Aus der Klinik für Herz-, Thorax- und Gefäßchirurgie
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DISSERTATION

Restoration of supra-aortic vessel perfusion after open hybrid stenting of the aortic arch for acute type A aortic dissection

Wiedererstellung der Perfusion in den supra-aortalen Ästen durch offenen hybrid Stenting des Aortenbogens für akute Typ A Aortendissektion

zur Erlangung des akademischen Grades
Doctor medicinae (Dr. med.)

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Summary

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Abbreviations

ACS	Acute coronary syndrome
AMDS	Ascyrus Medical Dissection Stent
BMI	Body mass index
BSA	Body surface area
CT	Computed tomography
CPB	Cardio-pulmonary bypass
EVAR	Endovascular aortic replacement
GERAADA	German registry of acute type A aortic dissection
ICU	Intensive care unit
INA	Innominate artery
IRAD	International registry of aortic dissection
LCC	Left common carotid artery
MPR	Multi-planar reconstructions
PENN	University of Pennsylvania
PTFE	Polytetrafluoroethylene
RCC	Right common carotid artery
SAV	Supra-aortic vessel
SD	Standard deviation
TAVI	Transcatheter aortic valve implantation
TEVAR	Thoracic endovascular aortic replacement

Abstract

Objectives:
Acute type A aortic dissection is a lethal condition that requires emergent surgical repair, especially in case of cerebral malperfusion. In this setting, we aimed to investigate perfusion patterns in the aorta and in the supra-aortic vessels after implantation of the Ascyrus Medical Dissection Stent (AMDS).

Methods: 16 consecutive patients presenting acute type A aortic dissection with involvement of at least one supra-aortic vessel treated with the AMDS device were retrospectively screened from our institutional database. Dissection anatomy, true and false lumen perfusion were investigated in pre- and postoperative computer tomography, using standardized centerline reconstructions. To perform an objective perfusion evaluation, the true lumen area was indexed to the entire vessel area and paired sample t-test was used to assess relevant differences prior and after surgery.

Results: AMDS implantation triggered a significant improvement of true lumen perfusion in the supra-aortic vessels and descending aorta. Innominate, right and left common carotid arteries indexed true lumen increased by 72%, 112% and 30%, respectively. Device implantation induced complete resolution of every total occlusion in both common carotid arteries. After surgery, proximal- and mid-descending aorta experienced a 78% and 48% improvement in indexed true lumen area, respectively.

Conclusions: hybrid arch repair using the AMDS shows promising results in terms of vascular remodeling after surgery for acute type A aortic dissection. A standardized comparison of imaging prior and after the operation demonstrated significant improvement of true lumen perfusion and complete elimination of vessel occlusions in the supra-aortic vessels. Further investigation in a larger cohort of patients is mandatory as well as the comparison with an isolated hemiarch repair.

Zusammenfassung

Ziele: die akute Aortendissektion Typ A ist eine tödliche Erkrankung der Hauptschlagader, die eine sofortige chirurgische Versorgung benötigt, insbesondere im Fall einer zerebralen Malperfusion. Die vorliegende Analyse zielt darauf ab, den nicht gecoverten Ascyrus Medical Dissection Stent (AMDS) im Hinblick auf die Perfusion der supra-aortalen Gefäße nach einer Operation für akuten Aortendissektion Typ A zu untersuchen.

Methode: Zwischen 2017 und 2020 wurden 16 konsekutive AMDS-Implantationen bei Patienten mit Dissektion oder Totalverschluss von mindestens einem supra-aortalen Gefäß retrospektiv analysiert. Prä- und postoperative Computertomografien wurden standardisiert hinsichtlich der wahren, falschen und gesamten Lumenfläche unter Verwendung von Mittellinienrekonstruktionen ausgewertet. Die wahre Lumenfläche wurde auf die gesamte Gefäßfläche bezogen, und ihre Veränderungen vor und nach der AMDS-Implantation wurden mit einem t-Test für gepaarte Stichproben verglichen.

Ergebnisse: Die AMDS-Implantation führte zu einer signifikanten Verbesserung der wharen Lumen Perfusion in den supra-aortalen Gefäßen und in der absteigenden Aorta. Das wahre Lumen der Arteria Anonima, der rechten und linken Arteria Carotis communis nahm jeweils um 72 %, 112 % bzw. 30 % zu. Die Implantation des Stents führte zu einer vollständigen Auflösung jedes Totalverschlusses in beiden Karotisarterien. Nach der Operation verbesserte sich das indizierte wahre Lumen der proximalen und der mittleren Aorta descendens um 78 % bzw. 48 %.

Schlussfolgerungen: Die Hybridbogenreparatur mit dem AMDS-Device führt zu günstigen Ergebnissen bei der chirurgischen Behandlung akuten Aortendissektionen Typ A. Nach einem standardisierten Vergleich der Bildgebung vor und nach der Operation konnte eine signifikante Vergrößerung der wahren Lumenfläche und eine vollständige Rückbildung der total verschlossenen supra-aortalen Äste nachgewiesen werden. Diese vorläufigen Ergebnisse zur positiven Gefäß-Remodelling nach AMDS-Implantation müssen in zahlreicheren Kohorten bestätigt werden, möglicherweise nach einem Vergleich mit einer Teilbogen-Reparatur allein.

1. Introduction

1.1 Definition, epidemiology and presentation

Acute type A aortic dissection (ATAAD) represents an emergency in cardiac surgery which requires urgent treatment to avoid death and severe complications. In the majority of cases, an ATAAD is caused by a tear in the ascending aorta, which leads to the detachment of the intima from media and adventitia with the formation of two lumina, called true and false lumen, respectively. The expansion of the false lumen along the aorta can compromise main aortic branches, leading to malperfusion and end organ ischemia, or the aortic valve, causing acute insufficiency. During this process, the disruption of the wall layers can culminate in aortic rupture, with circulatory collapse and/or massive bleeding in pericardium or mediastinum. Therapy of choice is a surgical repair, since untreated patients show a mortality rate of 1-2%/hour[1]. Target of surgery are the elimination of the intimal tear by replacing the ascending aorta, the depressurization of false lumen and the restoration of true lumen perfusion[2,3].

ATAAD was reported to range between 2 and 16 cases/100,000 inhabitants/year[4,5], but according to recent findings based on autoptic examinations, the number of undiagnosed dissections can increase the assumed incidence by 50%[6]. This can be explained by the fact, that the pre-hospital deaths account for roughly the half of mortality for ATAAD[7,8]. In this constellation, rapid diagnosis and immediate referral for surgical repair are of vital importance to improve outcomes[9]. Clinical symptoms at presentation can vary and complicate the diagnostic process. A sudden and destructive chest or back pain is the most described onset symptomatology of an ATAAD, which puts it in differential diagnosis with acute coronary syndrome (ACS) and can cause significant delay in the detection of the pathology, especially in case of coronary artery involvement, electrocardiographic ischemic signs and cardiac enzymes elevation[10–12]. Signs of end organ dysfunction can also be present due to malperfusion, along with acute aortic regurgitation, cardiac tamponade and shock[13]. Due to the heterogeneous presentation patterns, the aortic dissection detection risk score (ADDRS) was defined to trigger faster diagnosis and referral for surgery[14,15]. Nevertheless, near the half of patients was described to be diagnosed in more than 6 hours in Europe and more than 15 hours in the United States, with 75% of patients having diagnostic times exceeding 3-4 hours[16]. The acceleration of the diagnostic process should also consider major risk factors associated with ATAAD: risk was described to increase with age, affecting on average mostly male patients (ratio 1,5:1)[17]. Still, the gender ratio shifts when considering patients over 75 years of age, showing an overall higher incidence in women[18]. Arterial hypertension is the most common cardiovascular risk factor associated with ATAAD, along with atherosclerosis, diabetes and history of smoke[7]. An important role is also played by connective tissue disorders, preexisting aortic pathology (i.e. bicuspid aortic valve, aortic aneurysms), previous cardiac surgery and interventions such as cardiac catheterization, transcatheter aortic valve implantation (TAVI) or endovascular aortic procedures (TEVAR/EVAR)[19]. Even if patients are referred to specialized aortic centers after certain diagnosis of aortic dissection and successfully undergo emergent aortic repair, outcomes remain poor despite continuous improvements in medical and surgical treatment. According to several international multicentric registries, perioperative mortality for ATAAD ranges from 16% to 26%[13,20,21]. In multivariate models, older age, preoperative resuscitation, coma or cardiogenic shock at presentation and severe malperfusion syndrome were identified as independent predictors for mortality[22,23].

1.2 Standard classification of ATAAD

Due to the multifactorial nature of the disease, several methods were proposed to classify aortic dissections and drive appropriate preoperative evaluation and surgical treatment.

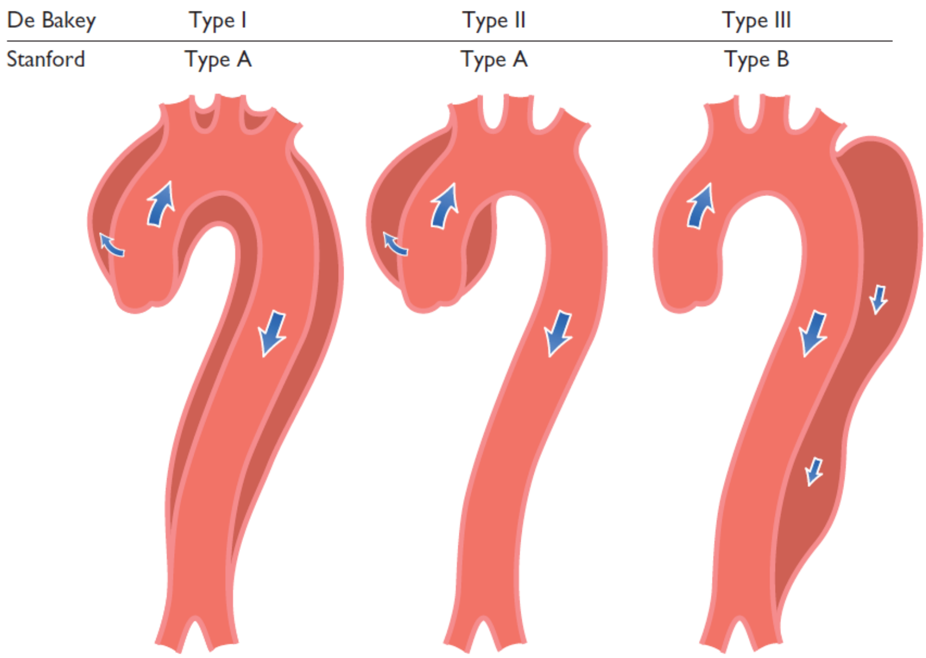

Figure 1. De Bakey and Stanford classification of acute aortic dissection*[2]*.

The first classification method was proposed by Michael DeBakey in 1965, according to the involvement of the aorta: ascending, arch and descending aorta (type I), ascending aorta only (type II), descending aorta only (type III)[24]. Some years later, the Stanford University proposed a simplified approach, differentiating aortic dissections on the basis of ascending (type A) or isolated descending involvement (type B)[25]. These two classifications are depicted in ***Figure 1***[2]. For almost 50 years, DeBakey and Stanford classifications have been the only used systems to characterize aortic dissections, with the indisputable advantage of simplicity at the expense of accuracy in the description of onset mechanism, side branches involvement and clinical status.

1.3 The role of malperfusion and new classifications methods

Thanks to the progresses in understanding the pathophysiology of aortic dissection, in diagnostic and treatment algorithms, novel classifying systems were developed to better assess dissection patterns and possibly adjunct prognostic value to preoperative assessment. In 2009, the University of Pennsylvania proposed the so-called PENN classification, which describes the preoperative presence and source of ischemia in patients with ATAAD[26]. According to PENN investigators, malperfusion is caused either by dissection of main aortic branches, meaning a localized ischemia (PENN Ab), or by circulatory collapse, meaning a generalized ischemia (PENN Ac), or by a combination of both (combined ischemia, PENN Abc). This classification was later validated from several independent investigators and currently shows a great prognostic value, since perioperative mortality raises with the worsening of malperfusion patterns[27,28].

In the analysis from the GERAADA registry, a consistent difference in early survival was detected depending on the presence or absence of any type of malperfusion syndrome and the number of organs involved[29]. Moreover, a linear correlation was demonstrated between the number of malperfused organs and mortality, with the latter increasing approximately of 10% with any additional organ involved. These findings led the authors to advocate a clear categorization of malperfusion patterns, when describing ATAAD: un-complicated (no clinical or imaging signs of malperfusion) or complicated (clinical or imaging signs of malperfusion).

With the aim to produce a comprehensive evaluation on dissection anatomy, also considering the cited findings, Sievers et al. proposed the novel TEM classification (***Figure 2***), in analogy to the TNM staging system for cancer[30]. The authors stated the inadequacy of Stanford/DeBakey classifications in triggering the most suited surgical treatment, considering the improvements in imaging techniques made in the last decades and the role of preoperative malperfusion. First, this new classification considers the dissection's *type*, adding to the Stanford A and B the non-A non-B type, in which the dissection involves the arch and descending aorta, but not the ascending aorta. Secondly, the location of the *primary entry* tear is described, if recognizable. The last step is the definition of radiologic *malperfusion* patterns: absence of malperfusion (M0), involvement of coronary arteries (M1), supraaortic (M2), or visceral vessels (M3). For every radiologic malperfused territory, the presence or absence of correlation with clinical signs has to be stated (+/-).

