True Lumen Stabilization to Overcome Malperfusion in Acute Type I Aortic Dissection

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Original Manuscript

Title

True Lumen Stabilization to Overcome Malperfusion in Acute Type I Aortic Dissection

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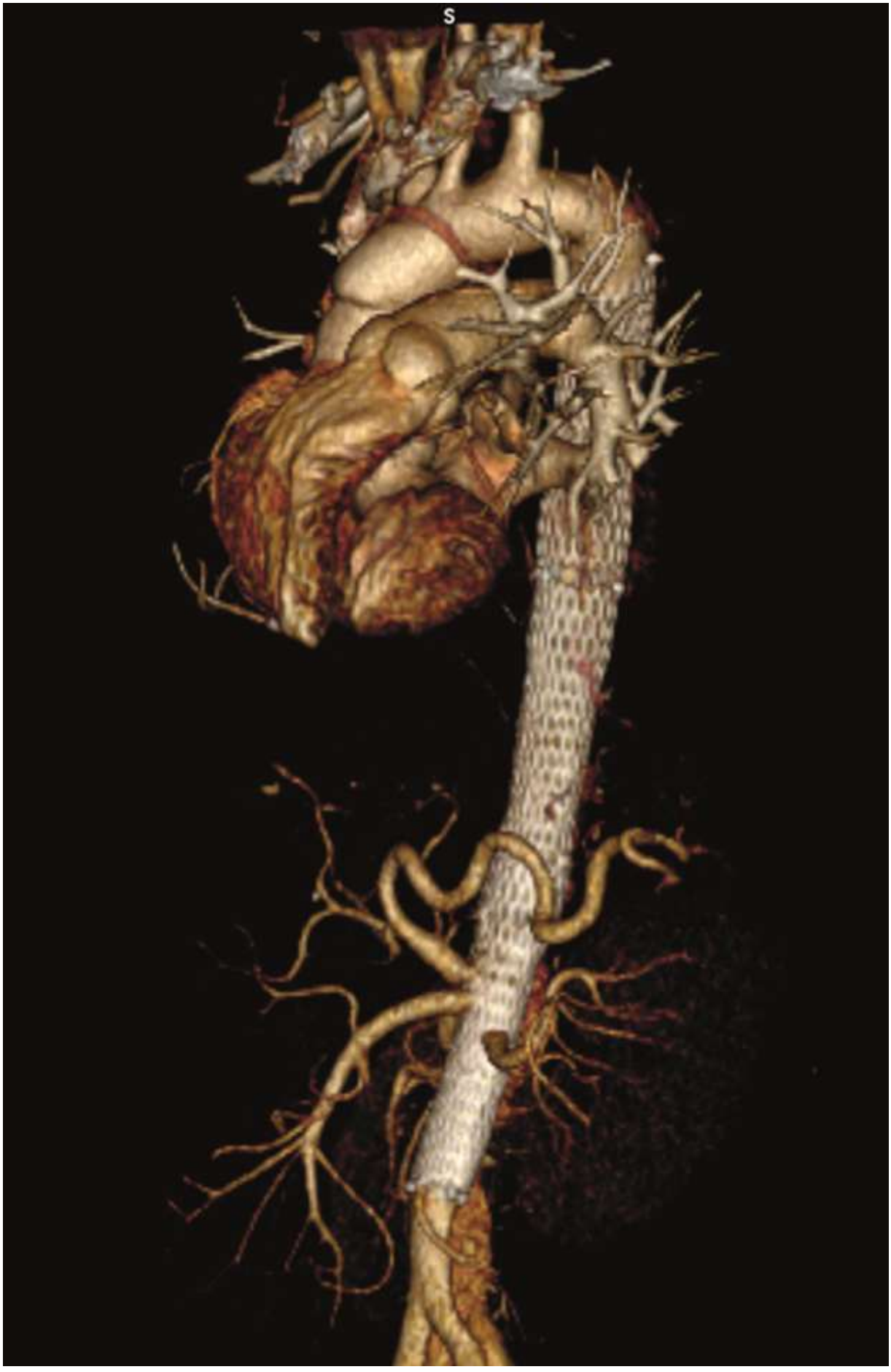
Glossary of Abbreviations

AD	Aortic dissection
FL	False lumen
FET	Frozen elephant trunk
TL	True lumen
SD	Standard deviation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Central Picture

Combined surgical and endovascular treatment in acute type I aortic dissection.

Central message

Treatment of true lumen collapse and malperfusion downstream by uncovered aortic stents combined with proximal repair in acute type I dissection is a safe approach in hybrid operating room setting.

Perspective message

Uncovered stents allow stabilization of a collapsed true lumen and became covered by neo-intima without impairment of end-organ perfusion in mid-term. The reinforced dissection´s septum by the encapsulated stent may allow selective endovascular closure of residual entries. In case of complete false lumen exclusion, neo-intima ingrowth may induce complete healing of aortic dissection.

Abstract

Objectives

Acute type I aortic dissection (AD) complicated from true lumen (TL) collapse and malperfusion downstream is associated with devastating prognosis. The study reports an institutional mid-term experience with TL stabilization by uncovered stents to restore perfusion as a supplement to proximal thoracic aortic surgery.

Methods

Between 01.2007-05.2017 181 out of 270 acute type A AD patients were operated on type I AD. In 18 (10%) uncovered stents were used to expand the aortic TL in presence of visceral/peripheral malperfusion. The procedures took place in a hybrid operating room and were combined with proximal aortic surgery. During follow up (mean±SD 3.44±2.1 years) the fate of AD was evaluated by computed tomography.

