหน่ง zone0 4 ราย zone1 3 ราย และ zone2 8 ราย อัตราการเสียชีวิตในช่วง 30 วันแรกหลังผ่าตัดเท่ากับ 6.7% และในช่วงเวลาติดตามศึกษาเฉลี่ย 11.7 เดือน พบว่าผู้ป่วยมีอัตราการรอดชีวิตหลังผ่าตัดเฉลี่ย 80% อัตราการเกิดภาวะแทรกซ้อนทางสมองอย่างรุนแรง 6.7% และมีอัตราการเกิดการรั่วซึมของหลอดเลือดเทียม (endoleak) 1 ราย

สรุป: จากการติดตามผลของการรักษาโรคหลอดเลือดแดงใหญ่เอออร์ตาในบริเวณอาร์ค ด้วยการผ่าตัดร่วมกับการใส่หลอดเลือดเทียมชนิดมีขดลวด ในระยะสั้น พบว่าเป็นการรักษาที่ปลอดภัย และนับเป็นทางเลือกที่ดีของผู้ป่วยที่มีความเสี่ยงสูง ซึ่งไม่เหมาะกับการผ่าตัดเปิดช่องอกตามแบบปกติ