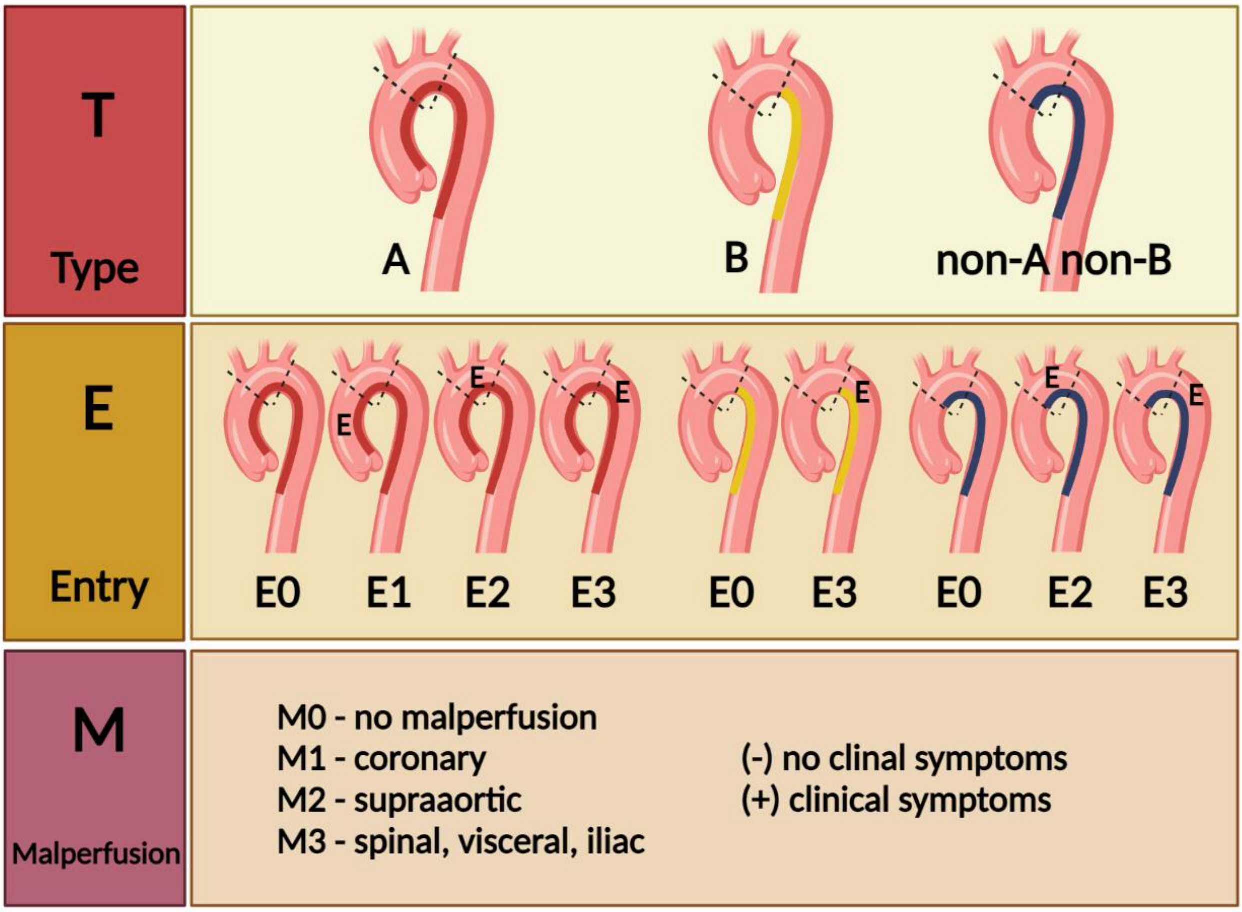

Figure 2. **TEM classification of aortic dissection, readapted from Sievers et al.*[30]***

The TEM classification represents the summary of the knowledge achieved in the last decades about ATAAD, should drive a more precise preoperative evaluation of the pathology and successively trigger patient-tailored surgical therapies.

1.4 Preoperative cerebral malperfusion

The involvement of supra-aortic vessels (SAV) can compromise cerebral perfusion, cause severe brain injury and lead to reduced quality of life for survivors[31]. Preoperative neurologic impairment was described to affect approximately 15% to 20% of patients with ATAAD[32,33]. Moreover, acute neurologic deficit, stroke or coma at presentation are independent predictors of mortality and poor perioperative outcomes, especially in older patients[34–36]. Nevertheless, preoperative flow impairment of carotid arteries does not affect in-hospital mortality and therefore surgery should not be denied in these patients[37,38]. In the last decades great effort was made to optimize neuroprotection during aortic repair, involving intensive neuromonitoring techniques, selective cerebral perfusion strategies and diversified surgical approaches. Along with clinical evaluation, of vital importance is the preoperative imaging assessment of SAV, which should include the description of true and false lumen flow patterns, re-entries or aortic arch anomalies (i.e. bovine aortic arch, lusoric artery, left vertebral artery arising from the aortic arch) and if possible, the conformation of Willis's circle. These aspects play a central role in the surgical planning and must be considered while choosing arterial cannulation site or selective cerebral perfusion strategy[39].

1.5 Neuroprotection during surgery for ATAAD

Surgery for ATAAD complicated by SAV involvement constitutes a challenge, which can be overcome only with a diversified approach based on anatomy and clinical presentation, to produce a patient-tailored therapy. At the same time, the surgeon must consider some general principles at the basis of arterial cannulation, neuromonitoring, cerebral perfusion and surgical technique, in order to perform a successful aortic repair.

In terms of arterial cannulation for cardio-pulmonary bypass (CPB), the right axillary artery has become the standard for ATAAD repairs because it allows for switching between full body and selective cerebral perfusion just by clamping of the innominate artery. Moreover, right axillary artery was demonstrated to grant lower stroke risk in comparison to femoral cannulation with retrograde aortic perfusion[40]. Cannulation of common carotid artery was proposed as valuable alternative, as it allows for fast establishment of selective cerebral perfusion and possibly for completion of an aortic-carotid bypass in case of SAV occlusion not recovering after aortic repair[41].

Intraoperative neuromonitoring is mandatory during surgery for ATAAD and is mainly based on near infrared spectroscopy (NIRS), which enables continuous transcranial measurement of oxygen saturation and gives information on cerebral perfusion with normal values ranging between 55% and 80%. Major drawbacks of the technique are the impossibility to detect changes in the distribution of arterial and venous blood and the measurement of the frontal cortex only (i.e. anterior and medial cerebral artery territory)[42]. For these reasons, trends are more reliable than absolute values for NIRS: a 20% reduction from baseline tissue oxygen saturation is considered abnormal and requires correction. Fundamental for the evaluation of cerebral perfusion is also carotid artery Doppler sonography, which gives valuable information on dissection pattern and true and false lumen relationship, with the possibility to monitor perfusion changes during the operation (baseline vs. full CPB flow vs. selective cerebral perfusion).

Several cerebral protection strategies can be applied during aortic repair. The first and most effective measure is hypothermia: it has been calculated that the metabolic demand of the brain sinks to 37% of baseline at 25°C and even 16% at 15°C[43]. For this reason, surgery for ATAAD has been performed for decades in deep hypothermic circulatory arrest (DHCA), but this technique was lately demonstrated as independent predictor for postoperative neurologic injury, especially with prolonged circulatory arrest times[44]. Currently, gold standard for neuroprotection in arch surgery in Europe is a selective cerebral perfusion in adjunct to systemic hypothermia[45]. The brain can be selectively perfused in a retrograde or antegrade fashion, with the latter being performed unilaterally or bilaterally. The application of any cerebral perfusion allows for moderate hypothermia, which brings benefits in terms of operative time and bleeding complications[46]. In a retrospective analysis from our institution, these three methods were compared in the setting of an open zone-0 anastomosis for ATAAD using propensity score triple-matching and were demonstrated to grant comparable results regarding perioperative mortality and neurologic outcome[47]. Nevertheless, bilateral antegrade cerebral perfusion seems to prevent neurologic injuries if long circulatory arrest times (>50minutes) are scheduled[48].

1.6 Surgical technique

Standard of care in the surgical treatment of ATAAD is the so-called hemiarch resection with an open distal anastomosis to the aortic arch[2]. Surgery should accomplish several goals: the resection of the primary entry tear, to avoid aortic rupture and the expansion of true lumen with contemporary reduction of pressure in the false lumen, to reveal malperfusion in the acute phase and induce positive aortic remodeling at follow up, thus avoiding the need of reoperations. The hemiarch procedure was shown to be a reliable technique in addressing these issues, with favorable short and long-term outcomes[49]. Nevertheless, the hemiarch technique fails to address malperfusion and does not prevent reoperation for aortic growth in certain cases. Rylski et al. described the reason for this failure in the distal anastomotic new entry (DANE), an insufficiency of the distal hemiarch anastomosis that preserves antegrade false lumen perfusion, possibly leading to unsolved malperfusion[50]. Moreover, the retrospective analysis showed that up to 70% of patients undergoing negative aortic remodeling at follow up presented a DANE in the first postoperative CT scan.

In the effort to address these issues, new vascular prosthesis have been developed to prevent the hemiarch pitfalls and possibly perform single-stage repairs. One example is the frozen elephant trunk (FET) technique for hybrid total arch replacement, which already represents a safe option in the surgical treatment of ATAAD[51]. Especially in the configuration with side branches for the SAVs, the FET can reliably treat cerebral malperfusion by restoring adequate flow to the carotid arteries.

On one side, the hemiarch is a simple and fast procedure to overcome the acute phase, on the other side high surgical skills are requested for total arch replacement surgeries. The actual planning should consider all these aspects, always ensuring patient’s safety.

1.7 A new tool in the box: the AMDS device

The drawbacks of the hemiarch procedure led to the development of a new vascular prosthesis, which aims to cut complexity in surgery for ATAAD and address malperfusion issues. The AMDS is a hybrid device for arch repair in DeBakey I aortic dissection, which consists in a 10mm proximal polytetrafluoroethylene (PTFE) cuff and a super-helical nitinol non-covered stent[52,53]. These two components work together for the sealing of the distal anastomosis, to prevent DANE formation, and for the expansion of true lumen in the arch and descending aorta, to relieve malperfusion. The AMDS device is demonstrated in **Figure 3**. Indication for AMDS implantation is currently a DeBakey I acute aortic dissection or intramural hematoma, with primary entry tear in the root or ascending aorta. Known allergy to nitinol or connective tissue disorders are currently deemed as contraindications for the device.

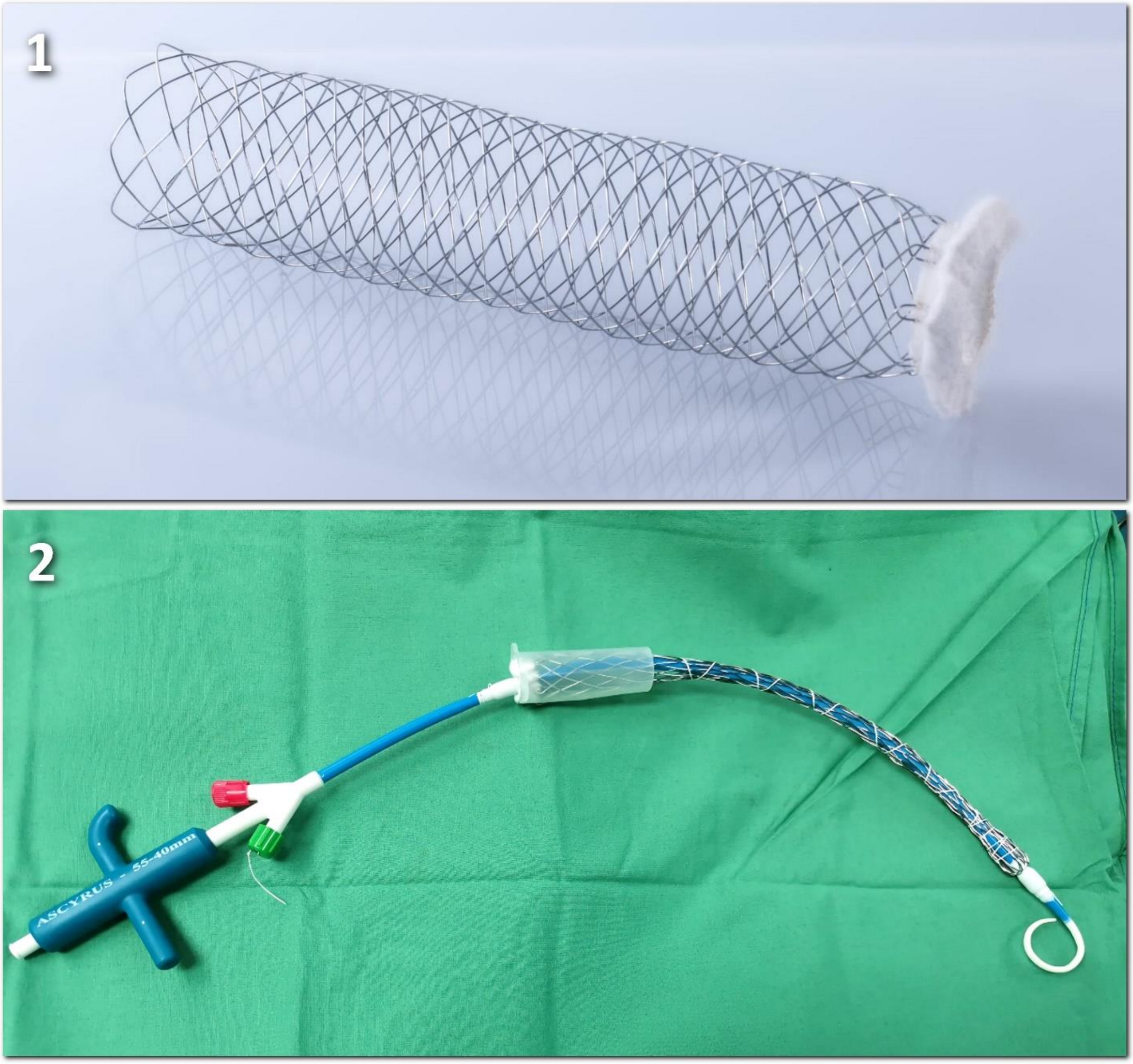

Figure 3. ***AMDS device overview.*** In 3.1 is demonstrated the unfolded straight device, whereas 3.2 shows the AMDS mounted along the deploying system (own production).

The device is available in two different shapes and two diameters, in order to fit every range of aortic sizes. Shapes are defined as *straight*, with fixed diameter along the stent, and *tapered*, with decreasing diameter proximal to distal. Diameters are measured at the level of the proximal stent's edge and amount to 40mm or 55mm. Combining all the configurations, the AMDS comes with a total of 4 stent dimensions. The sizing of the device is performed in the preoperative CT scan at two aortic landmarks according to the sizing tables available in the Ascyrus medical website (https://ascyrus.com/sizes-and-configurations, **Table 1**). Given the preoperative CT scan, it should be elaborated in multi-planar (MPR) or centerline reconstructions, in order to perform diameter measurements in orthogonal planes to the aortic axis. At the German Heart Center Berlin, two software are available for this purpose: Aquarius iNtuition viewer (TeraRecon, Durham, NC, United States) and Syngo.Via (Siemens Healthineers, Erlangen, Germany). In alternative, the CT axial view can also be used for sizing. The aortic landmarks considered for stent's choice are zone 1 of the aortic arch (between innominate and left common carotid artery) and the descending aorta at the level of tracheal bifurcation.