Results

Indication for TL stenting included visceral (44%) or peripheral malperfusion (11%) or both (45%). Stenting of aortic branches followed in 33%. All patients underwent proximal repair and was combined with frozen elephant trunk (67%) or retrograde descending aorta stentgrafting (11%). Thirty-day mortality was 16.7%. Two-year survival was 71.8%. The false lumen (FL) around the uncovered stents remained patent in 89% and the aortic diameter increased 0.1cm/year. No intimal rupture or occlusion of arteries occurred. In one patient, the stented aortic lumen was visualized after 6.3 years and neo-intima ingrowth covering the nitinol frame was found.

Conclusion

In acute type I AD combined endovascular-surgical procedures in a hybrid-operation room setting can be used safely to resolve distal malperfusion. Encapsulation of uncovered stents within the intimal wall provides a stable fundament for endovascular techniques to close entry tears and FL.

Word count = 250

Introduction

Acute type I aortic dissection (AD) complicated from severe true lumen (TL) collapse and malperfusion has a devastating prognosis [1]. The recommended "straight forward" surgical treatment consisting of immediate sternotomy and proximal aorta replacement enables the release of tamponade and circulatory stabilization and in many cases restoration of TL perfusion in the thoracic aorta, simply by exclusion of the proximal entry tear [2]. Depressurization of the false lumen (FL), however, does not regularly result in TL expansion, since re-entries in the descending and abdominal aorta may maintain increased pressure in the FL, thus sustaining the distal malperfusion. Furthermore, narrowing of abdominal or peripheral aortic branches as a result of thrombus formation into the FL leads to static malperfusion. Malperfusion may persist throughout the operative treatment despite FL depressurization, increasing the risk for an end-organ ischemia and thus resulting in necrosis which is associated with a high mortality rate of 40-70% [3-5].

To reduce the duration of end-organ ischemia, in 2007 we have started to restore abdominal organ perfusion endovascularely prior to surgery in a hybrid operating room setting using self-expandable uncovered stents [6]. The study reports our experience with this kind of malperfusion management in acute type I AD patients and presents the durability of the treatment and the fate of residual AD in mid-term follow-up.

Patients and Methods

From 01.2007 to 05.2017 270 patients underwent emergency surgery for acute type A AD, out of whom 181 had type I AD. Eighteen of them (10%) underwent endovascular TL stabilization along the thoracoabdominal aorta by placing self-expandable uncovered stents. The study was

approved from the institutional review board of University Duisburg-Essen and no informed consent was required. Patients' characteristics are presented in Table 1. Malperfusion was obvious according to clinical symptoms at the time of admission and in association to the computed tomography (CT) findings. Visceral malperfusion was documented in case of abdominal pain, ~~or~~ vomiting, hematemesis or hematochezia. Peripheral malperfusion presented with peripheral pain, pulselessness or paresis. In intubated and sedated patients, clinical symptoms were documented according to the external clinical report. According to our "Hybrid-Concept" in acute AD [7], admission and treatment took place in a hybrid operating room, which incorporates invasive angiography and surgery on the same operating table. Invasive angiography was used to confirm the severity of TL collapse and malperfusion and to differentiate between static and dynamic malperfusion. In case of dynamic malperfusion, a threshold of 6 hours of near complete visceral malperfusion after onset of symptoms was chosen to restore distal perfusion prior to surgery. In case of a shorter than 6 hours period of dynamic malperfusion, surgery of the thoracic aorta was immediately performed followed by repeat angiography postoperatively, to detect potential persistence of malperfusion. In such a case, additional stenting was undertaken. In case of static malperfusion, TL and abdominal aortic side branch perfusion was restored prior to surgery independently from malperfusion duration. In case of evidence for bowel necrosis explorative laparotomy was performed and an interim stay in the ICU to overcome the metabolic disorder prior to proximal aortic repair in otherwise hemodynamically stable patients followed [6]. Coronary angiography was performed in all patients over 50 years to exclude concomitant coronary artery disease.

Hybrid room concept

All patients with suspected aortic syndrome are submitted to our hybrid room since 2005 with an aortic team awaiting the patient, consisting of a cardiac surgeon, cardiologist and anesthetist. The patient was controlled hemodynamically by placing arterial lines into both radial arteries and one femoral artery as well as central venous catheters including a pulmonary artery catheter in sedation followed by intubation when the patient was admitted breathing spontaneously. Transesophageal echocardiography has been performed for confirmation of suspected AD and evaluation of tamponade and/or aortic valve regurgitation. In circulatory stable patients, angiography was performed first though the femoral artery, using an 8F sheath with a side-port for additional monitoring of the artery pressure. In circulatory unstable patients, immediate tamponade release via median sternotomy and cautious pericardial drainage placement took place. Angiography followed under stable conditions. In case of cardiopulmonary resuscitation or free rupture, immediate surgery was started and invasive diagnostics followed postoperatively.

Endovascular true lumen treatment

Stenting was performed though a surgically exposed femoral artery and over a Back-up Meier guide wire (Boston Scientific, Marlborough, USA). The limb arising from the TL was chosen, even in case of malperfusion. Dynamic malperfusion was treated by TL expansion with the sinus-XL (Optimed, Ettlingen, Germany) or the E-XL (Jotec, Hechingen, Germany) 100-130 mm in length stents. The first uncovered stent was deployed at the proximal part of TL collapse, commonly at the diaphragmatic level. A serial stent implantation distally was added, if required (Figure 1A). Narrowed visceral arteries were stabilized by balloon-expandable stents through the frame of the aortic stents (Figure 1B). Stent diameter was chosen according to the measurement of maximal TL diameter perpendicular to the course of the aorta in axial CT image or according to intravascular ultrasound. Maximal TL diameter was defined as the distance between the

anchor points of the dissected intimal wall. A one size smaller or equal stent diameter to TL maximal diameter was chosen. Oversizing was avoided in order to reduce the risk of stent infolding.

