

## Arch replacement and downstream stent grafting in complex aortic dissection: first results of an international registry<sup>☆</sup>

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### Abstract

**Objectives:** Arch replacement combined with antegrade stent grafting of the descending aorta represents a hybrid surgical approach for extensive thoracic aortic disease. This multicentre study evaluates the early results of this method in complex aortic dissection (AD). **Methods:** Retrospective data acquisition was achieved by institution of an international registry. A hybrid stent graft with integrated vascular prosthesis for arch replacement (E-vita open<sup>®</sup>) was used. From January 2005 to March 2009, 106 patients (mean age 57; 77% male) with complex AD (55 acute, 51 chronic) were studied. **Results:** As many as 49/106 (46%) patients underwent emergency surgery. Stent-graft deployment and arch replacement (95 total, 11 subtotal) were performed under hypothermic circulatory arrest (HCA ( $8 \pm 6$  min) and selective antegrade cerebral perfusion (SACP) ( $74 \pm 23$  min). Stent-graft placement into the true lumen was successful in all but one case (99%). Ascending aortic replacement was performed in 91/106 (86%), aortic valve repair/replacement in 49/106 (46%), coronary artery bypass grafting (CABG) in 17/106 (16%) and mitral valve repair in 2/106 (2%). Cardiopulmonary bypass (CPB) and cardiac arrest times were  $242 \pm 64$  and  $144 \pm 44$  min, respectively. In-hospital mortality was 12% (13/106; six acute, seven chronic AD) and new strokes observed in 5/106 (5%). The false lumen (FL) was evaluated in 96/106 (91%) patients postoperatively. At first follow-up computed tomography (CT)-examination, thoracic FL thrombosis was 93% (76 complete, 13 partial) and 58% (31 complete, 25 partial) in the thoraco-abdominal aorta. **Conclusions:** By combining arch replacement with downstream stent grafting, one-stage repair of complex aortic dissection with almost unanimous thoracic FL thrombosis can be achieved at acceptable perioperative risk.

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**Keywords:** Aortic dissection; Aortic arch; Aortic operation

### 1. Introduction

Complex aortic dissection (AD) involving the aortic arch and the descending aorta represents a surgical challenge due to the limited access to the descending aorta. Thus, a two-stage approach was favoured in chronic AD consisting of arch repair via median sternotomy followed by a secondary distal aortic repair through left lateral thoracotomy. However, the substantial cumulative mortality, including the adverse outcome between the stages, sobers the good results of the first stage. Thus, a one-stage strategy may be preferable [1]. The one-stage arch-first technique using a clamshell incision represents, in chronic aortic disease, a suitable alternative

to staged repair, but the major trauma includes potential hazards [2,3]. In the last decade, based on the 'elephant trunk' technique, described by Borst et al. in the early 1980s, hybrid stent-graft devices were developed to achieve one-stage repair of the arch and the downstream aorta using a conventional median sternotomy [4–7]. This hybrid approach combines the conventional arch replacement with the antegrade endovascular treatment of the descending aorta using a covered stent graft. Stent grafting in chronic AD aims to improve the true lumen perfusion and to intercept aortic enlargement by false lumen exclusion and obliteration [8,9]. The hybrid approach has found application also in acute AD for immediate exclusion of additional intima tears in the descending aorta, promising aortic recovery [10,11]. However, although persisting patency of the false lumen (FL) is associated with aortic complications, additional antegrade stent grafting in acute AD is discussed controversially with regard to extending repair under emergency conditions [12].

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Table 1  
Baseline characteristics.

Aortic disease Mean $\pm$ SD, no (%)	Overall (n = 106)	Acute AD (n = 55)	Chronic AD (n = 51)
Age (year)	57 $\pm$ 13	58 $\pm$ 13	56 $\pm$ 13
Age $\geq$ 70 years	18 (17)	12 (22)	6 (12)
Male	82 (77)	41 (75)	41 (80)
BMI	26 $\pm$ 4	27 $\pm$ 4	26 $\pm$ 4
Marfan syndrome	9 (9)	5 (9)	4 (8)
Aortic calcification	27 (26)	15 (27)	12 (24)
Coronary artery disease	13 (12)	8 (15)	5 (10)
EF < 60	43 (41)	17 (31)	26 (51)
Previous cardiovascular surgery	38 (36)	3 (6)	35 (69)
Hypertension medication	83 (78)	36 (66)	47 (92)
Diabetes mellitus	5 (5)	3 (6)	2 (4)
Chronic obstructive lung disease	21 (20)	14 (26)	7 (14)
Creatinin > 2	14 (13)	8 (15)	6 (12)
History of stroke	5 (5)	4 (7)	1 (2)

AD: aortic dissection; BMI: body mass index.