Table 1. Sizing tables for the AMDS device (readapted from *https://ascyrus.com/sizes-and-configurations*).

	Item	**Stent diameter (mm)**	**Proximal aortic diameter (mm)**	**Distal aortic diameter (mm)**	**Device length (mm)**	**PTFE cuff diameter (mm)**
Straight	AMDS 40-40	40	20 - 35	25 - 35	155 - 208	24
	AMDS 55-55	55	36 - 45	36 - 45	195 - 231	32
Tapered	AMDS 40-30	40 proximal 30 distal	20 - 35	20 - 24	170 - 210	24
	AMDS 55-40	55 proximal 40 distal	36 - 45	27 - 35	190 - 225	32

In our institution, standard AMDS implantation takes place under moderate hypothermia (26°-28°C) and unilateral antegrade selective cerebral perfusion, with the right axillary artery and the right atrium or femoral vein as target vessels for the establishment of the CPB. Selective cerebral perfusion is performed with 10ml/Kg/min after clamping of the innominate artery (INA) and continuously monitored with NIRS, in order to detect possible mismatches between the two cerebral hemispheres. The ascending aorta and the SAVs are prepared in standard fashion, but in contrast to the hemiarch procedure, aortic transection is performed in an orthogonal plane to the vessel, 1cm before the rise of the INA. The folded system is inserted in the TL of the aortic arch under direct view, although implantation through a guidewire previously placed from the femoral artery is also possible. After removing of the protection sheath, the proximal cuff has to be carefully unfolded and four cardinal stitches are placed to secure the stent in position before deployment, using a felt stripe on the outer side of the aortic arch. The stent is released by unscrewing and pulling the green cap attached to the white fixation suture. After complete withdrawal of the delivery system, a running 3-0 prolene suture in sandwich technique seals the FL at the distal anastomosis between AMDS-cuff and outer felt stripe. The vascular prosthesis for the ascending aorta is finally connected through a second circumferential suture with the aorta-AMDS complex.

The AMDS device is not intended to relaminate the aorta, but expand TL as the antegrade flow in FL is abolished at the distal anastomosis. These hemodynamic changes should lead to improved perfusion of the dissected aorta and all its branches, especially the SAVs, in order to prevent malperfusion complications.

The first-in-man AMDS implantation was conducted in 2017 in Canada. In February 2018, the German Heart Center in Berlin performed the first case in Europe. Since then, several other centers adopted this new device but due to the short presence on the market, poor literature on the outcomes after AMDS implant is available.

2. Methods

The present analysis represents a retrospective, single center study. The German Heart Center Berlin is a leading center in the field of aortic surgery, with more than 600 procedures/year, covering the whole spectrum of aortic diseases and therapies. Approximately 100/year are performed in case of an ATAAD. The wide catchment area (almost 4 million inhabitants for 2 cardiac surgery departments considering only the Berlin urban territory) and the establishment of the so-called "*Aortentelefon*" contribute to the high case load[54,55].

2.1 Objectives and endpoint definition

Goal of the study is to gather information on outcomes of patients undergoing AMDS implantation for ATAAD and presenting involvement of SAVs, with or without preoperative malperfusion.

Outcomes are described based on clinical and imaging data.

Clinical endpoints are 30-day mortality and the presence of postoperative neurologic deficits.

Imaging endpoints were defined according to the comparison of TL perfusion prior and after AMDS implantation. Primary imaging endpoint was the indexed-TL area in the SAVs and descending aorta, expressed as percentage of TL over the whole vessel area. Secondary imaging endpoint was the pre-/postoperative comparison of the dissection patterns in the SAVs.

2.2 Data capture

Data regarding patients undergoing surgery for ATAAD were retrospectively collected in an anonymized form on the basis of the clinical documentation at the German Heart Center Berlin, which uses mainly two software for electronic patients' data administration (KIS, [Nexus-AG, Donaueschingen, Germany] and m.life®, [Medisite GmbH, Hannover, Germany]). Data were entered an online RedCap2 (Research Electronic Data Capture, Version 9.7.8 © Vanderbilt University, US) database, designed to store all the relevant pre-, intra- and postoperative data relevant for our research purposes.

The Charité ethic committee (No. EA2/096/20) approved data collection; informed consent was waived due to the retrospective nature of the analysis.

2.3 Patient population

Our retrospective ATAAD database was screened between February 2018 and March 2020, when 233 patients underwent urgent surgical treatment. Among these patients, 48 (21%) were treated with AMDS implantation for DeBakey I aortic dissection and defined the primary cohort of this study. Since the focus of the analysis was the fate of diseased SAVs after AMDS device implant, the involvement of at least one SAV in the preoperative CT scan was the main inclusion criterium, which isolated 18 patients. The exclusion of 2 patients was necessary, due to the lack of full SAVs capture in CT scan. The final cohort counted 16 patients.

2.4 Computed tomography analysis

Imaging analysis was conducted in pre- and postoperative CT scans through centerline reconstructions of the aorta and the SAVs using the Aquarius iNtuition viewer software (TeraRecon, Durham, NC, United States). Standardized measurements were performed to collect information on TL, FL and whole vessel diameter and area: landmarks were the most stenotic level in diseased SAVs or 20mm distal from the respective ostium in non-affected vessels (**Figure 4.1** and **4.2**). Moreover, the most stenotic segment in diseased branches was described according to dissection patterns: "*dissected*", in case of dissection without perfusion impairment, "*sub-total occlusion*", in case of 75-99% stenosis and "*total occlusion*", with complete TL obliteration. The measurements of TL area collected prior and after AMDS implantation were indexed to whole vessel area (**Figure 4.3a** and **4.3b**). Similar quantitative data were collected along the descending aorta at two levels: the half-length of the AMDS (proximal descending aorta) and 1cm distal to stent's tip (mid descending aorta). These two postoperative landmarks were identified in the preoperative CT considering as starting point 1cm proximal to INA origin.

2.5 Neurologic assessment

Presence and quality of neurologic deficits was assessed prior and after surgery with focus on limbs' mobility. An acute preoperative neurologic deficit was described as present on the base of clinical evaluation on admission in our hospital. In the postoperative course, neurologic outcome was defined according to quality and temporal development, discriminating between *loss of function* (0 points out of 5 at neurologic examination, Medical research council Muscle Scale) and impaired function (1-4 points out of 5). About duration, deficits were divided in *transient*, with symptoms improving or recovering within days after surgery, and *permanent*, when no perioperative recovery was observed.

2.6 Statistical analysis

Clinical and imaging data are reported as frequencies with corresponding percentages for categorical variables and as mean with standard deviation (SD) for continuous data.

Paired sample *t*-test was applied using SPSS software Version 25 (IBM SPSS Statistics, Armonk, New York USA) to assess differences in the standardized measurements performed prior and after surgery. A p-value of <0.05 was considered statistically significant.

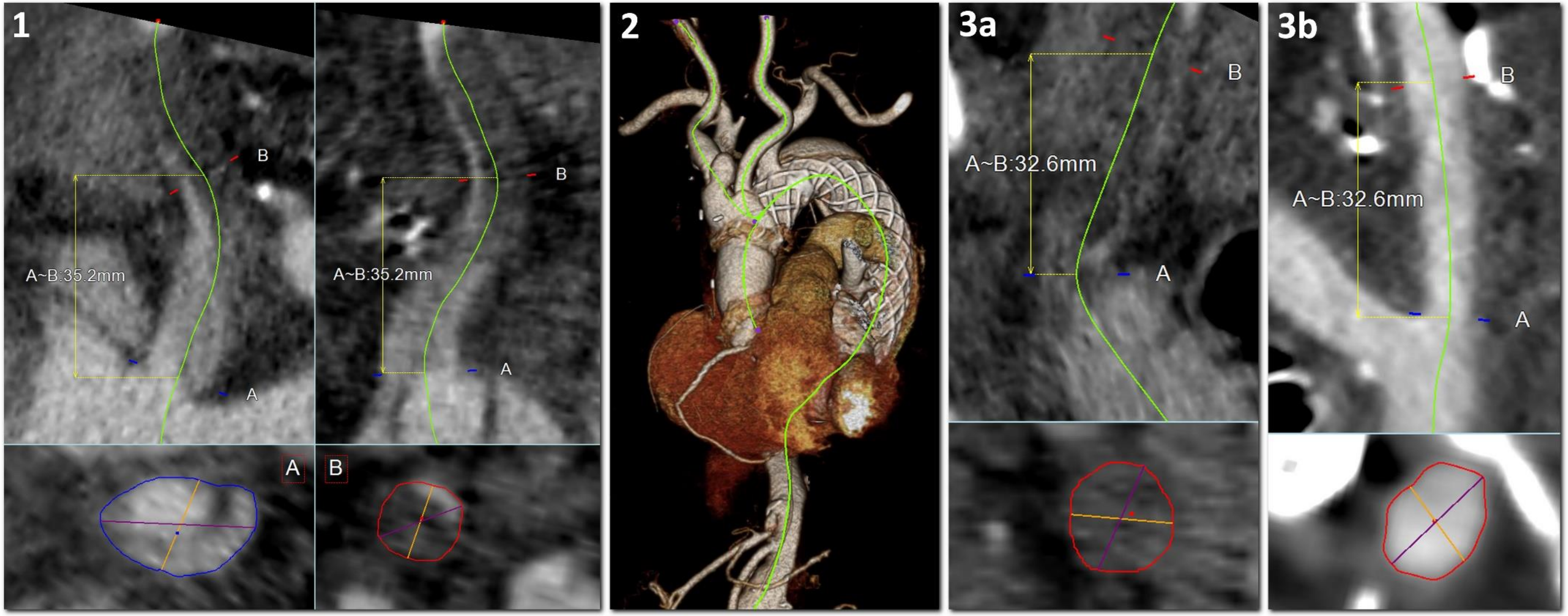

***Figure 4. Center-line assessment of SAVs*[56].** (**1**) 2-Dimensional visualization of center-line and recognition of the most stenotic segment in preoperative CT scan. (**2**) 3-Dimensional reconstruction of postoperative CT. (**3**) Comparison of the center-line measurements prior (**a**) and after (**b**) AMDS implantation.

3. Results

3.1 Baseline characteristics

Table 2: Baseline characteristics

Baseline characteristics mean (SD), n(%)	**Total population** n=16
Age (years)	61 (SD:12)
Gender (female)	5 (31.25)
BMI (kg/m^2)	25.8 (SD: 3.8)
BSA (m^2)	2.0 (SD: 0.3)
Hypertension	11 (68.75)
Diabetes	1 (6.25)
Smoker	6 (37.5)
Chronic obstructive pulmonary disease	1 (6.25)
Kidney insufficiency	1 (6.25)
Coronary artery disease	2 (12.5)
Previous aortic disease	1 (6.25)
Intubation	1 (6.25)
Acute shock	1 (6.25)
Acute neurological deficit	6 (37.5)
Malperfusion (any sign)	6 (37.5)
Coronary	1 (6.25)
Cerebral	6 (37.5)
Peripheral	2 (12.5)
Visceral	1 (6.25)
PENN Classification	
Aa - No ischaemia	10 (62.5)
Ab - Localized ischaemia	5 (31.25)
Ac - generalized ischaemia	0 (0)
Abc - combined ischaemia	1 (6.25)
GERAADA score	20.47 (SD: 6.85)
Aortic regurgitation	
No-Trace	3 (18.75)
Mild	2 (12.5)
Moderate	10 (62.5)
Severe	1 (6.25)
Left ventricular ejection fraction (%)	52 (SD: 8)
Right ventricular ejection fraction (%)	53 (SD: 4)
Pericardial effusion	4 (25)

Considering baseline data, mean age was 61 years (SD: 12 years) and 5 (31.25%) patients were women. One case (6.25%) was admitted with profound combined malperfusion (PENN class Abc) because of a massive pericardial effusion and with acute left-sided hemiparesis. The mean GERAADA score was 20.47% (SD: 6.8%). An acute neurologic symptomatic was present in six patients (37.5%): 5 of them had a left-sided hemiparesis, and 1 patient had isolated left leg paresis. Considering these patients, 2 supra-aortic branches were involved in 50% of cases according to preoperative CT scans and 67% had at least 1 sub-totally occluded vessel.

3.2 Surgical data

Table 3: Intraoperative data

Intraoperative data mean (SD), n(%)		**Total population** n=16
Pain-to-cut time (min)		398 (SD: 268)
Operation time (min)		370 (SD: 114)
Cardiopulmonary bypass time (min)		194 (SD: 40)
Cross-clamp time (min)		112 (SD: 33)
Reperfusion (min)		56 (SD: 28)
Intraoperative transfusions (units)		
	Red cell concentrate	1.2 (SD: 1.9)
	Platelets concentrate	4.4 (SD: 2.3)
	Fresh frozen plasma	5.2 (SD: 5.8)
Hypothermia (°C)		27.3 (SD: 1.2)
Selective cerebral perfusion time (min)		45 (SD: 11)
Bicuspid valve		1 (6.25)
Aortic valve surgery		
	Repair	11 (68.75)
	Biological replacement	4 (25)
	Mechanical replacement	1 (6.25)
Root operation		
	Reconstruction	9 (56.25)
	Bentall	5 (31.25)
	David	2 (12.5)
AMDS sizing		
	40 tubular	4 (25)
	40-30 tapered	3 (18.75)
	55 tubular	1 (6.25)
	55-40 tapered	8 (50)
Revision for bleeding		2 (12.5)

Time between symptoms' onset and surgery (pain-to-cut time) was 398 min (SD: 268 min) for the whole cohort and 270 min (SD: 110 min) in patients with acute neurologic deficits. Mean caudal circulatory arrest time was 45 min (SD: 11 min). A tapered AMDS 55-40 was implanted in 50% of cases. At echocardiographic evaluation, moderate-to-severe aortic regurgitation was present in 69% of patients, with consecutive aortic valve replacement performed in 5 patients (31.25%).