Aortic Surgery

Our surgical management in acute type I AD has been described previously [8]. In brief, cannulation site for the extracorporeal circulation varied according to the extent of AD into the arch vessels. In case of absent brachiocephalic trunk dissection, cannulation of the right axillary artery was favored. Otherwise, central cannulation of the ascending aorta under direct vision during a short period of warm circulatory arrest (≤120 seconds) was preferred [9]. Entries in the ascending aorta and the arch were resected and the distal anastomosis was performed in open fashion. Patients with full circular arch AD and/or re-entries in the proximal descending aorta underwent frozen elephant trunk (FET) surgery using the E-vita open (Jotec GmbH, Hechingen, Germany) prosthesis. FET was performed in combination with left subclavian artery debranching using an 8mm prosthesis in order to facilitate the arch replacement and to perfuse all arch arteries during arch repair and to increase ~~the~~ spinal cord perfusion via collaterals. In addition, selective descending aorta perfusion was re-established immediately in 7 patients after FET fixation using a Foley catheter as endoclamp into the body of the stentgraft in order to reduce visceral ischemia [10]. Circulatory arrest distally was initiated at 28°C bladder temperature and arch repair was performed under bilateral or triple selective cerebral perfusion at 22°C blood temperature. Cerebral saturation was controlled by near infrared spectroscopy. The TL of the descending aorta was visualized endoscopically using a autoclavable flexible bronchovideoscope (BF type Q180-AC, Olympus®), so called angioscope or aortoscope, to define re-entries and to guide the FET deployment [11].

Definitions and statistics

Malperfusion was confirmed and defined according to invasive angiography findings. Dynamic malperfusion was identified where the AD crossed the vessels´ origin compromising perfusion [12]. Static malperfusion was identified where the dissection extended into the vessels´ origin narrowing the TL. To evaluate the fate of the FL downstream, the aorta was divided in 3 segments. The proximal and mid part of the descending aorta down to TH 8 level was defined as Segment A, distally down to coeliac trunk as Segment B and more distally down to bifurcation as Segment C. Measurements of aortic diameter (cm) and area (cm^2) of the aorta and TL were done at the level of pulmonary artery bifurcation, distal descending aorta, coeliac trunk and inferior mesenteric artery. Measurements were undertaken in cross-sectional images after three dimensional multiplanar reconstruction. The SPSS Package 24 was used for statistical analysis. The Shapiro-Wilk´s test was used to evaluate data distribution. The paired-samples t-test or the Wilcoxon signed-ranks test was used to determine the differences of aortic diameter and area between the first and last CT examination, if appropriate. Continuous variables are presented in mean ± standard deviation (SD). Categorical variables are presented in percent. Survival and freedom from re-intervention postoperatively were estimated by Kaplan Meier analysis.

Results

Malperfusion treatment

The first diagnosis of AD was established elsewhere by CT in 14 (78%) and echocardiography in 4 (22%) patients. The delay between onset of symptoms and admission to the hybrid room (15±33 hours) was less than 6 hours in 11 (61%) and more than 6 hours in 7 (39%) patients. At the time of admission 7 (39%) patients were hemodynamically compromised. Severe tamponade

occurred in 4 patients. In 2 of them invasive angiography was performed immediately after tamponade release. In the other 2 angiography followed the aortic surgery postoperatively.

Angiography demonstrated TL collapse inducing malperfusion in the mesenteric aortic part in 8 (44%), the infrarenal part in 2 (12%) and both in 8 (44%). Static malperfusion into the aortic branches was observed in 6 (33%); 2 in visceral arteries, 2 in visceral and iliac arteries and 2 in iliac arteries only. TL stabilization by uncovered stents was achieved via the femoral artery in 16 and through the opened arch under angioscopic guidance in 2 patients. The reason to use the antegrade route was a persisting TL collapse after stent displacement in one (Figure 2, Supplement 1) and a large residual entry tear beyond the distal end of the FET in the other. In total, 35 uncovered stents, 7 sinus-XL and 28 E-XL stents, and 2 covered stents were placed. Stent deployment took place in Segment A in 5 (28%), Segment B in 14 (78%) and Segment C in 15 (83%), Table 2. Static malperfusion could be resolved preoperatively by stenting of the aorta and the occluded arteries in all cases. In 4 of them, proximal aortic repair was performed after explorative laparotomy and an interim stay in ICU of 10.6±29.7 hours to overcome severe metabolic disorder. Proximal repair consisted of ascending aorta ± arch replacement or FET surgery in 6 and 12 patients, respectively. In addition, aortic valve repair/replacement or coronary artery bypass grafting for coronary artery disease was required in 15 (83%) patients. The time of cardiopulmonary bypass, cardioplegic arrest, visceral perfusion arrest and selective cerebral perfusion was 261±57, 142±38, 48±25 and 60±21 minutes, respectively.

Postoperative results

In-hospital and 30 days mortality was 16.7%. Cause of death was myocardial infarction in one and bowel necrosis in 2 patients after dynamic visceral malperfusion. In one of them the delay to

endovascular treatment was 14 hours. The other patient was admitted after 6 hours delay but with Leriche syndrome. In addition, residual visceral and peripheral ischemia after the primary endovascular repair was observed in 2 (11%) and 2 (11%) patients, respectively. One patient underwent bowel resection prior to proximal aortic repair. The second patient underwent endoscopy and medical treatment postoperatively. Peripheral interventions were performed in the distal extremities by thromboendarterectomy in one and transcatheter treatment in the second. No new stroke occurred. All patients with a preoperative cerebral neurological deficit did recover but one. Eleven patients (61%) underwent temporary renal replacement therapy due to acute kidney injury. Of them, 10 had TL collapse at the visceral aortic part, 3 had additional renal artery dissection and 1 had static renal artery malperfusion. No patient required dialysis after discharge. Hospital stay was 28.2±21.5 days. All discharged patients except for one – due to residual neurological deficit - turned back to normal life.