First single-centres reports demonstrate promising results with hybrid stent grafts, but are limited to small numbers. Thus, an international registry was established to collect a large patient number and to accumulate information across several referral sites, according to implementation of antegrade stent grafting to arch repair. The present multi-centre study evaluates the early results of arch replacement combined with antegrade stent grafting of the descending aorta in complex AD.

## 2. Methods

### 2.1. International E-vita open Registry

Five large referral centres (Barcelona, Bologna, Essen, Prague and Vienna,) in five European countries are currently participating in the International E-vita open Registry (IEOR). All enrolled patients underwent arch replacement combined with open antegrade stent grafting using the E-vita open (Jotec GmbH, Hechingen, Germany) hybrid stent graft; the data have been enrolled beginning January 2005. The variables studied include demographics, history, specific characteristics of the aortic disease, physical findings and imaging studies, operative management, post-operative morbidity and mortality, as well as follow-up data including aortic imaging. The variables were developed according to standard definitions and were validated from the participating centres. Care had been taken for specification of variables according to the different natural characteristics of extended aortic disease. The reports identified aneurysmal disease or dissection, which was separated into the acute form, when the delay between onset of symptoms and operation was less than 14 days, or into chronic thereafter. The records were collected by surgeons of the referral centres, in case report form, and were entered electronically into the database of IEOB located at the West-German Heart Center Essen, University Hospital Essen, Germany. Before publication, the data were reviewed and controlled by the participating centres. The DeBakey classification for AD was used to provide the extension of false lumen, which was evaluated by at least

one aortic imaging modality. Only cases with complete data evaluation were included. For false lumen analysis in follow-up, only patients with control aortic imaging were considered.

### 2.2. Patient population

From January 2005 to March 2009, a total of 128 patients with complex aortic disease were enrolled to the IEOB; 106 were operated for AD and 22 for extended aortic aneurysm. The data of all AD cases were verified as complete and were included in the study. The mean  $\pm$  SD age was 57  $\pm$  13 years and 82 (77%) patients were male (Table 1). Fifty-five (52%) patients were operated for acute AD and 51 (48%) for chronic AD. Type I AD was documented in 96 (91%) patients and a type III AD involving the arch in 10 (9%). Extension of the dissection into the ascending aorta was observed in 102 (96%) patients and into the abdominal aorta in 91 (86%). Nine patients were operated for Marfan syndrome. In acute AD, 47 (86%) patients underwent emergency surgery within 24 h after onset of symptoms (Table 2). In chronic AD, 24 (47%) patients underwent redo surgery after proximal aortic repair for acute AD. Computed tomography (CT) was available in 102 (96%) patients and in four (4%) emergency cases angiography alone was performed.

### 2.3. Hybrid stent graft

E-vita open represents a hybrid polyester stent-graft prosthesis consisting of a 15-cm-long nitinol covered stent graft with an integrated 7-cm (unstretched) long non-stented vascular prosthesis on the top. The vascular prosthesis is in continuity with the stent graft to avoid a proximal endoleak. For antegrade implantation through the opened aortic arch into the descending aorta, the E-vita open is crimped inside a flexible delivery system and the vascular prosthesis is invaginated inside the stent graft. The nitinol wire skeleton enables self-expansion. After deployment, the stent graft has to be fixed to the aortic stump using a continuous polypropylene suture between the rim of the vascular prosthesis and the aortic wall to prevent

Table 2  
Clinical status preoperatively.

Aortic disease, no (%)	Overall (n = 106)	Acute AD (n = 55)	Chronic AD (n = 51)
Emergency < 24 h	49 (46)	47 (86)	2 (4)
Inotropics preoperatively	23 (22)	21 (38)	2 (4)
Cardiac tamponade	13 (12)	13 (24)	0
Intubated prior to admission	14 (13)	12 (22)	2 (4)
Malperfusion			
Cardiac	9 (9)	9 (16)	0
Cerebral	13 (12)	13 (24)	0
Spinal cord	4 (4)	4 (7)	0
Visceral	7 (7)	7 (13)	0
Renal	9 (9)	8 (15)	1 (2)
Peripheral	9 (9)	8 (15)	1 (2)
Aortic valve regurgitation	57 (54)	37 (67)	20 (39)

AD: aortic dissection.

bleeding and stent-graft migration. Then, the vascular prosthesis is pulled back to the arch position for continuous arch replacement and re-insertion of the supra-aortic vessels.