3.3 Perioperative data and neurological outcome

Table 4: Perioperative data

Perioperative data mean (SD), n(%)	**Total population** n=16
ICU length of stay (days)	11 ± 8
Ventilation time (days)	5 ± 6
Open chest therapy	1 (6.25)
Reintubation	2 (12.5)
Tracheotomy	2 (12.5)
Delirium	6 (37.5)
Postoperative low cardiac output syndrome	1 (6.25)
Dialysis	2 (12.5)
Postoperative neurological deficit	8 (50)
Neurological deficit duration	
Transient	5 (62.5)
Permanent	3 (37.5)
Neurological deficit quality	
Impaired function	6 (75)
Loss of function	2 (25)
Postoperative CT-diagnosed stroke	6 (37.5)
30-Day mortality	3 (18.75)

Patients experienced a mean intensive care unit (ICU) length-of-stay of 10 days (SD: 8 days). At postoperative clinical evaluation, 8 (50%) patients presented neurologic deficits: considering the 6 patients with preoperative acute stroke, 5 (83%) were still affected after surgery and 1 recovered completely. Three new postoperative neurologic deficits were diagnosed: 1 patient had an occluded RCC and a subtotally occluded LCC preoperatively, and 2 presented with subtotal occlusion of RCC or LCC. Neurologic deficits were transient in 62.5% of cases, and 75% were classified as impaired function.

3.4 Impact of the AMDS on true lumen perfusion

Table 5: Centre-line based measurements of dissected supra-aortic vessels and descending aorta before and after surgery

Assessment of dissected vessels Mean (SD), n(%)	**Preoperative** **n=16**	**Postoperative** **n=16**
Innominate artery		
Dissected	12 (75)	11 (68.75)
Subtotal occlusion	4 (25)	1 (6.25)
Total occlusion	0 (0)	0 (0)
True lumen diameter (mm)	9.15 (SD: 1.81)	11.51 (SD: 2.42)
True lumen area (mm^2)	68.04 (SD: 25.16)	108.22 (SD: 44.92)
False lumen diameter (mm)	13.67 (SD: 1.93)	10.18 (SD: 6.25)
False lumen area (mm^2)	149.60 (SD: 41.78)	110.53 (SD: 80.03)
Total area (mm^2)	214.82 (SD: 54.11)	221.42 (SD: 78.00)
Measurement landmark (mm)	18.82 (SD: 6.93)	20.16 (SD: 8.34)
Right common carotid		
Dissected	4 (25)	3 (18.75)
Subtotal occlusion	6 (37.5)	3 (18.75)
Total occlusion	3 (18.75)	0 (0)
True lumen diameter (mm)	4.24 (SD: 2.34)	5.98 (SD: 2.06)
True lumen area (mm^2)	18.21 (SD: 13.66)	31.25 (SD: 15.87)
False lumen diameter (mm)	7.04 (SD: 3.57)	3.21 (SD: 4.56)
False lumen area (mm^2)	48.42 (SD: 28.59)	23.48 (SD: 34.97)
Total area (mm^2)	67.12 (SD: 20.35)	54.84 (SD: 25.82)
Measurement landmark (mm)	30.74 (SD: 21.17)	28.46 (SD: 17.20)
Left common carotid		
Dissected	4 (25)	4 (25)
Subtotal occlusion	2 (12.5)	0 (0)
Total occlusion	1 (6.25)	0 (0)
True lumen diameter (mm)	5.91 (SD: 2.12)	7.51 (SD: 1.49)
True lumen area (mm^2)	30.92 (SD: 15.60)	45.92 (SD: 18.39)
False lumen diameter (mm)	3.89 (SD: 4.40)	2.37 (SD: 4.01)
False lumen area (mm^2)	26.37 (SD: 33.09)	16.28 (SD: 30.51)
Total area (mm^2)	57.13 (SD: 22.84)	62.60 (SD: 31.87)
Measurement landmark (mm)	40.30 (SD: 29.62)	35.49 (SD: 20.00)
Proximal descending aorta		
True lumen diameter (mm)	18.34 (SD: 4.42)	23.91 (SD: 3.86)
True lumen area (mm^2)	278.59 (SD: 130.33)	460.13 (SD: 144.61)
False lumen diameter (mm)	24.30 (SD: 3.34)	16.36 (SD: 8.45)
False lumen area (mm^2)	471.88 (SD: 134.24)	262.81 (SD: 150.36)
Total area (mm^2)	749.75 (SD: 175.57)	728.00 (SD: 193.56)
Measurement landmark (mm)	105.56 (SD: 13.79)	105.56 (SD: 13.79)
Mid-descending aorta		
True lumen diameter (mm)	16.13 (SD: 2.96)	19.43 (SD: 2.82)
True lumen area (mm^2)	211.31 (SD: 80.47)	303.00 (SD: 85.55)
False lumen diameter (mm)	22.12 (SD: 3.24)	19.34 (SD: 6.42)
False lumen area (mm^2)	392.06 (SD: 117.40)	324.13 (SD: 158.53)
Total area (mm^2)	602.13 (SD: 166.26)	621.63 (SD: 193.72)
Measurement landmark (mm)	220.31 (SD: 28.44)	220.31 (SD: 28.44)

Preoperatively, the INA was involved in all patients, showing either dissection without perfusion impairment (75%) or subtotal occlusion (25%). Mean total vessel area was 214.82 mm^2 (SD: 54.11 mm^2) whereas the false lumen occupied most of vessel surface with 149.60 mm2 (SD: 41.78 mm^2). The most involved vessel was the RCC, presenting 6 subtotal occlusions (37.5%) and 3 total occlusions (18.75%); also in this branch, false lumen covered most of the vessel area and decreased postoperatively. The LCC was diseased in 7 cases (43.75%), with 2 (12.5%) subtotal occlusions and 1 (6.25%) total occlusion.

Considering the dissection morphology in the SAVs before and after surgery, AMDS implantation could trigger a complete regression of total occlusions in both common carotid arteries, as well as an increase in dissection-free vessels: 0% to 25% for the INA, 18.75% to 62.5% for the RCC and 56.25% to 75% for the LCC (**Figure 5**).

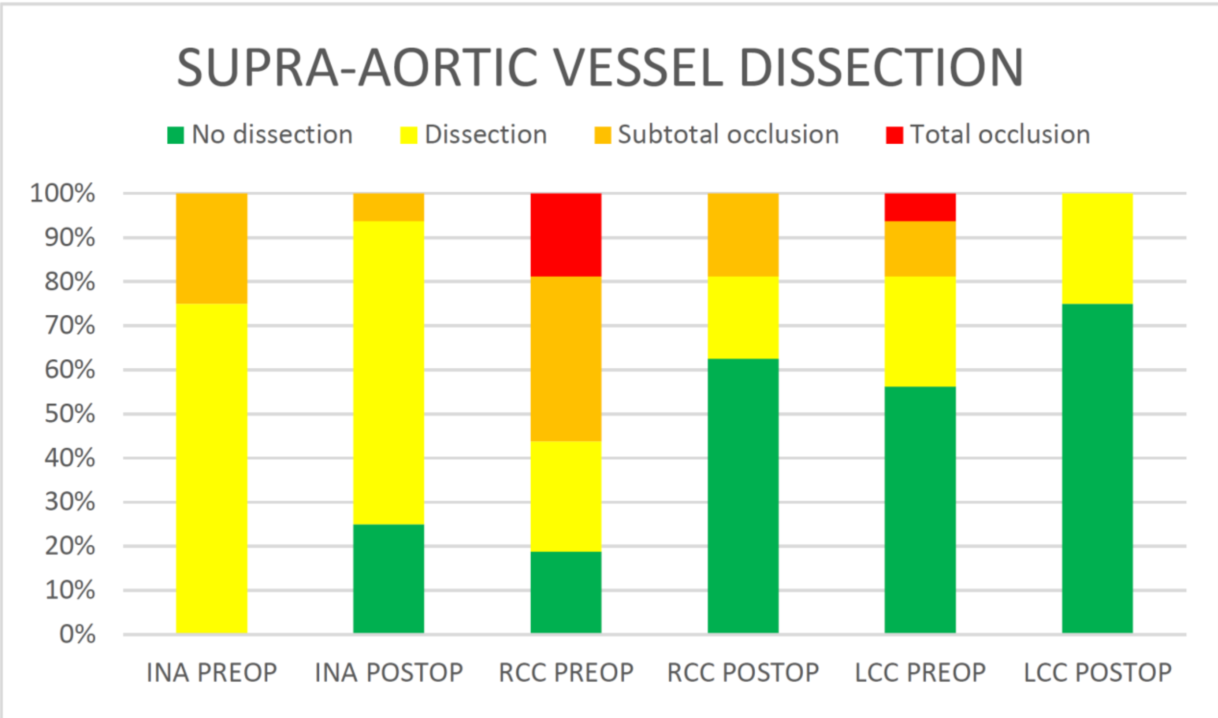

Figure 5. Dissection morphology of SAVs prior and after AMDS implantation*[56]*.

After indexing the true lumen as a percentage of the whole vessel area, all the 3 SAVs experienced an improvement in TL perfusion (**Table 6**). Indexed INA-TL increased from 32% to 55% (p=0.002) and indexed RCC-TL doubled from 34% to 72% (p=0.01). No statistical relevance was reached by the LCC (p=0.13), despite TL increases from 64% to 83%.

Table 6: Paired *t*-test comparison of indexed true lumen area in the supra-aortic vessels and descending aorta after AMDS implant.

Indexed true lumen area Mean (SD)	**Preoperative**	**Postoperative**	**P-value**
Indexed INA true lumen (%)	32 (SD: 9)	55 (SD: 28)	0.002
Indexed RCC true lumen (%)	34 (SD: 33)	72 (SD: 40)	0.01
Indexed LCC true lumen (%)	64 (SD: 40)	83 (SD: 29)	0.13
Indexed proximal-descending true lumen (%)	36.53 (SD: 12.49)	64.31 (SD: 18.91)	<0.001
Indexed mid-descending true lumen (%)	35.09 (SD: 8.66)	50.74 (SD: 16.41)	0.002

At the postoperative imaging assessment, full AMDS expansion was confirmed in every patient and no device-related complication was experienced. Abolition of antegrade FL perfusion in the aortic arch could be achieved in 87.5% of cases, with 68.75% rate of partial or complete FL thrombosis in the descending aorta.
According to the postoperative quantitative assessment of the descending aorta, TL area increased from 278.59 mm^2 (SD: 130.33 mm^2) to 460.13 mm^2 (SD: 144.61mm^2) at the proximal descending landmark (105 mm [SD: 13.79 mm] at the half-length of the AMDS), with a gain in indexed true lumen area of 77.8% (p<0.001). Similarly, the indexed true lumen area increased from 35% to 50% (p-value=0.002) at the mid-descending landmark (220 mm [SD: 28.44 mm] 1 cm distal to the tip of the stent).

4. Discussion

4.1 Results' summary

The analysis focused on the effects of AMDS implantation on dissected SAVs in the surgical treatment of ATAAD, with particular attention to neurologic outcome and imaging results. Postoperative neurologic deficit rate was 50%, but showed impaired function in quality and was transient in duration in most of cases. Moreover, the retrospective imaging analysis of the patients presenting postoperative neurologic deficits revealed a massive preoperative involvement of SAVs, which may have played a relevant role in terms of neurologic outcome.

Standardized imaging evaluation showed full recovery of all branch occlusions and an increase in dissection-free vessels. Quantitative measurements on SAVs diameter and area demonstrated a significant increase in TL area after surgery. In detail, patients experienced a 72%, 112% and 30% increase in indexed-TL area for INA, RCC and LCC, respectively. In addition, the descending aorta showed early positive remodeling with 78% and 48% increase in indexed-TL area at the proximal and mid-descending landmarks.

4.2 Results' interpretation

ATAAD complicated by supra-aortic branches malperfusion and acute preoperative neurologic deficit remains a severe condition, with 83% of patients in our cohort still presenting neurologic symptoms after surgery, although the AMDS improved cerebral perfusion. Three additional patients developed postoperative neurologic deficits after showing no impairment before surgery. Careful examination of preoperative CT in these cases revealed at least a preoperative subtotal occlusion in one carotid artery. Since cerebral perfusion was reestablished and no embolic events could be detected postoperatively, the 3 new neurologic deficits were probably due to prolonged dynamic malperfusion. Such results confirm the importance of fast referral for surgery in the setting of ATAAD with involvement of SAVs[9], with the goal to restore adequate cerebral perfusion. The AMDS successfully accomplishes this task, since it triggers a relevant increase in dissection-free carotid arteries: 18.75% to 62.5% for RCC and 56.25% to 75% for LCC. The discrepancy in the postoperative outcomes between both carotid arteries may have been influenced by right axillary cannulation and INA recovery, leading to a higher perfusion gain in the RCC, as well as by the lower involvement of LCC.

Great value of this analysis is the high level of standardization in the quantitative assessment of SAVs TL perfusion: center-line based reconstructions, the recognition of the same landmark in pre- and postoperative CT and the indexing of TL-area as percentage of whole vessel area are fundamental to obtain reproducible and comparable measurements. With this background, the 72%, 112% and 30% increase in indexed-TL area for INA, RCC and LCC, respectively, represents an objective statement regarding postoperative improvement of SAVs perfusion.
Considering the descending aorta, our results confirm an early positive vascular remodeling triggered by the AMDS, underlining the importance of avoiding DANE formation with the sealing of the distal anastomosis, which allows the stent to expand TL and reveal malperfusion. The abolition of antegrade FL flow might be the most relevant factor inducing thrombosis of FL and the early positive vascular remodeling experienced in our cohort.
The present analysis is of great interest also considering technical aspects: AMDS implantation prolongs 5 to 10 minutes the standard hemiarch procedure, without adding significant complexity. In this perspective, the AMDS represents a safe and valuable alternative to face ATAAD complicated by SAVs malperfusion for centers without dedicated aortic departments or experience in extensive arch surgery.