Follow-up lasted 3.44±2.1 years and estimated survival after 2 years was 71.8% (95% CI 1.167-1.890). Four of 15 discharged patients died. Cause of death was secondary thoracoabdominal aortic surgery, unknown death at home, pneumonia after permanent stroke and suicide. Three patients underwent secondary aortic intervention; one thoracoabdominal aortic replacement for infrarenal abdominal aneurysm as mentioned above, one proximal arch replacement due to pseudoaneurysm formation at the distal anastomosis after ascending aorta repair and one FET for progressive distal arch enlargement after 2, 6 and 8 years, respectively. No patient underwent an endovascular re-intervention.

Aortic results

In the first postoperative CT examination complete or partial FL thrombosis in Segment A was documented in 61% and 28%, respectively (Table 3). Complete FL patency occurred in 11% and only in absence of FET treatment. In Segments B and C the FL remained completely or partially perfused in 83% and 89%, respectively. Infolding of the uncovered stents occurred in 3 (17%) patients; 2 with sinus-XL and 1 with E-XL stents implanted. In the last CT examination complete or partial FL patency in Segments A, B and C was 33%, 73% and 87%, respectively. No occlusion of visceral arteries arising either from TL or FL occurred (Figure 1 C-F).

Between first and last CT the aortic diameter decreased in the mid descending aorta 0.1cm/year ($p=0.005$) and increased in the distal descending aorta 0.1cm/year ($p = 0.014$), Table 4. In the abdominal aorta the aortic diameter increased proximally ($p = 0.005$) and distally ($p = 0.027$) 0.08cm/year. The TL/AL ratio increased in mid descending aorta ($p=0.005$) and remained stable distally.

Remodeling of inner aortic surface – Case

One patient (55 years, male) was treated initially with uncovered stents in all 3 Segments using 4 E-XL stents and ascending aorta repair (Figure 3A). He had to undergo re-do surgery after 6.3 years for pseudoaneurysm in the distal anastomosis. In absence of an entry tear in the aortic arch and proximal descending aorta, the AD across the arch had resolved. The FL in Segment A was obliterated and remained perfused in Segments B and C (Figure 3 B, D). During secondary surgery and open anastomosis in the proximal arch, the angioscope was used to visualize the aortic lumen downstream (Supplement 2). All uncovered stents were endothelialized and encapsulated into the aortic wall (Figure 3C). No lesion along the intimal surface was found apart from re-entries in the proximal and distal abdominal aorta. The overstented visceral orifices

were open and the new intimal surface did not extend macroscopically into the vessels´offsprings (Figure 3E).

Discussion

Classic approach to treat accompanying visceral and/or peripheral malperfusion in acute type I AD is the fast replacement of the proximal thoracic aorta, thus achieving exclusion of the proximal entry tear and FL depressurization in many cases. However, the malperfusion associated increased mortality demonstrates the necessity of alternative strategies to keep the patient alive [13, 14]. Deeb et al. reported in 1997 the implementation of primary endovascular restoration of the abdominal perfusion followed by a surgical delay thereafter to overcome metabolic abnormalities and to reduce the surgical trauma in a hemodynamic and metabolic stable patient [1]. Though heavily criticized for this kind of "natural selection" approach, this concept revealed the shortcomings of classic open surgery to deal with extensive mesenteric and peripheral malperfusion in emergency AD situations and introduced a new way to address the malperfusion sequelae. Modern hybrid operating room concepts like ours enable the combination of endovascular and surgical techniques and give the option for on-time diagnostics and treatment. Since no patient transport from a cath-lab to an operating room and vice versa is needed, we accepted a short delay to sternotomy and cardiopulmonary bypass in order to evaluate the extent of AD and malperfusion severity by angiography and to decide for a specific treatment. Even in initially circulatory unstable patients due to tamponade invasive diagnostics and treatment is possible after cautious tamponade release and pericardial drainage under blood pressure control (7).

Implantation of uncovered stents to further expand the TL is frequently applied in complicated acute type B AD and is known as the PETTICOAT concept [15, 16]. Uncovered stents are placed for extension of a proximally deployed stentgraft in order to eliminate TL collapse and to improve perfusion distally. Similarly, we used this technique in acute type I AD in reverse fashion by first placing the uncovered stents into the abdominal aorta to resolve malperfusion and then by proceeding to the proximal aortic repair. In contrast to treatment by a stentgraft, the uncovered stent allows deployment over the aortic vessels´ orifices without need of precise landing except for the aortic bifurcation level. This simple technique justifies its use in emergency situation with minimal loss of time and less endovascular jeopardies. However, placement of a guide wire within the TL must be secured in order to prevent misplacement, as described from our experience (Figure 2). Thus, intravascular ultrasound is suggested to follow the wire along the TL of the abdominal aorta.

The stabilization of the TL by uncovered stents could be demonstrated throughout the investigation period but their use had less impact on FL exclusion, which is similar to the experience in type B AD [17]. In contrast to the proximal descending aorta, in which shrinkage of FL and aortic diameter was demonstrated after FET, the FL distally around the uncovered stents remained completely or partially patent in 89%. Although less or no oversizing was applied in our series, we believe that even in case of excessive oversizing, exclusion of FL would fail due to the stent´s tendency to infold. The perfused FL resulted into enlargement of the distal aortic segment 0.1cm/year, which is similarly to other reports (18, 19). However, the stable ratio of TL/AL area demonstrates that this enlargement refers to a dilatation of the entire aorta rather than to isolated FL progression.