#### 2.4. Operative procedure

No standard surgical protocol for stent-graft placement and arch replacement was used. Therefore, the use of a guide wire for stent-graft insertion, the choice to oversize (over > 10%) the true lumen or not and the operative technique for arch replacement differed among the surgeons. Artery access for cardiopulmonary bypass (CPB) was achieved by cannulation of the right subclavian artery. Cannulation of the native ascending aorta or a vascular prosthesis after previous surgery was determined by the surgeon. The complete resection of the aortic arch was defined as total. When a tissue bridge between the left subclavian artery and the descending aorta was left, arch replacement was defined as subtotal [8]. When a branched or another tubular prosthesis was preferred for arch replacement, the integrated vascular prosthesis of E-vita open was resected after deployment and replaced by continuous suture. For reimplantation of the supra-aortic vessels, the island or a separate technique was used. Selective antegrade cerebral perfusion (SACP) for cerebral protection during arch replacement was performed in all patients but one, in whom deep hypothermia was used solely. The period of circulatory arrest without SACP was defined as hypothermic circulatory arrest (HCA).

#### 2.5. Data analysis

Categorical variables are presented as frequencies and analysis was performed using the two-sided *p* value of the Fisher's exact test. Continuous values are expressed as mean  $\pm$  SD and were compared with the two-tailed unpaired *t*-test. Median and range were used for presentation of hospital and intensive care unit stay. A *p* value less than 0.05 was considered statistically significant. Survival was analysed with the Kaplan–Meier actuarial method and compared with the log-rank test. Statistical analysis was performed using the SPSS software package version 16.0 (SPSS Inc., Chicago, IL, USA).

### 3. Results

#### 3.1. Aortic replacement

Total arch replacement was performed in 95 (90%) and subtotal arch replacement in 11 (10%) of the patients. In 51 (48%) of the cases, the integrated vascular prosthesis of E-vita open was used, an additional branched prosthesis in 22 (21%) or a simple tubular prosthesis in 33 (31%) cases. A branched prosthesis was used more often in chronic (17/51, 33%) than in acute AD (5/55, 9%),  $p < 0.01$ . The island technique for supra-aortic artery reimplantation was associated with a shorter CPB time ( $p = 0.05$ ), cross-clamp time ( $p < 0.01$ ), SACP time ( $p < 0.01$ ) and HCA time ( $p = 0.01$ ). When the island technique was performed using the integrated E-vita open prosthesis, a shorter SACP time ( $p < 0.01$ ) became evident. Univariate analysis demonstrated no association between the different techniques for arch replacement and the incidence of postoperative stroke and in-hospital mortality. Ascending aorta replacement was combined in 91 patients (86%) using the E-vita open prosthesis alone in nine (10%) and an additional vascular graft in 82 (90%,  $p < 0.01$ ). Additional to aortic repair, a total of 68 valve or coronary artery bypass grafting (CABG) procedures were performed in 56 patients (acute AD vs chronic AD,  $p < 0.01$ ). The mean time of CPB, myocardial ischaemia, SACP and HCA was 242 min, 144 min, 75 min and 8 min, respectively. The SACP time was shorter in acute AD ( $p < 0.01$ ), (Table 3).

#### 3.2. Antegrade stent grafting

The choice of stent-graft size was adjusted to the true lumen size of the descending aorta in 89 (84%) patients and in 17 (16%) patients oversizing over 10% was performed. The stent-graft diameter in acute AD was in mean  $28 \pm 4$  mm and in chronic AD  $30 \pm 5$  mm,  $p = 0.01$ . Stent-graft placement was guided by a stiff wire in 71 (67%) patients (acute AD 30/55, 55% vs chronic AD 41/51, 80%;  $p < 0.01$ ) or without in 35 (33%). Stent-graft placement was successful in all cases, but complicated landing occurred in one acute and one chronic case, which could be overcome in both. Stent-graft deployment inside the true lumen was successful in all (99%) but one case, in which displacement of the distal stent

Table 3  
Intraoperative variables.