4.3 Embedding results in the available literature

Great effort was made in the past years to improve outcomes in the setting of ATAAD involving SAVs, since mortality and morbidity rates remain high. It is well known, that preoperative cerebral malperfusion constitutes a predictor for death and postoperative cerebral injuries[29,36]. Nevertheless, fast referral for emergency surgery (pain-to-cut time under 5 hours) can be crucial to allow low in-hospital mortality, neurologic recovery and considerable mid-term survival[9,57]. Moreover, SAVs involvement with or without preoperative cerebral impairment was shown to highly affect neurologic outcome but not survival[37]. Such findings clearly demonstrate that surgery should not be denied in patients presenting ATAAD complicated by SAVs dissection and cerebral malperfusion. In our experience, an overall pain-to-cut time under 7 hours and under 4 hours in case of preoperative neurologic deficits led to a satisfactory mortality rate (18.75% at 30 day) and an acceptable neurologic outcome (37.5% CT-diagnosed stroke), considering the high risk of neurologic complications our patients' cohort is prone.

The literature lacks of studies where improvements of cerebral perfusion after surgery for ATAAD are clearly quantified. To address this issue, we defined a standardized and rigorous methodology, which can be used irrespective of the surgical technique adopted. A systematic evaluation of the aorta and the SAVs through centerline is the most suited method to obtain automated diameter and surface measurements, thus improving reproducibility and accuracy. This is of great advantage when investigating the hemodynamic changes happening in the SAVs after surgery for ATAAD.

In addition, surgical strategy has a great impact on neurologic outcome and vascular remodeling. In the last decade, the paradigm of surgery for ATAAD in case of extensive arch and SAVs involvement shifted from the hemiarch procedure to more complex repairs, with the aim to grant single stage treatments. In this setting, the hemiarch repair have been performed for years with well-documented favorable outcomes[49]. Nevertheless, of concern are some data on negative vascular remodeling, most likely because of the DANE, which was shown to induce FL pressurization and aortic growth[50,58]. In this perspective, total arch replacement techniques have been advocated, to prevent late complications. The FET was demonstrated as a safe and valuable alternative in ATAAD surgery, especially in case of malperfusion, but due to high technical complexity its use is recommended in experienced high-volume aortic centers [51,59].

The AMDS concept was developed to solve these issues: cut complexity in arch repair for ATAAD, adding on average 5 to 10 minutes to the standard hemiarch procedure, solve malperfusion by expanding TL and seal the distal anastomosis, thus preventing DANE formation and consecutive negative vascular remodeling. The AMDS has not to be intended as a regular stenting of the aortic arch because of its low radial force: goal of the device is the readaptation of intima against media and adventitia, which is driven by hemodynamic changes leading to the expansion of TL and the concomitant depressurization of FL.

SAVs involvement in the setting of ATAAD is considered a severe clinical and technical complication, which may require challenging repairs, but it has been demonstrated that a radical treatment is not always necessary[60]. The present analysis shows that the most relevant stenosis in the SAVs was located 3 to 4 cm from branch origin in both carotid arteries, a segment which is in most cases hard to treat surgically and that the AMDS device can solve SAVs occlusions just by means of repairing the aortic arch.

Literature about the AMDS is scares, since the device have been on market only for 5 years now. Nevertheless, preliminary data from a multicenter trial already show promising results in terms of safety and reproducibility, especially in case of preoperative malperfusion, which resolved in 95.5% of the affected aortic branches[61,62]. Midterm data from the same trial also showed encouraging outcomes in terms of positive vascular remodeling, with an 87.7% rate of successful treatment of cerebral malperfusion involving SAVs[63].

Lately, our institution published an overall clinical experience with the AMDS device after 100 implants, confirming the satisfactory results presented in this analysis in relation to safety, neurologic outcome and early positive vascular remodeling[64].

4.4 Limitations and future perspective

Several limitations have to be considered, starting with the retrospective nature and the low sample size. In addition, the hemodynamic effects of the AMDS have been investigated in an extremely early phase and a more consistent follow up is required to confirm the present findings on positive vascular remodeling. The standardized approach in the examination of imaging is of great value, but could have been supported by other flow measurements to cross-check the results and give more consistency to the conclusions.

In general, further investigation considering larger sample sizes and longer follow up are mandatory, possibly comparing the AMDS device with the hemiarch procedure alone, in order to confirm the present preliminary results. Accordingly, a prospective randomized trial seems to be warranted in order to state the real adjunct of the AMDS to the standard hemiarch repair. Moreover, intensive imaging evaluation and subgroup analysis should be undertaken with the goal to better define patients and dissection patterns that best profit from an AMDS implantation.

5. Conclusion

The present study describes the performance of the AMDS device in the surgical treatment of ATAAD complicated by SAV involvement. This novel device represents an adjunct to the standard of care hemiarch replacement, with to date preliminary but promising results facing this challenging pathology. The stent seems to induce positive vascular remodeling of the aortic arch and descending aorta, thus leading to a complete regression of SAV occlusions and a significant increase in TL area.

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7. Solemn declaration

„Ich, Matteo Montagner, versichere an Eides statt durch meine eigenhändige Unterschrift, dass ich die vorgelegte Dissertation mit dem Thema: „Restoration of supra-aortic vessel perfusion after open hybrid stenting of the aortic arch for acute type A aortic dissection bzw. Wiedererstellung der Perfusion in den supra-aortalen Ästen durch offenen hybrid Stenting des Aortenbogens für akute Typ A Aortendissektion“ selbstständig und ohne nicht offengelegte Hilfe Dritter verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel genutzt habe.
Alle Stellen, die wörtlich oder dem Sinne nach auf Publikationen oder Vorträgen anderer Autoren/innen beruhen, sind als solche in korrekter Zitierung kenntlich gemacht. Die Abschnitte zu Methodik (insbesondere praktische Arbeiten, Laborbestimmungen, statistische Aufarbeitung) und Resultaten (insbesondere Abbildungen, Graphiken und Tabellen) werden von mir verantwortet.

Ich versichere ferner, dass ich die in Zusammenarbeit mit anderen Personen generierten Daten, Datenauswertungen und Schlussfolgerungen korrekt gekennzeichnet und meinen eigenen Beitrag sowie die Beiträge anderer Personen korrekt kenntlich gemacht habe (siehe Anteilserklärung). Texte oder Textteile, die gemeinsam mit anderen erstellt oder verwendet wurden, habe ich korrekt kenntlich gemacht.

Meine Anteile an etwaigen Publikationen zu dieser Dissertation entsprechen denen, die in der untenstehenden gemeinsamen Erklärung mit dem/der Erstbetreuer/in, angegeben sind. Für sämtliche im Rahmen der Dissertation entstandenen Publikationen wurden die Richtlinien des ICMJE (International Committee of Medical Journal Editors; www.icmje.og) zur Autorenschaft eingehalten. Ich erkläre ferner, dass ich mich zur Einhaltung der Satzung der Charité – Universitätsmedizin Berlin zur Sicherung Guter Wissenschaftlicher Praxis verpflichte.

Weiterhin versichere ich, dass ich diese Dissertation weder in gleicher noch in ähnlicher Form bereits an einer anderen Fakultät eingereicht habe.

Die Bedeutung dieser eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unwahren eidesstattlichen Versicherung (§§156, 161 des Strafgesetzbuches) sind mir bekannt und bewusst.“

Datum Unterschrift

8. Contribution to the published study

Matteo Montagner hatte folgenden Anteil an den folgenden Publikationen:

Publikation:

Montagner M, Kofler M, Heck R, Buz S, Starck C, Kurz S, Falk V, Kempfert J, ***Initial experience with the new type A arch dissection stent: restoration of supra-aortic vessel perfusion****, Interactive Cardiovascular and thoracic surgery, April 2021.*

Beitrag im Einzelnen: Konzeptualisierung der Analyse mit den Erst- und Zweitbetreurenden Lehrers (Prof. Falk und Prof. Kempfert), Erhebung der Bildgebung-Data nach Auswertung prä- und postoperativen CT-Rekonstruktionen. Statistische Auswertung mittels SPSS, Erstellung aller Tabellen und Abbildungen, sowie Verfassung des Manuskriptes. Revision des Manuskriptes nach erfolgter Begutachtung durch die EJCTS/ICVTS Reviewers.

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Unterschrift, Datum und Stempel des/der erstbetreuenden Hochschullehrers/in

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Unterschrift des Doktoranden/der Doktorandin

9. Extract from Journal summary list

Journal Data Filtered By: **Selected JCR Year: 2019** Selected Editions: SCIE,SSCI. Selected Categories: **"CARDIAC and CARDIOVASCULAR SYSTEMS"** Selected Category Scheme: WoS

Gesamtanzahl: 138 Journale

Rank	Full Journal Title	Total Cites	Journal Impact Factor	Eigenfactor Score
1	CIRCULATION	158,218	23.603	0.205020
2	EUROPEAN HEART JOURNAL	59,968	22.673	0.140620
3	JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY	101,927	20.589	0.190280
4	Nature Reviews Cardiology	7,100	20.260	0.021130
5	CIRCULATION RESEARCH	51,539	14.467	0.071470
6	JAMA Cardiology	4,740	12.794	0.030110
7	JACC-Cardiovascular Imaging	10,110	12.740	0.027550
8	BASIC RESEARCH IN CARDIOLOGY	4,704	11.981	0.006380
9	EUROPEAN JOURNAL OF HEART FAILURE	12,784	11.627	0.028700
10	JACC-Heart Failure	4,117	8.750	0.019180
11	JACC-Cardiovascular Interventions	11,371	8.432	0.037330
12	CARDIOVASCULAR RESEARCH	21,526	8.168	0.019950
13	JOURNAL OF HEART AND LUNG TRANSPLANTATION	12,465	7.865	0.028140
14	Cardiovascular Diabetology	6,179	7.332	0.011390
15	PROGRESS IN CARDIOVASCULAR DISEASES	4,193	6.763	0.008340
16	European Heart Journal-Cardiovascular Pharmacotherapy	521	6.696	0.001640

17	Circulation-Heart Failure	6,773	6.033	0.018490
18	European Journal of Preventive Cardiology	5,589	5.864	0.015370
19	HEART RHYTHM	12,246	5.731	0.028620
20	Circulation-Cardiovascular Imaging	5,574	5.691	0.016320

21	JOURNAL OF THE AMERICAN SOCIETY OF ECHOCARDIOGRAPHY	11,347	5.508	0.018230
22	Circulation-Cardiovascular Interventions	5,012	5.493	0.018140
23	JOURNAL OF CARDIOVASCULAR MAGNETIC RESONANCE	5,205	5.361	0.011120
24	Clinical Research in Cardiology	3,321	5.268	0.007280
25	HEART	18,108	5.213	0.030140
26	Circulation-Cardiovascular Quality and Outcomes	4,728	5.071	0.014350
27	CANADIAN JOURNAL OF CARDIOLOGY	6,980	5.000	0.017630
28	European Heart Journal-Cardiovascular Imaging	6,359	4.841	0.023110
29	TRENDS IN CARDIOVASCULAR MEDICINE	2,695	4.755	0.003920
30	REVISTA ESPANOLA DE CARDIOLOGIA	3,672	4.642	0.004610
31	Journal of the American Heart Association	17,149	4.605	0.070620
32	Circulation-Cardiovascular Genetics	3,090	4.534	0.008600
33	JOURNAL OF THORACIC AND CARDIOVASCULAR SURGERY	28,491	4.451	0.034300
34	Circulation-Arrhythmia and Electrophysiology	6,344	4.393	0.016630
35	AMERICAN HEART JOURNAL	19,814	4.153	0.026810

36	JOURNAL OF MOLECULAR AND CELLULAR CARDIOLOGY	14,031	4.133	0.017960
37	CARDIOVASCULAR DRUGS AND THERAPY	2,114	4.069	0.003340
38	Circulation-Genomic and Precision Medicine	375	4.063	0.002220
39	Hellenic Journal of Cardiology	987	4.047	0.001000
40	EUROPACE	9,973	4.045	0.024750
41	EuroIntervention	5,542	3.993	0.016590
42	ATHEROSCLEROSIS	24,587	3.919	0.036590
43	Frontiers in Cardiovascular Medicine	1,303	3.915	0.004020
44	ESC Heart Failure	1,276	3.902	0.004120
45	AMERICAN JOURNAL OF PHYSIOLOGY-HEART AND CIRCULATORY PHYSIOLOGY	26,114	3.864	0.020400
46	Global Heart	1,074	3.862	0.003180
47	European Heart Journal-Acute Cardiovascular Care	1,555	3.813	0.005430
48	NUTRITION METABOLISM AND CARDIOVASCULAR DISEASES	6,026	3.700	0.008820
49	ANNALS OF THORACIC SURGERY	35,221	3.639	0.040380
50	HEART FAILURE REVIEWS	2,697	3.538	0.005130
51	EUROPEAN JOURNAL OF CARDIO-THORACIC SURGERY	16,682	3.486	0.025820
52	JOURNAL OF CARDIAC FAILURE	4,983	3.435	0.008730
53	JOURNAL OF NUCLEAR CARDIOLOGY	3,600	3.366	0.004570

54	Journal of Cardiovascular Translational Research	1,656	3.312	0.003140
55	INTERNATIONAL JOURNAL OF CARDIOLOGY	31,193	3.229	0.068160
56	RESPIRATORY MEDICINE	11,934	3.095	0.013490
57	Annals of Cardiothoracic Surgery	1,828	3.058	0.005060
58	CURRENT PROBLEMS IN CARDIOLOGY	567	2.966	0.000740
59	Journal of Cardiovascular Computed Tomography	1,809	2.892	0.004850
60	American Journal of Cardiovascular Drugs	1,063	2.674	0.001580
61	Cardiovascular Diagnosis and Therapy	1,081	2.615	0.003050
62	JOURNAL OF CARDIOVASCULAR PHARMACOLOGY	5,340	2.598	0.003810
63	AMERICAN JOURNAL OF CARDIOLOGY	35,187	2.570	0.039490
64	CIRCULATION JOURNAL	9,860	2.540	0.014780
65	Cardiovascular Therapeutics	1,351	2.538	0.002120
66	Journal of Geriatric Cardiology	1,231	2.491	0.003270
67	Archives of Cardiovascular Diseases	1,628	2.434	0.003570
67	Current Cardiology Reports	2,127	2.434	0.005990
69	JOURNAL OF CARDIOVASCULAR ELECTROPHYSIOLOGY	6,886	2.424	0.010110
70	Heart Failure Clinics	1,020	2.327	0.002330
71	JOURNAL OF CARDIOVASCULAR PHARMACOLOGY AND THERAPEUTICS	1,358	2.322	0.002140
71	Korean Circulation Journal	1,335	2.322	0.002430
73	European Journal of Cardiovascular Nursing	1,723	2.296	0.002700