The modest experience with this technique in acute AD raises concerns about the interaction between the nitinol skeleton and the fragile intimal wall as well as about the patency of the overstented abdominal orifices [20]. We applied this technique rarely in acute type I AD and only as a bail-out option in order to prevent ~~a~~ fatal end-organ necrosis. Nevertheless, the encapsulation of the uncovered stents into the aortic wall 6.3 years after implantation demonstrates neointma-like ingrowth covering the nitinol frame and leaving the side branches untouched. No intimal rupture, no stent migration and no occlusion of an overstented artery did occur in these patients. The quantitative influence of TL stabilization to blood supply of arteries arising from false lumen is unknown. However, the 100% patency of the overstended FL-arteries and the residual FL perfusion around the uncovered stents supports our previous observation that FL- arteries act as "exits" keeping the blood supply intact against thrombosis [21]. The endothelialization of the stent can be considered as "reinforcement" of the dissected intimal wall. This observation was confirmed from Professor Roberto Chiesa, IRCCS San Raffaele Scientific Institute in Milano, Italy, by removal of an uncovered stent from the abdominal aorta 18 months after PETTICOAT treatment for acute type B AD (Figure 4F). Similarly to our finding, a neointima-like tissue covered the entire nitinol skeleton but not the visceral arteries orifices. The stent was completely encapsulated into the intimal wall and its removal became possible only after an endarterectomy-like maneuver. This evolution to endothelialized stent and stable intimal wall opens up the option for specific closure of residual entries and FL by endovascular devices in the chronic phase of the disease with probably lesser risk for endoleak or intimal rupture [22-23]. In addition, the endothelialization process may be supportive for the STABILISE concept [24-25], in which the entire aortic lumen is stabilized by uncovered stents after rupture of the dissection´s septum by balloon and depressurization of the false lumen. In this case, the

endothelialization process could be an important step towards complete healing of the entire aorta.

Conclusion

The application of endovascular diagnostics and treatment as a standard procedure for surgery of acute type I AD in our opinion is justified, when a hybrid operating room set up is available, especially in patients suffering from visceral and peripheral malperfusion. The presented low mortality in this high risk patient cohort demonstrates the safety of this hybrid concept in the presence of experienced cardiovascular surgeons and interventionalists. Although the endothelialization process over time of uncovered stent is not known in detail, the coverage of the fenestrated nitinol frame by "neo-intima" opens up opportunities for new endovascular strategies to exclude the residual false lumen or to heal the entire aorta.

Acknowledgments

None

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Figure legends

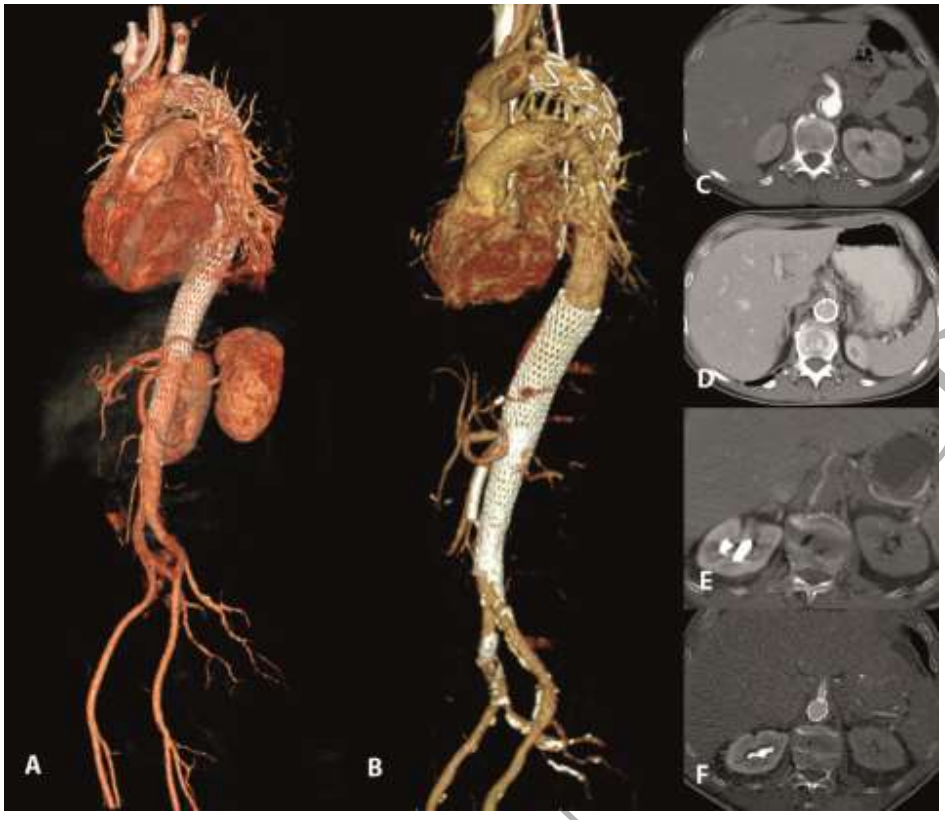


Figure 1. True lumen stabilization of the thoracoabdominal aorta by uncovered stents to resolve mesenteric malperfusion in acute type I aortic dissection combined with proximal descending aorta endografting (A) or Frozen Elephant Trunk (B). True lumen collapse (C) was abolished by isolated stenting of the abdominal aorta (D). In static malperfusion (E) additional artery stenting was performed (F).