Aortic disease Mean $\pm$ SD, no (%)	Overall (n = 106)	Acute AD (n = 55)	Chronic AD (n = 51)	p Value
<b>Cannulation site (n)</b>				
Axillary artery	70 (66)	34 (62)	36 (71)	0.41
Proximal aorta	22 (21)	17 (31)	5 (10)	<0.01
Femoral artery	1 (1)	1 (2)	0	1.0
Previous prosthesis	11 (10)	1 (2)	10 (20)	<0.01
Others	2 (2)	2 (4)	0	0.49
<b>Intraoperative values (min)</b>				
CPB time	242 $\pm$ 64	239 $\pm$ 59	246 $\pm$ 70	0.56
Cross-clamp time	144 $\pm$ 44	139 $\pm$ 40	150 $\pm$ 47	0.22
SACP time	75 $\pm$ 23	67 $\pm$ 19	83 $\pm$ 24	<0.01
HCA time	8 $\pm$ 6	9 $\pm$ 7	7 $\pm$ 6	0.13
<b>Antegrade stent grafting (n)</b>				
Stent-graft size (mm)	29 $\pm$ 5	28 $\pm$ 4	30 $\pm$ 5	0.01
Oversizing >10%	17 (16)	10 (18)	7 (14)	0.60
Use of guide wire	71 (67)	30 (55)	41 (80)	<0.01
<b>Arch replacement (n)</b>				
Total	95 (90)	48 (87)	47 (92)	0.53
Subtotal	11 (10)	7 (13)	4 (8)	
<b>Arch prosthesis (n)</b>				
E-vita	51 (48)	32 (58)	19 (37)	0.35
Branched	22 (21)	5 (9)	17 (33)	<0.01
Tubular	33 (31)	18 (33)	15 (29)	0.83
<b>Supra-aortic vessels (n)</b>				
Island	67 (63)	42 (76)	25 (49)	<0.01
Separate	39 (37)	13 (24)	26 (51)	
<b>Ascending aorta replacement</b>				
E-vita open prosthesis	9 (9)	3 (5)	6 (12)	0.30
Other prosthesis	82 (77)	51 (93)	31 (61)	<0.01
<b>Aortic valve intervention</b>				
Bentall	14 (13)	6 (11)	8 (16)	0.57
Isolated valve replacement	10 (9)	3 (5)	7 (14)	0.19
Resuspension	20 (19)	20 (36)	0	<0.01
Repair	5 (5)	5 (9)	0	0.03
Mitral valve repair	2 (2)	0	2 (4)	0.22
CABG	17 (16)	12 (22)	5 (10)	0.11

AD: aortic dissection; CPB; cardiopulmonary bypass; SACP: selective antegrade cerebral perfusion; HCA: hypothermic circulatory arrest; CABG: coronary artery bypass grafting.

graft end into the false lumen occurred. In this case, a guide wire was not used.

### 3.3. Postoperative outcome

The median length of stay in intensive care unit was 6 (range, 1–82) days and in hospital 21 (range, 1–101) days. Thirteen (12%) patients died during hospitalisation. The in-hospital mortality in acute AD was 11% (6/55) and in chronic AD was 14% (7/51),  $p = 0.77$ . One (1%) aortic-related death (rupture of abdominal aorta) in chronic AD was observed. The cause of death was cardiac failure in three, visceral malperfusion sequelae in two, severe bleeding in two, sepsis

in two, stroke in one and pulmonary insufficiency in two patients. The incidence of postoperative stroke was 5%. The incidence of spinal cord injury was 3%, one paraplegia and two parapareses, all in chronic AD (Table 4). Eleven (10%) secondary aortic interventions, 10 endovascular (acute AD 4/55, 7% vs chronic AD 6/51, 12%,  $p = 0.52$ ) for stent-graft extension and one surgical intervention for descending aorta replacement were performed during the hospital stay.

### 3.4. Postoperative aortic imaging

In 96 (91%) of 106 patients, a postoperative pre-discharged CT was performed and used for the false lumen

Table 4  
Postoperative results.

Aortic disease, no (%)	Overall (n = 106)	Acute AD (n = 55)	Chronic AD (n = 51)	p Value
In-hospital mortality	13 (12)	6 (11)	7 (14)	0.77
Intubation time > 72 h	36 (34)	22 (40)	14 (28)	0.21
Re-exploration	20 (19)	11 (20)	9 (18)	0.80
LOS	9 (9)	6 (11)	3 (6)	0.49
Visceral ischemia	4 (4)	3 (5)	1 (2)	0.61
Stroke	5 (5)	4 (7)	1 (2)	0.36
Spinal cord injury	3 (3)	0	3 (6)	0.10

AD: aortic dissection; LOS: low output syndrome.

Table 5  
False lumen in thoracic aorta according to the pre-discharged CT examination.

Aortic disease, no (%)	Overall (n = 96)	Acute AD (n = 49)	Chronic AD (n = 47)	p Value
FL peri-stent-graft level				
Thrombosis	76 (79)	45 (92)	31 (66)	<0.01
Partial thrombosis	13 (14)	4 (8)	9 (19)	0.14
Patent	7 (7)	0	7 (15)	<0.01
FL distally				
Thrombosis	31 (32)	18 (37)	13 (28)	0.38
Partial thrombosis	25 (26)	14 (29)	11 (23)	0.64
Patent	40 (42)	17 (35)	23 (49)	0.21

AD: aortic dissection; FL: false lumen.

Table 6  
Behaviour of the false lumen in follow-up.