74	Cardiovascular Toxicology	1,272	2.284	0.001730
75	JOURNAL OF CARDIOTHORACIC AND VASCULAR ANESTHESIA	5,371	2.258	0.007310
76	CLINICAL CARDIOLOGY	4,233	2.248	0.008620
77	Journal of Cardiology	3,243	2.246	0.006090
78	Pulmonary Circulation	1,651	2.205	0.004290
79	Heart Lung and Circulation	2,889	2.194	0.006490
80	CURRENT OPINION IN CARDIOLOGY	2,051	2.149	0.003530
81	Seminars in Thoracic and Cardiovascular Surgery	1,320	2.133	0.002210
82	BMC Cardiovascular Disorders	3,684	2.078	0.008950
83	JOURNAL OF THROMBOSIS AND THROMBOLYSIS	2,794	2.054	0.005740
84	Cardiovascular Ultrasound	1,112	2.051	0.001490
85	CATHETERIZATION AND CARDIOVASCULAR INTERVENTIONS	8,295	2.044	0.015230
86	CARDIOVASCULAR AND INTERVENTIONAL RADIOLOGY	5,675	2.034	0.007340
87	INTERNATIONAL JOURNAL OF CARDIOVASCULAR IMAGING	3,176	1.969	0.006730
88	Netherlands Heart Journal	1,233	1.933	0.001950
89	International Heart Journal	1,942	1.906	0.002670
90	Kardiologia Polska	1,665	1.874	0.002570
91	Cardiology in Review	1,080	1.816	0.001510
92	CARDIOLOGY CLINICS	1,086	1.811	0.002030

93	CARDIOLOGY	2,359	1.791	0.002520
94	Cardiovascular Engineering and Technology	504	1.771	0.001090
95	JOURNAL OF INTERVENTIONAL CARDIOLOGY	1,309	1.758	0.002400
96	CARDIOVASCULAR PATHOLOGY	1,998	1.756	0.002360
97	CardioRenal Medicine	485	1.754	0.001100
98	Interactive Cardiovascular and Thoracic Surgery	5,684	1.675	0.009110
98	Journal of Cardiovascular Nursing	1,795	1.675	0.002220
100	Cardiology Journal	1,164	1.669	0.001950
101	Congenital Heart Disease	1,648	1.663	0.004000
102	EUROPEAN HEART JOURNAL SUPPLEMENTS	551	1.655	0.000810
103	HEART & LUNG	2,351	1.630	0.003020
104	HEART AND VESSELS	2,176	1.618	0.003670
105	Annals of Thoracic and Cardiovascular Surgery	1,087	1.584	0.001370
106	PEDIATRIC CARDIOLOGY	4,344	1.564	0.006710
107	Journal of Cardiothoracic Surgery	2,089	1.506	0.004210
108	JOURNAL OF CARDIAC SURGERY	2,054	1.490	0.003000
109	Annals of Thoracic Medicine	735	1.456	0.000990
110	JOURNAL OF INVASIVE CARDIOLOGY	1,593	1.453	0.002420
111	Arquivos Brasileiros de Cardiologia	3,065	1.450	0.002850
112	JOURNAL OF CARDIOVASCULAR SURGERY	1,825	1.415	0.002130

113	ECHOCARDIOGRAPHY-A JOURNAL OF CARDIOVASCULAR ULTRASOUND AND ALLIED TECHNIQUES	3,173	1.393	0.005780
114	Journal of Cardiopulmonary Rehabilitation and Prevention	1,706	1.383	0.001840
115	Postepy w Kardiologii Interwencyjnej	311	1.347	0.000620
116	CORONARY ARTERY DISEASE	1,637	1.335	0.002200
117	PACE-PACING AND CLINICAL ELECTROPHYSIOLOGY	5,012	1.303	0.005720
118	Cardiology Research and Practice	833	1.292	0.001360
119	JOURNAL OF INTERVENTIONAL CARDIAC ELECTROPHYSIOLOGY	1,507	1.277	0.003230
120	PERFUSION-UK	1,271	1.234	0.001760
121	Journal of Cardiovascular Medicine	1,667	1.225	0.002970
122	Anatolian Journal of Cardiology	1,203	1.223	0.001940
123	THORACIC AND CARDIOVASCULAR SURGEON	1,812	1.209	0.002440
124	ACTA CARDIOLOGICA	960	1.208	0.001550
125	ANNALS OF NONINVASIVE ELECTROCARDIOLOGY	1,206	1.131	0.001750
126	General Thoracic and Cardiovascular Surgery	1,432	1.088	0.002400
127	SCANDINAVIAN CARDIOVASCULAR JOURNAL	804	1.084	0.001240
128	Brazilian Journal of Cardiovascular Surgery	849	1.053	0.001130
129	HERZ	1,083	1.033	0.001400
130	TEXAS HEART INSTITUTE JOURNAL	1,891	1.023	0.001310

131	CARDIOLOGY IN THE YOUNG	2,641	1.000	0.004660
132	Revista Portuguesa de Cardiologia	819	0.960	0.000910
133	JOURNAL OF ELECTROCARDIOLOGY	2,518	0.944	0.003260
134	Cardiovascular Journal of Africa	953	0.897	0.001820
135	MINERVA CARDIOANGIOLOGICA	371	0.713	0.000470
136	Reviews in Cardiovascular Medicine	245	0.659	0.000370
137	HEART SURGERY FORUM	518	0.404	0.000520
138	KARDIOLOGIYA	522	0.264	0.000240

10. Publication source of the doctoral thesis

Interactive CardioVascular and Thoracic Surgery (2021) 1–8
doi:10.1093/icvts/ivab085

ORIGINAL ARTICLE

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Initial experience with the new type A arch dissection stent: restoration of supra-aortic vessel perfusion

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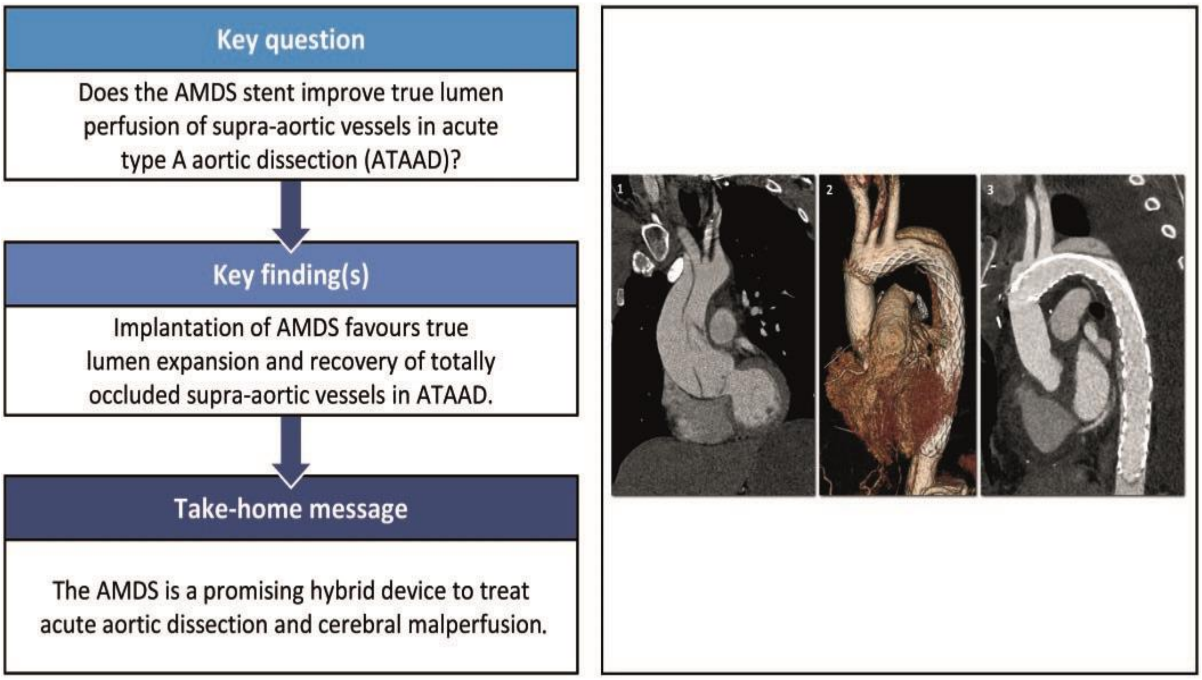

Presented at the 34th Annual Meeting of the European Association for Cardio-Thoracic Surgery, Barcelona, Spain, 8–10 October 2020.

Abstract

OBJECTIVES: The goal of the present study is to investigate changes in supra-aortic vessel perfusion after implantation of the non-covered Ascyrus Medical Dissection Stent (AMDS) for surgical treatment of acute type A aortic dissection.

METHODS: From 2017 to 2020, 16 consecutive patients treated with AMDS and involvement (dissection to total occlusion) of at least 1 supra-aortic vessel were included in the study. Centre-line based computed tomography measurements of true, false and total lumen area using Terarecon software were performed before and after surgery. Changes in the true lumen area were indexed to the entire vessel area. The paired sample t-test was used to assess the significance of the observed differences.

RESULTS: Analysis of supra-aortic vessels and the descending aorta showed significant improvement in true lumen perfusion after the AMDS was implanted. The indexed true lumen area increased postoperatively by 72%, 112% and 30% in the innominate, right and left common carotid arteries, respectively. Total occlusions of both common carotid arteries recovered completely after surgical treatment. The proximal- and the mid-descending aorta showed a 78% and 48% improvement of the indexed true lumen area, respectively.

CONCLUSIONS: Arch repair using AMDS shows promising results in the treatment of acute type A aortic dissection. Quantitative measurements of true and false lumen perfusion demonstrated a significant increase in true lumen area and a 100% regression of totally occluded supra-aortic branches. Further examination in a larger cohort of patients and comparison with isolated hemiarch repair are needed to confirm positive vascular remodelling after an AMDS implant.

Keywords: Type A aortic dissection • Arch repair • Cerebral malperfusion • DeBakey I • Ascyrus Medical Dissection Stent

ABBREVIATIONS	
ATAAD	Acute type A aortic dissection
AMDS	Ascyrus Medical Dissection Stent
CT	Computed tomography
SD	Standard deviation

INTRODUCTION

Acute type A aortic dissection (ATAAD) involving supra-aortic vessels represents an emergency in cardiac surgery with the need of urgent repair to reduce morbidity and mortality. Dissection of innominate and common carotid arteries with consecutive malperfusion syndrome can lead to brain injury, complicating postoperative care [1]. Despite continuous improvements in diagnosis, referral and surgical treatment, the management of supra-aortic vessel malperfusion remains challenging [2, 3]. Acute neurological impairment or stroke at presentation is a strong predictor of a poor perioperative outcome, especially in older patients [4, 5]. Adjustments regarding the re-establishment and monitoring of adequate cerebral perfusion were demonstrated to improve outcomes [6]. Innovations also involved surgical techniques: Besides the standard of care hemiarch repair, new prostheses were developed to perform more radical repairs, possibly reducing malperfusion complications and avoiding the need for reoperations [7, 8]. The Ascyrus Medical Dissection Stent (AMDS) was designed to upgrade the standard hemiarch procedure and to treat malperfusion: Sealing the distal anastomosis prevents antegrade false lumen flow and increases true lumen perfusion. The fate of dissected supra-aortic vessels after surgery for ATAAD remains unclear, and quantitative analyses of cerebral perfusion are lacking. Therefore, our goal was to investigate the effects of AMDS implants on true lumen perfusion in patients presenting with ATAAD and affected supra-aortic vessels.

Patient population

The study was approved by the local ethics committee (No. EA2/ 096/20) and complies with the Declaration of Helsinki. Informed patient consent was waived.

Between February 2018 and March 2020, a total of 233 patients were operated on for ATAAD; 48 (21%) were given an AMDS implant for DeBakey I acute dissection, representing the primary study cohort. Patients in whom at least 1 supra-aortic vessel (n = 16) was affected, based on preoperative computed tomography (CT) scans, comprised the final study population. Two patients were excluded because their supra-aortic vessels were not fully captured in the preoperative CT scan.

Computed tomography analysis

Quantitative measurements of true and false lumens and wholevessel diameter and area were performed using the centre-line based Terarecon software (Aquarius Intuition Viewer, Durham, NC USA) in a standardized fashion either at the most stenotic level in the affected vessels or 20 mm above the respective origin in the non-affected vessels (Fig. 1.1 and 1.2). The most stenotic portion of a diseased branch was defined as 'dissected' in cases of dissection without perfusion impairment, as 'sub-totally occluded' in cases of 75–99% stenosis and as 'totally occluded' in cases with 100% stenosis. The true lumen area was indexed to the whole vessel area and compared before and after the AMDS was implanted (Fig. 1.3a and 1.3b). Similar quantitative measurements were performed on postoperative CT scans of the descending aorta at the half-length of the AMDS and 1 cm distal to the tip of the stent. The same landmarks were then identified in preoperative CT scans, starting 1 cm proximal to the origin of the innominate artery.