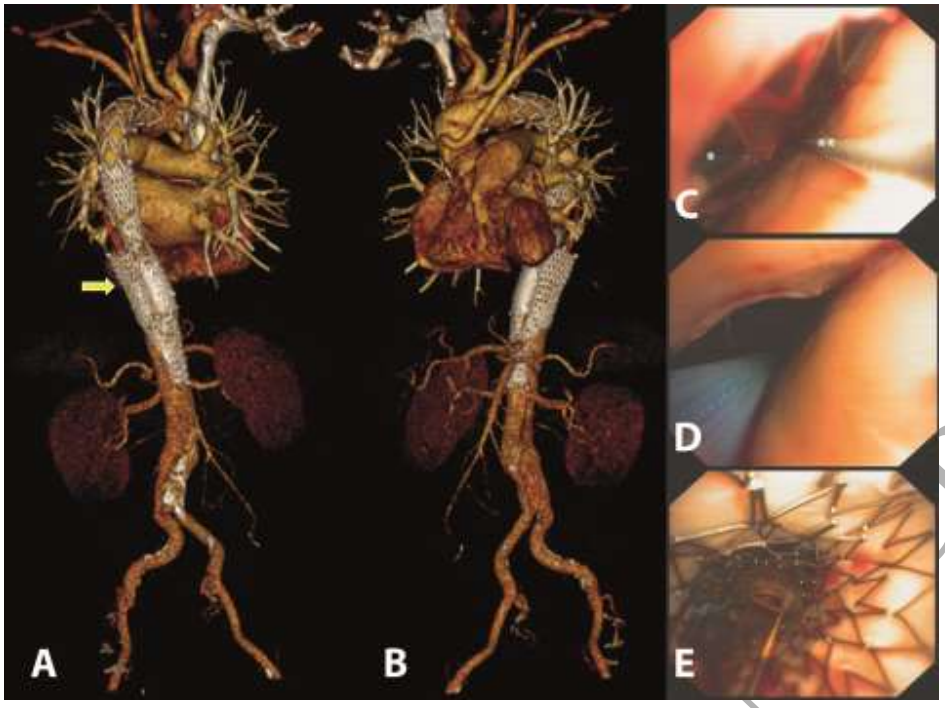


Figure 2. A 59 y/o patient presented with abdominal pain, hematemesis, pulselessness distally. To re-open the collapsed true lumen (TL) an uncovered stent was introduced retrogradely. Wire and stent crossed over an entry at the superior mesenteric artery (SMA) level and the stent was landed partially within the false lumen (FL) (arrow) resulting in TL occlusion proximally. To overcome this complication the TL was expanded upstream by placement of 2 additional stents through the opened arch under angioscopic guidance. Proximal aorta repair and frozen elephant trunk (E-vita open plus) placement in Zone 2 combined with subclavia artery debranching followed. The 18 months postoperative CT demonstrates the proximal part of the stent into the FL (A). The stented TL and visceral arteries remained open (B). C demonstrates the angioscopic view into the entry tear in the abdominal aorta and the stent and pigtail catheter (*) crossing into the FL. A back-up guide wire (**) was placed though the channel of the angioscope beside the stent into the infrarenal TL. Two uncovered stents were guided over the wire downstream (D) and re-opened the TL after deployment (E).

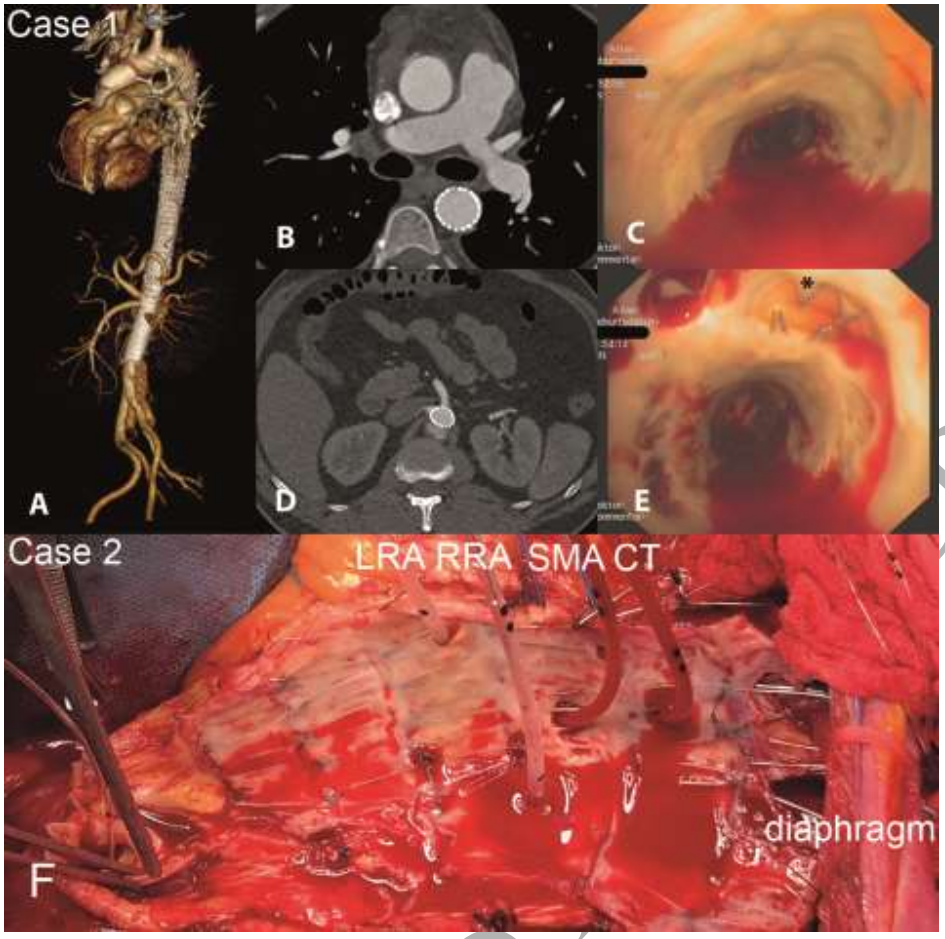
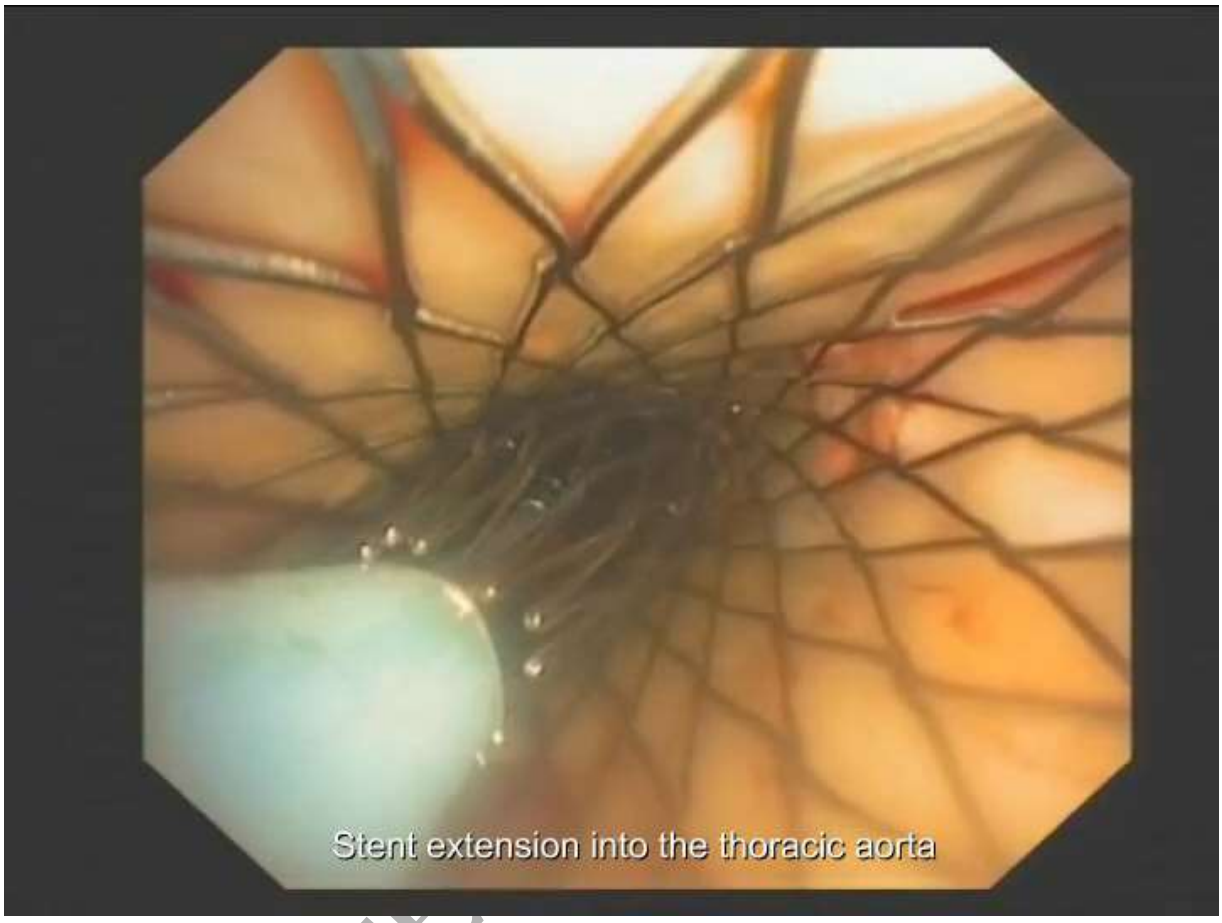