Aortic disease, no (%)	Overall (n = 74)	Acute AD (n = 38)	Chronic AD (n = 36)	p Value
FL peri-stent-graft level				
Thrombosis	69 (93)	37 (97)	32 (89)	0.19
Partial thrombosis	4 (5)	1 (2)	3 (8)	0.35
Patent	1 (1)	0	1 (3)	0.48
FL distally				
Thrombosis	39 (53)	18 (47)	21 (58)	0.36
Partial thrombosis	21 (28)	14 (37)	7 (19)	0.12
Patent	14 (19)	6 (16)	8 (22)	0.56

AD: aortic dissection; FL: false lumen.

evaluation (Table 5). In acute AD, incidence of immediate false lumen thrombosis in the peri-stent-graft level was 92% and in chronic AD 66% ( $p < 0.01$ ). In the thoraco-abdominal level, distal to stent graft, the rate of complete false lumen thrombosis was statistically similar in acute AD (37%) and chronic AD (28%,  $p = 0.38$ ). Chronic AD was associated with false lumen patency in peri-graft ( $p < 0.01$ ) but not in the distal aortic level ( $p = 0.21$ ). In addition, a partial false lumen thrombosis occurred in 14% of the patients in the peri-graft level and in 26% distally.

### 3.5. Survival and aortic behaviour in follow-up

Follow-up for the 93 (49 acute AD, 44 chronic AD) surviving patients was a mean of  $20 \pm 11$  months. Ten (11%) patients died within this period, six after acute AD and four after chronic AD. One succumbed after secondary endovascular procedure in the distal abdominal aorta and two due to aortic fistula, one aortotracheal and one aorto-oesophageal. Thus, the rate of aortic-related death was 3% (3/93). The actuarial survival rate was 93% at 12 months, 88% at 24 months and 81% at 36 months. No statistical significance of the actuarial survival rate was observed between acute AD (79%) and chronic AD (87%,  $p = 0.69$ ) (Fig. 1). Nine (10%) endovascular re-interventions were documented during follow-up for stent-graft extension, three after acute AD (6%) and six (14%) after chronic AD. Two patients underwent aortic root replacement after supracoronary ascending replacement and one mitral valve replacement. The actuarial freedom of secondary downstream aortic intervention was 91% after 12 months and 87% after 36 months (acute AD vs chronic AD,  $p = 0.25$ ) (Fig. 2). CT examination for aortic imaging was performed in 74 patients during follow-up. According to the last CT control examination, complete thrombosis of the false lumen in the peri-graft level was documented in 69 (93%)

patients; acute AD 97% (37/38) and chronic AD 89% (32/36),  $p = 0.19$ . In the distal thoracic aortic level false lumen thrombosis was documented in 39 (53%) and a partial thrombosis in an additional 21 (28%) patients (Table 6).

## 4. Discussion

Conventional surgical repair leaves the downstream aorta untreated in acute type I AD. Though a lifesaving procedure, long-term course thereafter is associated with a substantial number of complications resulting from the persistent flow through the false lumen, which remains open in most of the cases and causes aortic dilatation and re-operation [13,14]. Japanese authors addressed this problem in the 1990s, using homemade stent grafts for chronic, and later on for acute dissections with impressive results. The frozen elephant technique used by Karck et al. [6] uses the same principle, which was advanced by Jakob et al. [7] creating a one-piece stent graft/arch prosthesis to overcome proximal endoleakage associated with the separated use of antegrade positioned stent grafts into the descending aorta and conventionally sewn arch prostheses.

However, the experience with this approach is short and limited to small numbers of a single-centre study. Thus, a multicentre registry was founded for the integration of data using this approach. The data expanded over a 4-year period including 106 patients and aortic imaging of 74 patients during a mean follow-up of 20 months. In-hospital mortality of 12–11% for the acute, and 14% for chronic cases is acceptable with regard to the severity of the disease and patient co-morbidities and compares well with conventional arch repair with or without elephant trunk [15,16].

Postoperative re-exploration rate seems somewhat high at 19% and probably correlates with the non-watertightness