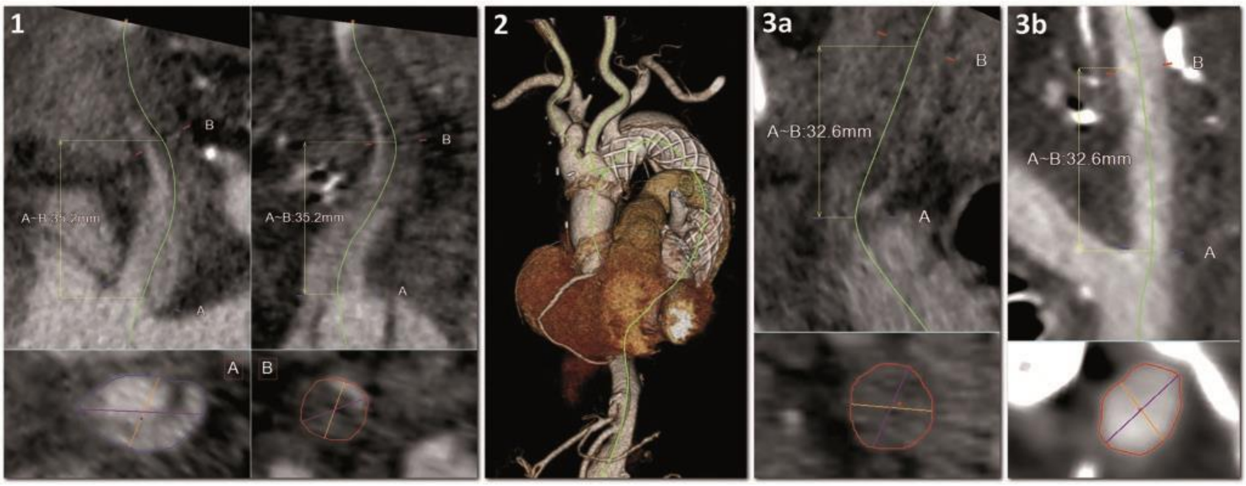

Figure 1: Centre-line definition of supra-aortic vessels. (1) 2-Dimensonal visualization of the centre line and recognition of the most stenotic level in the preoperative computed tomography scan. (2) 3-Dimensional reconstruction. (3a,b) Comparison of the standardized centre-line measurements before (3a) and after (3b) the Ascyrus Medical Dissection Stent is implanted.

How to use the AMDS

A detailed description of the AMDS device and of the sizing and implant procedures was published previously [9]. In brief, AMDS is a hybrid graft that comprises a 10-mm proximal polytetrafluoroethylene cuff for sealing the distal anastomosis and a super-helical non-covered nitinol stent for remodelling of the arch and the descending aorta (Fig. 2). The indication for an AMDS implant is a DeBakey I dissection with a primary entry tear in the ascending aorta and the absence of tears in the aortic arch or the proximal descending aorta. The stent is available in 2 shapes: tubular, with a fixed diameter along the stent, and tapered, with a decreasing diameter proximal to distal. Sizing is performed through multiplanar or centre-line reconstructions in the preoperative CT scan at 2 aortic landmarks: zone 1 of the aortic arch and the descending aorta at the level of the tracheal bifurcation. Based on obtained measurements, an appropriate stent can be selected according to tables provided on the Ascyrus Medical website (https://ascyrus.com/sizes-and-configu rations/). The operative setting considers right axillary cannulation for the arterial line and right atrium or femoral access for venous drainage. After preparing the ascending aorta and the supra-aortic branches, aortic transection is performed in an orthogonal plane to the vessel, 1 cm proximal to the innominate artery. The device was implanted under unilateral selective cerebral perfusion (with 10 ml/kg/min flow) at moderate systemic hypothermia (core temperature, 28 degrees Celsius). Near infra-red spectroscopy is used during the operation to monitor cerebral perfusion. Placement of the AMDS in the true lumen can be assured either through direct view or using a femoral guidewire.

Figure 2: Overview of the Ascyrus Medical Dissection Stent.

As soon as the stent is fully inserted, the protection sheath is removed, and the proximal cuff is unfolded and fixed in place through 4 cardinal stitches using a Teflon strip on the outer side of the aorta to avoid tension or tearing. The stent is released by unscrewing and pulling the green cap attached to the fixation suture along the delivery system. A circumferential 3–0 Prolene suture is performed using the sandwich technique to seal the distal anastomosis, readapting the aortic wall layers between the stent cuff and the outer felt strip. The ascending vascular graft is secured through a second running suture to the aorta-AMDS complex.

Assessment of neurological symptoms

Acute preoperative neurological symptoms were classified only if present on admission to our hospital. Postoperatively, the presence and quality of neurological symptoms were assessed for all patients by discriminating between loss of function (0 points out of 5 at neurological examination, Medical Research Council Muscle Scale) and impaired function (1–4 out of 5). Duration was divided into transient (symptom improves or recovers within days after surgery) and permanent (no recovery observed perioperatively).

Statistical analyses

Clinical and anatomical data are expressed as frequencies with corresponding percentages for categorical variables and as mean with standard deviation (SD) for continuous data. Statistical analyses were performed with the paired sample t-test using SPSS software Version 25 (IBM SPSS Statistics, Armonk, New York USA). A P-value of <0.05 was considered statistically significant. Statistical analyses and data reporting were in line with the statistical and data reporting guidelines of the European Journal of Cardio-thoracic Surgery and Interactive Cardiovascular and Thoracic Surgery [10].

RESULTS

Baseline characteristics

Baseline characteristics are shown in Table 1. The mean age was 61 years (SD: 12 years); 5 (31.25%) patients were women. One patient (6.25%) was admitted in cardiogenic shock due to a massive pericardial effusion and with acute left-sided hemiparesis (PENN class Abc). The average German Registry for Acute

Aortic Dissection Type A score was 20.47% (SD: 6.8%). Six patients (37.5%) presented with acute neurological symptoms: 5 of them had a left-sided hemiparesis, and 1 patient had isolated left leg paresis. Among these patients, preoperative CT scans showed involvement of 2 supra-aortic branches in 50% of cases, and 67% had at least 1 subtotally occluded vessel.

Table 1:Baseline characteristics

Baseline characteristics, mean (SD), n (%)	Total population, N = 16
Age (years)	61 (SD : 12)
Gender (female)	5 (31.25)
BMI (kg/m^2)	25.8 (SD: 3.8)
BSA (m^2)	2.0 (SD: 0.3)
Hypertension	11 (68.75)
Diabetes	1 (6.25)
Smoker	6 (37.5)
Chronic obstructive pulmonary disease	1 (6.25)
Kidney insufficiency	1 (6.25)
Coronary artery disease	2 (12.5)
Previous aortic disease	1 (6.25)
Intubation	1 (6.25)
Acute shock	1 (6.25)
Acute neurological deficit	6 (37.5)
Malperfusion (any sign)	6 (37.5)
Coronary	1 (6.25)
Cerebral	6 (37.5)
Peripheral	2 (12.5)
Visceral	1 (6.25)
PENN Classification	
Aa-no ischaemia	10 (62.5)
Ab-localized ischaemia	5 (31.25)
Ac-generalized ischaemia	0 (0)
Abc-combined ischaemia	1 (6.25)
GERAADA score	20.47 (SD: 6.85)
Aortic regurgitation	
No-trace	3 (18.75)
Mild	2 (12.5)
Moderate	10 (62.5)
Severe	1 (6.25)
Left ventricular ejection fraction (%)	52 (SD: 8)
Right ventricular ejection fraction (%)	53 (SD: 4)
Pericardial effusion	4 (25)

BMI: body mass index; BSA: body surface area; GERAADA: German Registry for Acute Aortic Dissection Type A; SD: standard deviation.

Surgical data

Operative data are shown in Table 2. Time between onset of symptoms and the operation (pain-to-cut time) was 398 min (SD: 268 min) in the overall population and 270 min (SD: 110 min) in patients with acute neurological deficits. Mean caudal circulatory arrest time was 45 min (SD: 11 min). In 50% of cases, a tapered AMDS 55–40 was used. Moderate-to-severe aortic regurgitation was present in 69% of patients, with consecutive aortic valve replacement in 5 patients (31.25%).

Table 2: Intraoperative data

Operative data, mean (SD), n (%)	Total population, N = 16
Pain-to-cut time (min)	398 (SD: 268)
Operation time (min)	370 (SD: 114)
Cardiopulmonary bypass time (min)	194 (SD: 40)

Cross-clamp time (min)	112 (SD: 33)
Reperfusion (min)	56 (SD: 28)
Intraoperative transfusions (units)	
Red cell concentrate	1.2 (SD: 1.9)
Platelets concentrate	4.4 (SD: 2.3)
Fresh frozen plasma	5.2 (SD: 5.8)
Hypothermia (C)	27.3 (SD: 1.2)
Selective cerebral perfusion time (min)	45 (SD: 11)
Bicuspid valve	1 (6.25)
Aortic valve surgery	
Repair	11 (68.75)
Biological replacement	4 (25)
Mechanical replacement	1 (6.25)
Root operation	
Reconstruction	9 (56.25)
Bentall	5 (31.25)
David	2 (12.5)
AMDS sizing	
40 tubular	4 (25)
40–30 tapered	3 (18.75)
55 tubular	1 (6.25)
55–40 tapered	8 (50)
Revision for bleeding	2 (12.5)

AMDS: Ascyrus Medical Dissection Stent; SD: standard deviation.

Perioperative data and neurological outcome

Perioperative data are presented in Table 3. The mean intensive care unit stay was 10 days (SD: 8 days). Postoperative neurological deficits were present in 8 patients (50%): among the 6 patients with preoperative acute deficits, 5 (83%) had the deficits also after surgery and 1 recovered completely. Three new postoperative neurological deficits were diagnosed: 1 patient had an occluded right common carotid and a subtotally occluded left common carotid artery preoperatively, and 2 presented with subtotal occlusion of the right or left common carotid. Neurological deficits were transient in 62.5%, and 75% were classified as impaired function.

Table 3: Perioperative data

Perioperative data, mean (SD), n (%)	Total population, N = 16
ICU length of stay (days)	11 ± 8
Ventilation time (days)	5 ± 6
Open chest therapy	1 (6.25)
Reintubation	2 (12.5)
Tracheotomy	2 (12.5)
Delirium	6 (37.5)
Postoperative low cardiac output syndrome	1 (6.25)
Dialysis	2 (12.5)
Postoperative neurological deficit	8 (50)
Neurological deficit duration	
Transient	5 (62.5)
Permanent	3 (37.5)
Neurological deficit quality	
Impaired function	6 (75)
Loss of function	2 (25)
Postoperative CT-diagnosed stroke	6 (37.5)
30-Day mortality	3 (18.75)

CT: computed tomography; ICU: intensive care unit; SD: standard deviation.

Impact of the AMDS on true lumen perfusion

Quantitative measurements of supra-aortic vessels and descending aorta are summarized in Tables 4 and 5; dissection characteristics of the supra-aortic vessels are provided in Fig. 3.

Table 4: Centre-line-based measurements of dissected supra-aortic vessels and descending aorta before and after surgery

Assessment of dissected vessels, mean (SD), n (%)	Preoperative, N = 16	Postoperative, N = 16
Innominate artery		
Dissected	12 (75)	11 (68.75)
Subtotal occlusion	4 (25)	1 (6.25)
Total occlusion	0 (0)	0 (0)
True lumen diameter (mm)	9.15 (SD: 1.81)	11.51 (SD: 2.42)
True lumen area (mm^2)	68.04 (SD: 25.16)	108.22 (SD: 44.92)
False lumen diameter (mm)	13.67 (SD: 1.93)	10.18 (SD: 6.25)
False lumen area (mm^2)	149.60 (SD: 41.78)	110.53 (SD: 80.03)
Total area (mm^2)	214.82 (SD: 54.11)	221.42 (SD: 78.00)
Measurement landmark (mm)	18.82 (SD: 6.93)	20.16 (SD: 8.34)
Right common carotid		
Dissected	4 (25)	3 (18.75)
Subtotal occlusion	6 (37.5)	3 (18.75)
Total occlusion	3 (18.75)	0 (0)
True lumen diameter (mm)	4.24 (SD: 2.34)	5.98 (SD: 2.06)
True lumen area (mm^2)	18.21 (SD: 13.66)	31.25 (SD: 15.87)
False lumen diameter (mm)	7.04 (SD: 3.57)	3.21 (SD: 4.56)
False lumen area (mm^2)	48.42 (SD: 28.59)	23.48 (SD: 34.97)
Total area (mm^2)	67.12 (SD: 20.35)	54.84 (SD: 25.82)
Measurement landmark (mm)	30.74 (SD: 21.17)	28.46 (SD: 17.20)
Left common carotid		
Dissected	4 (25)	4 (25)
Subtotal occlusion	2 (12.5)	0 (0)
Total occlusion	1 (6.25)	0 (0)
True lumen diameter (mm)	5.91 (SD: 2.12)	7.51 (SD: 1.49)
True lumen area (mm^2)	30.92 (SD: 15.60)	45.92 (SD: 18.39)
False lumen diameter (mm)	3.89 (SD: 4.40)	2.37 (SD: 4.01)
False lumen area (mm^2)	26.37 (SD: 33.09)	16.28 (SD: 30.51)
Total area (mm^2)	57.13 (SD: 22.84)	62.60 (SD: 31.87)
Measurement landmark (mm)	40.30 (SD: 29.62)	35.49 (SD: 20.00)
Proximal-descending aorta		
True lumen diameter (mm)	18.34 (SD: 4.42)	23.91 (SD: 3.86)
True lumen area (mm^2)	278.59 (SD: 130.33)	460.13 (SD: 144.61)
False lumen diameter (mm)	24.30 (SD: 3.34)	16.36 (SD: 8.45)
False lumen area (mm^2)	471.88 (SD: 134.24)	262.81 (SD: 150.36)
Total area (mm^2)	749.75 (SD: 175.57)	728.00 (SD: 193.56)
Measurement landmark (mm)	105.56 (SD: 13.79)	105.56 (SD: 13.79)
Mid-descending aorta		
True lumen diameter (mm)	16.13 (SD: 2.96)	19.43 (SD: 2.82)
True lumen area (mm^2)	211.31 (SD: 80.47)	303.00 (SD: 85.55)
False lumen diameter (mm)	22.12 (SD: 3.24)	19.34 (SD: 6.42)
False lumen area (mm^2)	392.06 (SD: 117.40)	324.13 (SD: 158.53)
Total area (mm^2)	602.13 (SD: 166.26)	621.63 (SD: 193.72)
Measurement landmark (mm)	220.31 (SD: 28.44)	220.31 (SD: 28.44)

INA: innominate artery; LCC: left common carotid artery; RCC: right common carotid artery; SD: standard deviation.