Figure 3. Documentation of uncovered stents endothelialization in the thoracoabdominal aorta in two patients. Case 1 (A-E): :Status post proximal aortic repair and thoracoabdominal true lumen stabilization with 3 E-XL uncovered stents for acute type I aortic dissection and open proximal arch re-surgery for pseudoaneurysm after 6.3 years (A). The false lumen was excluded in the descending aorta (B) and remained perfused at the superior mesenteric artery level (C). Intraoperative angioscopy downstream during the opened arch re-surgery demonstrated ingrowth of neointima along the entire stented aorta (D). Abdominal arteries were open without extention of the neontima into the orificies as visualized in superior mesenteric artery* (E).

Case 2 (F) is provided from Roberto Chiesa (Milan, Italy) and confirms the coverage of uncovered stent by neointima in aortic dissection. Thoracoabdominal open aortic repair 18

months after PETTICOAT treatment for acute type B aortic dissection and progressive false lumen enlargement was performed. The uncovered stent was placed from diaphragm down to infrarenal aorta. The nitinol skeleton was covered by neontima-like tissue except of the space crossing the visceral arteries orifices (CT: coeliac trunk, SMA: superior mesenteric artery, RRA: right renal artery, LRA: left renal artery). Due to the encapsulation of the stent into the intimal wall endarterectomie-like manoeuver to remove the stent became necessary.

Supplements



Video 1. Endoscopically guided antegrade stenting to expand a collapsed true lumen in the abdominal aorta

The video refers to Figure 2 and demonstrates true lumen stabilization by stent placement downstream through the opened aortic arch in a bail-out situation. The endoscopically guided procedure was performed under selective cerebral perfusion and intermittent hypothermic circulatory arrest distally at 24°C bladder temperature. The endoscopy was

performed by an autoclavable videoscope (BF type Q180-AC, Olympus®), the so called angioscope. True lumen collapse and the entry tear in the mid abdominal aortic level are demonstrated. The proximal part of the previously implanted uncovered stent had unintendedly crossed over a reentry tear into the false lumen resulting in collapse of the true lumen. The distal part of the stent was located correctly within the true lumen of the infrarenal aorta. Therefore a stiff guide wire was advanced though the channel of the angioscope besides the stent skeleton into the true lumen. The angioscope was then removed and placed again to release the wire for stenting. An uncovered E-XL stent was introduced and deployed into the true lumen in over the wire technique thus compressing the first stent. This stenting was extended proximally into the thoracic aorta with an additional uncovered stent to secure the treatment. A complete expansion of the true lumen was achieved. Finally, an E-vita open plus hybrid stentgraft was inserted and unfolded within the lumen of the uncovered stent, guided and controlled by angioscopy. The final control angioscopy demonstrates the satisfactory result with full restoration of the true lumen of the thoracoabdominal aorta. The time of selective cerebral perfusion and intermittent hypothermic circulatory arrest was 56min and 16min, respectively.