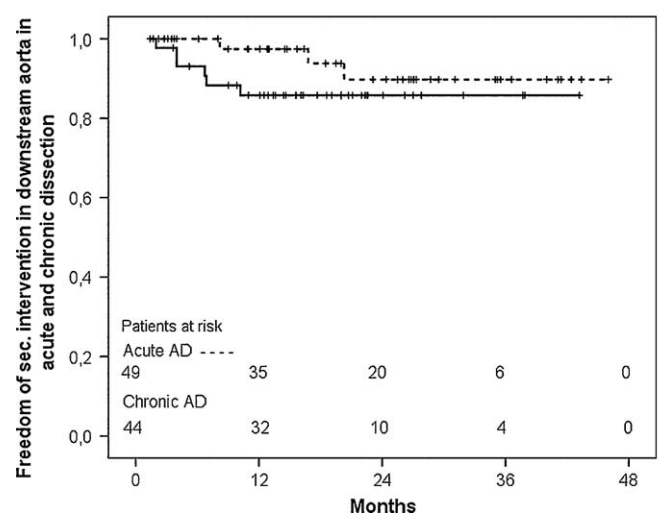
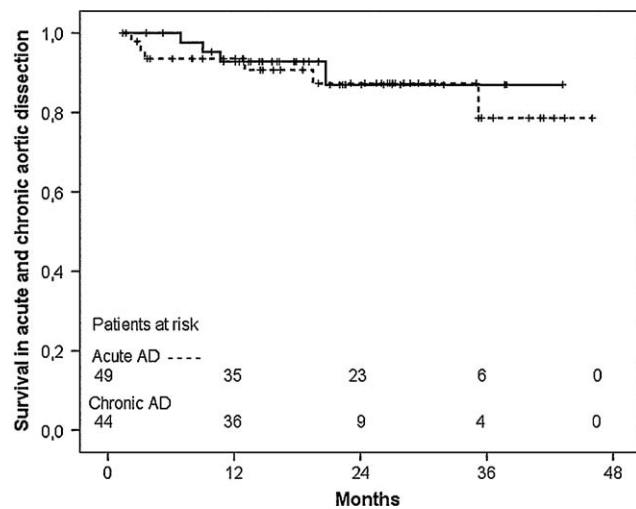
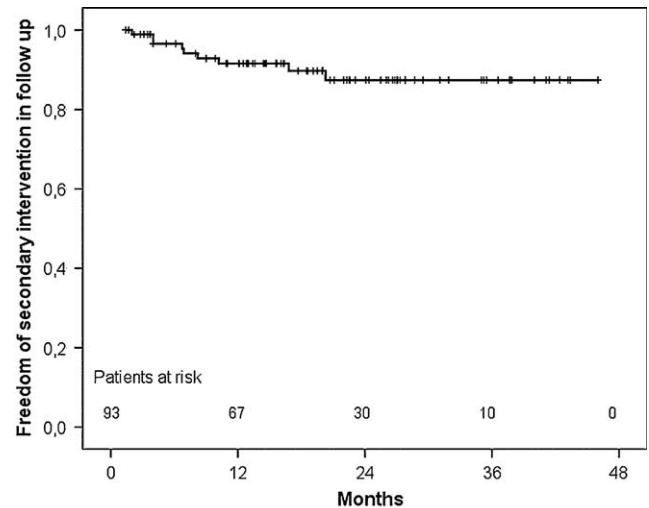
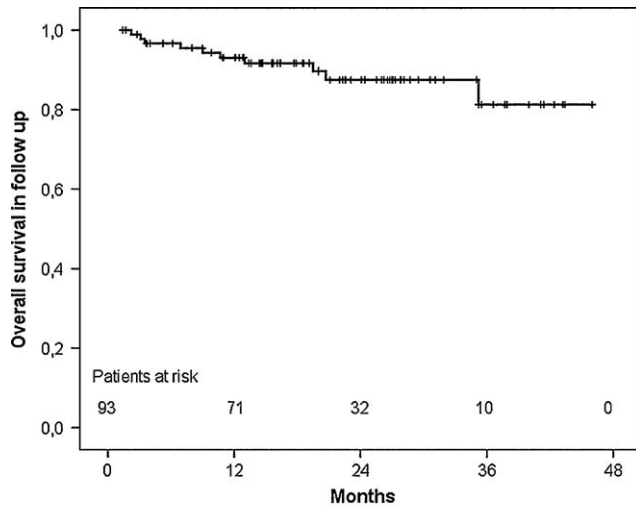


Fig. 1. Estimation of actuarial survival after arch replacement and antegrade stent grafting in aortic dissection. Kaplan–Meier in overall, acute and chronic dissection during follow-up.

Fig. 2. Estimation of actuarial freedom of re-intervention in downstream aorta during follow-up after arch replacement combined with antegrade stent grafting in extended aortic dissection.

of the E-vita open prosthesis, which will be eliminated with the introduction of the tightly woven and water-impervious E-vita open plus prosthesis. No consensus seems to be existing with regard to the use of a stiff guide wire among the participants of the registry for the introduction of the hybrid prosthesis into the descending aorta, since only 55% in the acute versus 80% in the chronic cases relied on its use for landing within the true lumen. However, a guide wire warrants safe placement of the graft in the target zone in all cases. Another issue is the extent of oversizing after measuring the true lumen size. Most participants restricted oversizing to 10% (82% in the acute and 86% in the chronic cases) to possibly avoid secondary problems which could be the creation of an aorto-oesophageal fistula [17].

The main goal of the presented surgical approach seems to be achieved in creating an obliteration of the false lumen channel around the E-vita open stent graft at the thoracic aortic level without the risk of proximal endoleak [18]. Prior to discharge after surgery, 92% of the acute patients, and 66% of the chronic patients had full thrombosis of their false

lumen, which rose to 93% during follow-up, and 97% in acute AD versus 89% in chronic AD patients. Re-intervention rate for distal endoleak or growth of the false lumen channel diameter during follow-up was 10%. Stent-graft extension was safe using the placed stent graft for the proximal landing zone, as demonstrated in our results and from others [19]. Only one patient of this series with 106 patients required surgical re-intervention for complete thoracic aortic replacement down to the diaphragmatic level. In chronic cases, care has to be taken for monitoring of the cerebrofluid pressure. The 6% incidence of spinal cord injury in chronic dissection indicates not only the use of cerebrofluid drainage but also the use of a shorter stent graft with a landing zone above Th9 in selected cases [20].