The innominate artery was affected in all patients, presenting either dissection without impaired perfusion (75%) or subtotal occlusion (25%). Mean total vessel area was 214.82 mm^2 (SD: 54.11 mm^2) whereas the false lumen occupied most of vessel surface with 149.60 mm^2 (SD: 41.78 mm^2). The right common carotid had the worst involvement, showing 6 subtotal occlusions (37.5%) and 3 total occlusions (18.75%); also in this branch, false lumen covered most of the vessel area and decreased postoperatively. The left common carotid was diseased in 7 cases (43.75%), with 2 (12.5%) subtotal occlusions and 1 (6.25%) total occlusion.

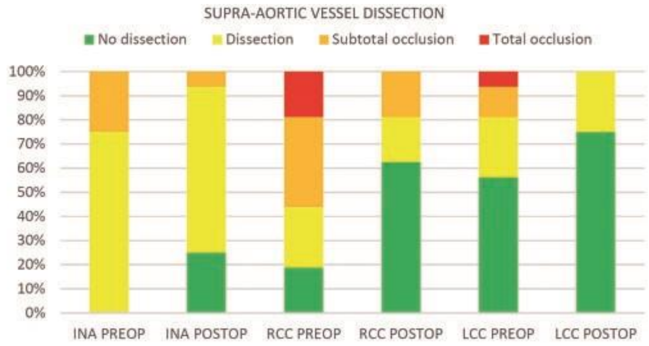

Figure 3: Dissection morphology of supra-aortic vessels before and after the Ascyrus Medical Dissection Stent is implanted. INA: innominate artery; LCC: left common carotid artery: preop: preoperative; postop: postoperatively; RCC: right common carotid artery.

The comparison between dissection morphology in the supraaortic vessels before and after surgery shows complete regression of total occlusions in both common carotid arteries and an increase in dissection-free vessels: 0–25% for the innominate artery, 18.75–62.5% for the right common carotid and 56.25–75% for the left common carotid artery.

After indexing the true lumen as a percentage of the whole vessel area, perfusion improvement was achieved in all supraaortic branches. Indexed innominate artery true lumen increased from 32% to 55% (P = 0.002) and indexed right common carotid true lumen doubled from 34% to 72% (P = 0.01). No statistical relevance was reached by the left common carotid (P = 0.13), despite true lumen increases from 64% to 83%.

Full AMDS expansion was confirmed in all patients postoperatively, without any device-related complications. In 87.5% of cases, elimination of antegrade false lumen perfusion in the aortic arch was achieved, with partial or full false lumen thrombosis of the descending aorta in 68.75% of patients.

Table 5: Paired t-test comparison of indexed true lumen area in the supra-aortic vessels and descending aorta after an Ascyrus Medical Dissection Stent implant

Indexed true lumen area, mean (SD)	Preoperative	Postoperative	P-value
Indexed INA true lumen (%)	32 (SD: 9)	55 (SD: 28)	0.002
Indexed RCC true lumen (%)	34 (SD: 33)	72 (SD: 40)	0.01
Indexed LCC true lumen (%)	64 (SD: 40)	83 (SD: 29)	0.13
Indexed proximal-descending true lumen (%)	36.53 (SD: 12.49)	64.31 (SD: 18.91)	<0.001
Indexed mid-descending true lumen (%)	35.09 (SD: 8.66)	50.74 (SD: 16.41)	0.002

INA: innominate artery; LCC: left common carotid artery; RCC: right common carotid artery; SD: standard deviation.

After quantitative assessment of the descending aorta, the true lumen area increased from 278.59 mm^2 (SD: 130.33 mm^2) to 460.13 mm^2 (SD: 144.61mm^2) at the proximal descending landmark [105 mm (SD: 13.79 mm) at the half-length of the AMDS], with an increase in indexed true lumen area of 77.8% (P < 0.001). Similarly, the indexed true lumen area increased from 35% to 50% (P-value = 0.002) at the mid-descending landmark (220 mm [SD: 28.44 mm] 1 cm distal to the tip of the stent).

DISCUSSION

ATAAD involving the supra-aortic branches have been object of intensive study in past years due to the poor prognosis and high morbidity rates. Preoperative cerebral malperfusion was demonstrated as a relevant risk factor for hospital death and as an independent predictor of postoperative cerebral injuries [3, 11]. In

2011, Tsukube et al. showed a favourable cut-off of 5 h between the onset of symptoms and the operation, a treatment window that granted low hospital mortality (14%), remarkable postoperative neurological improvement and a 71.8% cumulative survival rate at 3 years [12]. These results show that preoperative neurological deficits and cerebral malperfusion do not represent contraindications for surgery in patients with ATAAD, above all if patients reach the operating room within a few hours after the onset of the dissection and sufficient cerebral perfusion is reestablished. The improvements in cerebral protection led to the development of numerous surgical strategies for arch repair in ATAAD. Although procedures like hemiarch repair or the frozen elephant trunk technique have been analysed extensively [13, 14], showing comparable and reproducible results in terms of mortality and freedom from reoperation, a wide consensus about which strategy should be used is currently not available. The AMDS was properly designed to address these issues: reduce complexity in the surgery for ATAAD, prolonging by only a few min the hemiarch procedure, treat malperfusion and promote true lumen expansion, which should lead to positive remodelling and prevent the need for reinterventions. The proximal AMDS cuff prevents the formation of the distal anastomotic new entry, an insufficiency of the distal anastomosis that was shown to be present in up to 70% of postoperative CT scans from patients who developed aortic growth after isolated hemiarch repair [15]. Due to its low radial force, the non-covered AMDS is not intended to relaminate the aorta but just to readapt the intima against the media and adventitia; the subsequent expansion of the true lumen will drive the resolution of malperfusion and the depressurization of the false lumen. It is well known that the involvement of supraaortic vessels is a great challenge and might need complex repairs, but not all occlusions in supra-aortic branches can or should be radically treated [16]. Our CT assessment showed that the location of the most stenotic segment was at 30.7 and 40.3 mm from vessel's origin for the right and left common carotid arteries, respectively, meaning a level often difficult to reach during open surgery. Moreover, the AMDS enables the treatment of supra-aortic vessel occlusions, as underlined by our findings. Considering all mentioned arguments, the AMDS is an arch repair device that represents an upgrade of the hemiarch procedure and should not be primarily compared to total arch replacement techniques, due to the profound differences in concept, implant technique and mechanism of function.

Initial data about the AMDS device were published as a result of a multicentre trial, showing encouraging results, especially regarding the treatment of acute malperfusion [17, 18]. A cohort of 26 patients experienced a 95.5% resolution rate of vessel malperfusion, with no device-related adverse events. A previous report described positive aortic arch remodelling with elimination of antegrade false lumen flow and resolution of cerebral malperfusion involving supra-aortic vessels in 85.7% of patients [19].

The recently proposed German Registry for Acute Aortic Dissection Type A score and other malperfusion classifications confirm the high risk of our cohort [20, 21]. Also the novel TEM classification, which considers dissection type, entry location and the presence of clinical or radiological signs of malperfusion, may be a valuable tool to shift the treatment paradigm to a better risk stratification and a more comprehensive assessment of dissection complexity [22].

The present analysis underlines the fact that supra-aortic branch malperfusion and preoperative neurological deficit represent a severe condition, with 5 patients out of 6 still presenting neurological symptoms after the operation, although the AMDS improved cerebral perfusion relieving carotid artery occlusions. The 3 additional patients presenting with postoperative stroke had no preoperative neurological deficits but had at least a subtotal occlusion in 1 carotid artery. Despite full postoperative recovery of cerebral perfusion and no signs of embolic events, these 3 patients suffered from brain injury, probably due to prolonged dynamic malperfusion. These outcomes indirectly underline the importance of fast referral in case of supra-aortic vessel involvement, enabling a prompt surgical repair to restore cerebral perfusion. This goal is fully achieved with the AMDS device, with a remarkable increase in dissection-free vessels, especially for carotid arteries (18.75–62.5% for the right common carotid and 56.25–75% for the left common carotid artery).

Considering the different results between carotid arteries, right axillary cannulation and recovery of innominate artery may have played an additional role in terms of perfusion gain in the right common carotid as well as the lower involvement rate of the left common carotid. Also, the descending aorta shows improved perfusion of the true lumen along and distal to the stent: the sealing of the distal anastomosis and the elimination of antegrade false lumen flow in 87.5% of patients induce thrombosis and positive vascular remodelling. Contemporarily, the non-covered stent allows for full perfusion of the supra-aortic branches and for expansion of the descending true lumen, without increasing the risk of paraplegia. Implanting an AMDS does not add complexity to the standard hemiarch procedure and shows a high safety profile, with no device-related complications observed in this cohort. Details regarding surgical treatment in case of aneurysmatic arch dilatation following an AMDS implant cannot be provided since no case was observed during the currently available follow-up period.

Resolution of vessel occlusions, postoperative improvement in dissection-free supra-aortic branches and a relevant gain in the indexed true lumen area in the descending aorta are the main achievements of the AMDS concept and the key of malperfusion treatment.

CONCLUSION

This study represents a confirmation of the encouraging results achieved by the AMDS device in the treatment of ATAAD, especially in cases of vessel malperfusion. The remodelling of the aortic arch, driven by the sealing of the distal anastomosis and by the antegrade expansion of the true lumen, produces notable benefits in the supra-aortic vessels and downstream aorta, with significant increase of the true lumen area.

Limitations

This analysis is limited by its retrospective nature and the small sample size. Moreover, the analysis refers to the perioperative course only. A longer follow-up period is required to provide valuable information regarding positive vascular remodelling. The collected quantitative measurements are derived from the CT scan, which is known to provide a static flow pattern only. A dynamic analysis using carotid Doppler may have been a more precise tool to assess cerebral perfusion. Due to the lack of availability of dynamic measurements for most patients, we were not able to provide meaningful results regarding this topic.

Further investigation on a larger cohort and the comparison to hemiarch repair alone are necessary to confirm the present results, but the AMDS already appears to be a safe and reproducible adjunct to the standard of care in case of malperfusion, the goal being to effect a single-stage hybrid restoration of perfusion of the supra-aortic vessels.

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Conflict of interest: none declared.

Author contributions

Matteo Montagner: Conceptualization; Data curation; Formal analysis; Methodology; Writing—original draft. Markus Kofler: Conceptualization; Formal analysis; Methodology; Writing—review & editing. Roland Heck: Data curation; Investigation. Semih Buz: Investigation; Software; Supervision. Christoph Starck: Investigation; Supervision; Writing—review & editing. Stephan Kurz: Data curation; Investigation. Volkmar Falk: Conceptualization; Methodology; Supervision; Writing—review & editing. Jo¨rg Kempfert: Conceptualization; Methodology; Supervision; Validation; Writing—review & editing.

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11. Curriculum vitae

Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht.

12. List of publications

Minimally Invasive Surgical Mitral Valve Repair: State of the Art Review

Karel Van Praet, Christof Stamm, Simon Sündermann, Alexander Meyer, Axel Unbehaun, Matteo Montagner, Timo Nazari Shafti, Stephan Jacobs, Volkmar Falk, Jörg Kempfert

Interventional Cardiology Review 2017; doi: 10.15420/icr.2017:30:1

Impact factor: 0.14 (2017)

Acute intraoperative echocardiographic changes after transapical off-pump mitral valve repair with NeoChord implantation

Andrea Colli, Laura Besola, Matteo Montagner, Nicola Soriani, Erica Manzan, Eleonora Bizzotto, Fabio Zucchetta, Danila Azzolina, Roberto Bellu, Cristiano Sarais, Demetrio Pittarello, Gino Gerosa

International Journal of Cardiology 2018; doi: 10.1016/j.ijcard.2018.01.026

Impact factor: 2.11 (2018)

Prognostic impact of leaflet-to-annulus index in patients treated with transapical off-pump echo-guided mitral valve repair with NeoChord implantation

Andrea Colli, Laura Besola, Matteo Montagner, Danila Azzolina, Nicola Soriani, Erica Manzan, Eleonora Bizzotto, Fabio Zucchetta, Roberto Bellu, Demetrio Pittarello, Gino Gerosa

International Journal of Cardiology 2018; doi: 10.1016/j.ijcard.2018.01.049

Impact factor: 2.11 (2018)

An overview of surgical treatment modalities and emerging transcatheter interventions in the management of tricuspid valve regurgitation

Karel Van Praet, Christof Stamm, Christoph Starck, Simon Sündermann, Alexander Meyer, Matteo Montagner, Timo Nazari Shafti, Axel Unbehaun, Stephan Jacobs, Volkmar Falk, Jörg Kempfert

Expert Review of Cardiovascular Therapy 2018; doi: 10.1080/14779072.2018.1421068

Impact factor: 1.68 (2018)

Erratum to: Minimally Invasive Surgical Mitral Valve Repair: State of the Art Review

Karel Van Praet, Christof Stamm, Simon Sündermann, Alexander Meyer, Axel Unbehaun, Matteo Montagner, Timo Nazari Shafti, Stephan Jacobs, Volkmar Falk, Jörg Kempfert

Interventional Cardiology Review 2018; doi: 10.15420/icr.2018.13.2.er1

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Karel Van Praet, Markus Kofler, Simon Sündermann, Matteo Montagner, Roland Heck, Christoph Starck, Christof Stamm, Stephan Jacobs, Jörg Kempfert, Volkmar Falk

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Lisa Zaschke, Helmut Habazettl, Jana Thurau, Christian Matschilles, Amélie Göhlich, Matteo Montagner, Volkmar Falk, Stephan Kurz

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Cocaine-Related Aortic Dissection: what do we know?

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New Hybrid Prosthesis for Acute Type A Aortic Dissection

Matteo Montagner, Roland Heck, Markus Kofler, Semih Buz, Christoph Starck, Simon Sündermann, Stephan Kurz, Volkmar Falk, Jörg Kempfert

Surgical technology international 2020

Impact factor: 0.57 (2020)

Reliability and Influence on Decision Making of fully-automated vs. semi-automated Software Packages for Procedural Planning in TAVI

Alexander Meyer, Markus Kofler, Matteo Montagner, Axel Unbehaun, Simon Sündermann, Semih Buz, Christoph Klein, Christof Stamm, Natalia Solowjowa, Maximilian Y. Emmert, Volkmar Falk, Jörg Kempfert

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Interact Cardiovasc Thorac Surg. 2022 Jul 9;35(2):ivac200. doi: 10.1093/icvts/ivac200.

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