Video 2. Endoscopic visualization of stented thoracoabdominal aortic lumen

Presentation of the endoscopic visualization of the descending and abdominal aortic lumen 6.3 years (Figure 4) after thoracoabdominal serial stenting with uncovered E-XL stents and proximal aorta replacement for acute type I aortic dissection. The procedure was performed through the opened arch under ongoing selective cerebral perfusion (50mmHg, 1000ml/min) and hypothermic circulatory arrest at 28°C distally. Cause for the reoperation was a pseudoaneurysm formation in the distal ascending aorta involving the arch. A sump

sucker placed into the descending aorta was used to create a bloodless field. Beginning from the proximal descending aorta downstream endothelialization of the nitinol frame of the stents throughout the entire stented aorta is demonstrated. The markedly reduced blood flow indicates compromised collateralization. In addition, rise of spinal arteries from false lumen was detected in the CT examination. At the ending of the stents in the distal abdominal aorta the true lumen is collapsed due to the circulatory arrest situation and the residual false lumen. Close to the distal end of the stent an entry tear in clock position 5 was identified. Pulling the angioscope back to the level of the visceral arteries the orifices were visualized. The artery orifice in clock position 2 is not affected from neo-intima ingrowth. This orifice refers to the superior mesenteric artery according to the CT imaging. Similar finding is presented in clock position 10 at the same video level. The orifice refers to a renal artery and the lumen is unaffected. Proximally, in clock position 10 and close to coeliac trunk a bleeding entry tear is suggested.

Table 1. Preoperative characteristics

N (%); mean±SD	**N = 18**
Age	55.4±30
Male	15 (83)
Intubated before admission	7 (39)
Tamponade	4 (22)
Penn classification *	
A	-
B	11 (61)
C	-
BC	7 (39)
Malperfusion related symptoms	
Neurological deficit	9 (50)
cerebral	5/9
peripheral	6/9
Abdominal pain	11 (61)
Vomiting	10 (56)
Hematemesis	2 (11)
Hematochezia	1 (6)
One side limb ischemia	4 (22)
Both side limb ischemia	5 (28)

No symptoms/unknown	
Aortic valve regurgitation	
Mild	6 (33)
Moderate	5 (28)
Severe	5 (28)
Coronary artery disease	7 (39)
Creatinine >1.5 mg/dl	8 (44)

* Classification of acute AD according to University of Pennsylvania, USA [26].

Table 2. Endovascular and surgical aortic treatment

(%), mean±SD	Malperfusion site downstream			
	Mesenteric	**Peripheral**	**Both**	**Total**
	N = 8	**N = 2**	**N = 8**	**N = 18**
Endovascular treatment				
Time of intervention				
Preoperative	5 (63)	1 (50)	7 (88)	13 (72)
Intraoperative	1 (12)	-	1 (12)	2 (11)
Postoperative	2 (25)	1 (50)	1 (12)	4 (22)
Aorta stenting				
Segment A	1 (12)	-	4 (50)	5 (28)
Segment B	6 (75)	-	8 (100)	14 (78)
Segment C	5 (62)	2 (100)	8 (100)	15 (83)
Arteries stenting				
Visceral arteries	2 (25)	-	2 (25)	4 (22)
Iliac arteries	-	1 (50)	3 (37)	4 (22)
Surgical treatment				

Aorta repair extension				
Ascending aorta	-	1 (50)	2 (25)	3 (17)
Ascending aorta + arch	1 (12)	-	2 (25)	3 (17)
Ascending aorta + FET	7 (88)	1 (50)	4 (50)	12 (67)
Perfusion management				
Bilateral selective cerebral perfusion	4 (50)	1 (50)	5 (62)	10 (56)
Triple selective cerebral perfusion*	4 (50)	1(50)	3 (37)	8 (44)
Selective descending aorta perfusion	2 (25)	1 (50)	4 (50)	7 (39)
Aortic root replacement				
Partial	2 (25)	1 (50)	2 (25)	5 (28)
Total	3 (37)	1 (50)	2 (25)	6 (33)
Aortic valve				
Repair	4 (50)	1 (50)	2 (25)	7 (39)
Replacement	3 (37)	1 (50)	2 (25)	6 (33)
CABG	5 (62)	-	1 (12)	6 (33)

*Both carotid arteries and left subclavia artery perfusion

Table 3. False lumen in postoperative and follow up examinations

N (%)	**1st CT**	**Last CT**
	N = 18	**N = 15**
Segment A		
Complete thrombosis	11 (61)	10 (67)
Partial thrombosis	5 (28)	3 (20)
No thrombosis	2 (11)	2 (13)
Segment B		
Complete thrombosis	3 (17)	4 (27)
Partial thrombosis	1 (5)	5 (33)
No thrombosis	14 (78)	6 (40)
Segment C		
Complete thrombosis	2 (11)	2 (13)
Partial thrombosis	-	3 (20)
No thrombosis	16 (89)	10 (67)

Table 4. Computed tomography changes of descending and abdominal aorta between postoperative and last follow-up examination

mean±SD	**Descending aorta**					
	Mid-level			**Distal-level**		
	postop	**FU**	**p**	**postop**	**FU**	**p**
Diameter (cm)	3.3±0.5	3.0±0.4	0.005	3.1±0.4	3.4±0.6	0.014
Ratio TL/AL (%)	57±17	81±27	0.005	58±22	57±27	0.792
mean±SD	**Abdominal aorta**					
	Proximal-level			**Distal-level**		
	postop	**FU**	**p**	**postop**	**FU**	**p**
Diameter (cm)	2.9±0.5	3.2±0.6	0.005	2.4±0.7	2.6±0.8	0.027
Ratio TL/AL (%)	65±19	63±25	0.196	65±23	61±26	0.280

TL: true lumen, AL: Aortic lumen, FU: Follow-up