In conclusion, this multicentre study confirms a single-centre experience with this one-stage approach for surgical treatment of extensive acute as well as chronic type I AD without increase in hospital mortality in contrast to a more conservative approach and clearly demonstrates immediate false lumen thrombosis at downstream aorta to the end of the

stent-graft prosthesis. Despite still short follow-up, this represents an optimistic perspective towards reduction of late thoracic aortic complications, though not yet proven. Depending on the re-entry status within the thoraco-abdominal aorta, complete thrombosis of the entire false lumen probably can be expected in roughly 30% of the cases.

The definitive answer, whether or not this approach is superior to the conventional proximal repair leaving the downstream aorta untreated, can only be given by a randomised controlled study. The prerequisite for such a study has been gained by the increasing experience with this surgical strategy among the registry participants and currently is under discussion.

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## Appendix A. Conference discussion

**Dr Grabenwoger:** First, Dr Tsagakis, I want to congratulate you, and special thanks to your department chief, Dr Jakob, for initiating such a registry which is extremely important in a very special field where every department has only 10 to 30 patients. The mortality results are very good; however, this complex procedure is not free of complications. Therefore, I want to pose two questions to you.

The first one is the circulatory arrest time of 70 to 80 min; even if you're installing antegrade cerebral perfusion, it is rather long. And in your series you report 3 cases of paraplegia/paraparesis. Do you think this complication is due to the long circulatory arrest time and maybe the patients are not cooled down to deep hypothermia, so due to the long circulatory arrest time, or due to the coverage of intercostals by introducing the stent-graft into the descending aorta in the same procedure?

**Dr Tsagakis:** Spinal cord injury was observed in 3 patients with chronic aortic dissection. The time of selective cerebral perfusion was shorter in acute than in chronic, and in acute dissection no paraparesis occurred.

The association between selective perfusion and spinal cord injury is not very clear from this data. However, especially in chronic cases, it will be very useful to use cerebral fluid spinal drainage for controlling the pressure of the spinal fluid.

Now, paraparesis associated with the length of the stent-graft: the E-vita open has a length of 15 cm, and we know also from results with the Talent stent-graft that the length of the stent-graft of 20 cm was associated with increased injury of the spinal cord. There are also results from Japan with paraparesis with shorter stent-grafts with a landing zone TH6, and the landing zone with E-vita open is about TH9.

I think in acute dissection it seems to be safe. In chronic dissection I think we have to use CSF drainage for controlling.

**Dr Grabenwoger:** I have a second question. I was a little bit disappointed concerning the late re-intervention rate, because the most important aim of this complex hybrid procedure is to reduce late re-intervention. And in this series, in 10% secondary re-interventions on the downstream aorta were performed. Can you elaborate a little bit on the reason why it was necessary to do secondary stent-grafting of the descending aorta.

**Dr Tsagakis:** I think the question also will be: Why should secondary intervention be performed after antegrade stent-grafting?

The indication for secondary intervention after antegrade stent grafting is not yet defined and we could demonstrate that the thrombosis rate of the false lumen increased during the follow-up. Maybe it's better to wait for the secondary intervention than to perform one immediately. I think we will have an answer for this in the future.

**Dr J. Bachet (Abu Dhabi, United Arab Emirates):** Personally, I'm more and more convinced that in acute dissection this frozen elephant trunk is a good solution.

However, I think that in your study there is a bias that I have denounced for decades. You have mixed chronic dissections and acute dissections. And I think this is a real bias, because they represent totally different patterns. Acute dissection, as we know, is emergency surgery. Chronic dissection is elective surgery. We have the time to assess the dimension, size and the precise shape of the aorta. So mixing them is like mixing apples and oranges. It makes a nice basket, but the taste is not exactly the same.

Another thing is that in my opinion, or, rather, in my small experience, we have noticed that the trouble, that is, the need for reoperation on the distal aorta, came, in general, 5 or 6 years after the acute emergency operation. Your

follow-up is a little short to allow you to say that your method will solve the problem.

And finally, there is another pattern which you didn't allude to, which is the group that pays the highest toll to distal reoperation and complications. It is the group with connective tissue diseases and in particular Marfan patients. Would you propose to use stent-grafting in those Marfan patients to reduce this problem? And, incidentally, how many Marfan patients did you have among your 128 patients?

**Dr Tsagakis:** Regarding the first question, acute and chronic dissection are different diseases. However, we evaluated the antegrade stent-grafting with regard to the feasibility of it. We presented the acute and the chronic dissection together and the results were similar. So, we can conclude that antegrade stent-grafting is safe, not only in chronic cases under stable conditions, but also in acute under emergency conditions. For a definite answer with regard to stent grafting or not in acute dissection, a randomised study is needed, which is not very simple to perform.

**Dr Bachet:** But it's not possible to have a randomised study in acute dissection.

Quite impossible.

**Dr Tsagakis:** I have to agree. And now the second question – I'm sorry?

**Dr Bachet:** The delay between the onset of the acute dissection and the reoperation.

**Dr Tsagakis:** The follow-up is short. These are early results and we have no long-term follow-up, so we cannot give a definitive answer for this. However, the stent-graft gives a secure landing zone for secondary endovascular intervention. And this landing zone is at the distal part of the descending aorta. If in the future a secondary surgery is required, then we have to replace the entire descending aorta.

We performed this procedure also in Marfan patients. In our clinic we had experience with aortic complications in Marfan related to struts. The E-vita

open has no bar springs and oversizing of the true lumen over 10% was avoided. Therefore aortic injury should be minimised. However, the one late death of the study cohort was a Marfan patient.

**Dr S. Kucuker (Ankara, Turkey):** Use of this graft mandates to replace the total arch. Was the intimal tear in the arch in these cases, or had you to replace the arch anyway? But didn't that increase your mortality?

**Dr Tsagakis:** The entry tear is maybe in the arch or in the ascending aorta. In chronic dissection, the indication for arch replacement and antegrade stent grafting is defined by the preoperative diagnosis. We know if we have to perform stent-grafting or not. In acute cases, stent grafting is performed in case of re-entry in the descending aorta. The arch has to be replaced.

**Dr M. Motamedi (Tehran, Iran):** My question is for treatment of the descending aorta which is dissected in these patients; our goal is to obliterate the false lumen to prevent delayed complications. And you presented, as we heard, a small but significant number of paraplegia due to the long stent-grafts in the descending aorta. So my question is: Do you have any recommendations or experience with just a bare-metal stent for the descending aorta to obliterate the false lumen and expand the true lumen, of course, if you do not have an intimal tear in the descending and if you do not have, say, a distal re-entry? So what is your idea of just a bare-metal stent instead of a stent-graft?

**Dr Tsagakis:** You mean rather than to perform a stent-grafting use a bare-metal stent?

**Dr Motamedi:** Yes, bare-metal stent.

**Dr Tsagakis:** The procedure aims to exclude reentries.

**Dr Motamedi:** Yes. If you don't have intimal tear in the descending aorta, what is your idea of just a bare-metal stent to obliterate the false lumen?

**Dr Tsagakis:** In this situation, then you could have a problem with a strut of the bare-metal stent, the edges of the stent, and this could produce aortic injury. In addition, if you don't have continuity between the graft and the stent-graft thereafter, the risk of a proximal endoleak is present.

## Editorial comment

# Arch replacement and downstream stent grafting in complex aortic dissection – first results of an international registry

**Keywords:** Type A dissection; Aortic arch surgery; Stent-graft placement

Surgical repair of classical acute type A dissection is tear oriented. As such, the extent of surgical repair is usually limited to the proximal segments extending more or less into the concavity of the aortic arch. However, it has to be realised that this approach may be insufficient as tear-oriented surgical repair may require total arch replacement in patients with primary entry tears within the arch or even in the descending aorta, which may be critical. These patients may also well be the ones at high risk for developing secondary aneurysmal formation in downstream segments necessitating treatment.

According to the author, we do have to fulfil two tasks: first, defining the patients at risk for and second, developing treatment algorithms to prevent late aneurysmal formation in patients after tear-oriented surgical repair of classical acute type A dissection.

Defining these patients is difficult and the Essen group has set new standards regarding this issue by aortoscopy during hypothermic arrest. Future reports will reconfirm the clinical value of this approach.

The second task is prevention during primary surgery. For this purpose, the frozen elephant trunk was developed. This approach combines two treatment concepts and provides a unique possibility to treat the entire aortic arch during primary surgery. However, how is the risk–benefit ratio of this approach? It is clear that surgery becomes more extensive and hazards such as paraplegia and rupture, especially in a freshly dissected fragile vascular system, do exist. Otherwise, if the concept works, the arch is treated and the remaining pathology is shifted to downstream segments, thereby facilitating potential thoraco-abdominal replacement in years to come.

Therefore, the main task is to define patients who will benefit most. To date, it seems that patients with complex dissections with entry tears within the arch and the descending aorta resulting in retrograde type A dissection as well as patients with aneurysms encompassing the entire thoracic aorta are the ones who benefit most from this approach due to the reasons mentioned.