Mid-Term Outcomes of a Hybrid Approach Involving Open Surgery Plus TEVAR of the Descending Aorta in the Treatment of Complex Type A Dissection

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Abstract

Objectives Type A aortic dissection with true lumen collapse and malperfusion downstream is associated with a devastating prognosis. This study compares the clinical outcomes of two operative strategies for this disease: hybrid approach of ascending aorta (and hemiarch replacement) supplemented with retrograde stenting of the descending aorta (thoracic endovascular aortic repair [TEVAR]) and standard ascending aorta (and hemiarch) replacement without stent placement.

Methods From January 1, 2016 to December 31, 2019, 81 patients with type A aortic dissection were studied. The hybrid technique was applied in 30 patients (group 1), while 51 patients received standard surgical repair (group 2). Patient demographics, clinical and operative findings, postoperative outcome, follow-up interventions, and mid-term survival were analyzed.

Results Baseline characteristics were similar among the groups, except that more preoperative malperfusion was evident in group 1. The postoperative incidence of visceral malperfusion (0 vs. 15.7%, $p = 0.02$) and low cardiac output syndrome requiring extracorporeal membrane oxygenation support (3.3 vs. 19.6%, $p = 0.04$) was significantly less in group 1. In-hospital mortality was also significantly lower in group 1 as in group 2 (13.3 vs. 33.3%, $p = 0.04$). At follow-up, the need for secondary endovascular stenting (3.3 vs. 7.8%, $p = 0.65$) and surgical aortic reintervention (6.7 vs. 2.0%, $p = 0.55$) was comparable. One-year, 2-year, and 3-year survival rates were 83.3, 83.3, and 62.5% in group 1, and 58.7, 58.7, and 52.6% in group 2 ($p = 0.05$), respectively.

Conclusion The combination of open surgical replacement of the ascending aorta (and hemiarch) with TEVAR of the descending aorta for true lumen compromise is a feasible treatment option for patients with type A aortic dissection and is associated with a better perioperative outcome and improved mid-term survival rate.

Keywords
- type A aortic dissection
- true lumen occlusion
- TEVAR

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Introduction

Acute aortic dissection is a life-threatening disease. International guidelines for aortic disease management recommend immediate surgical repair if the ascending aorta is involved.[1,2] In most cases, however, aortic dissection is not limited to its proximal section, but involves the entire aorta with multiple intimal tears. As it is not possible to replace the whole aorta, a strategy for adequate surgical treatment has to be realized considering several aspects. Surgery for aortic dissection is often an emergency procedure in comorbid patients with a need for safe and straightforward surgery to reduce patient risk. Replacement of ascending aorta and hemiarch instead of extended arch repair is the simpler and thus a potentially more favorable procedure. The drawback of simplifying the operative procedure is the surgical disregard of the vascular lesions in the descending thoracic aorta (DTA). Early on, aortic dissection in the DTA may lead to detrimental malperfusion of visceral organs, later it may hinder the anticipated false lumen thrombosis and promote fatal false lumen growth. In the face of these aspects, an assumed complete aortic repair with a so-called frozen elephant trunk (FET) has been nominated the best surgical repair technique for type A aortic dissection (TAAD), but it is a time consuming and complex procedure, which cannot be performed on every patient and by every surgeon. It's no wonder that there are many controversies regarding timing and type of repair, and surgical techniques mainly depend on individual or institutional experience.

In our previous studies, TAAD patients undergoing conventional replacement of the ascending aorta (and hemiarch) presented acute postoperative visceral malperfusion in 7.1% of cases.[3] Since 2016, our group started to add prophylactic stenting of the DTA (thoracic endovascular aortic repair [TEVAR]) during hypothermic circulatory arrest in a nonrandomized manner to the replacement of the ascending aorta (and hemiarch) to enhance aortic flow through the true lumen and to lower the risk of malperfusion. The aim of the present study was to retrospectively compare the new operative strategy with the old one, and to provide mid-term results.

Materials and Methods

Study Population

From January 1, 2016 to December 31, 2019, 153 patients underwent surgery for acute TAAD at our institution. Patients with the entry of the dissection within the distal aortic arch (= non-A-non-B-dissections) were excluded as they were treated by partial or total arch replacement. Therefore, only 81 patients with TAAD could be included into the study (►**Fig. 1**).

The 81 patients were classified in two groups according to the surgical procedure performed. A hybrid approach of ascending aorta and hemiarch replacement supplemented

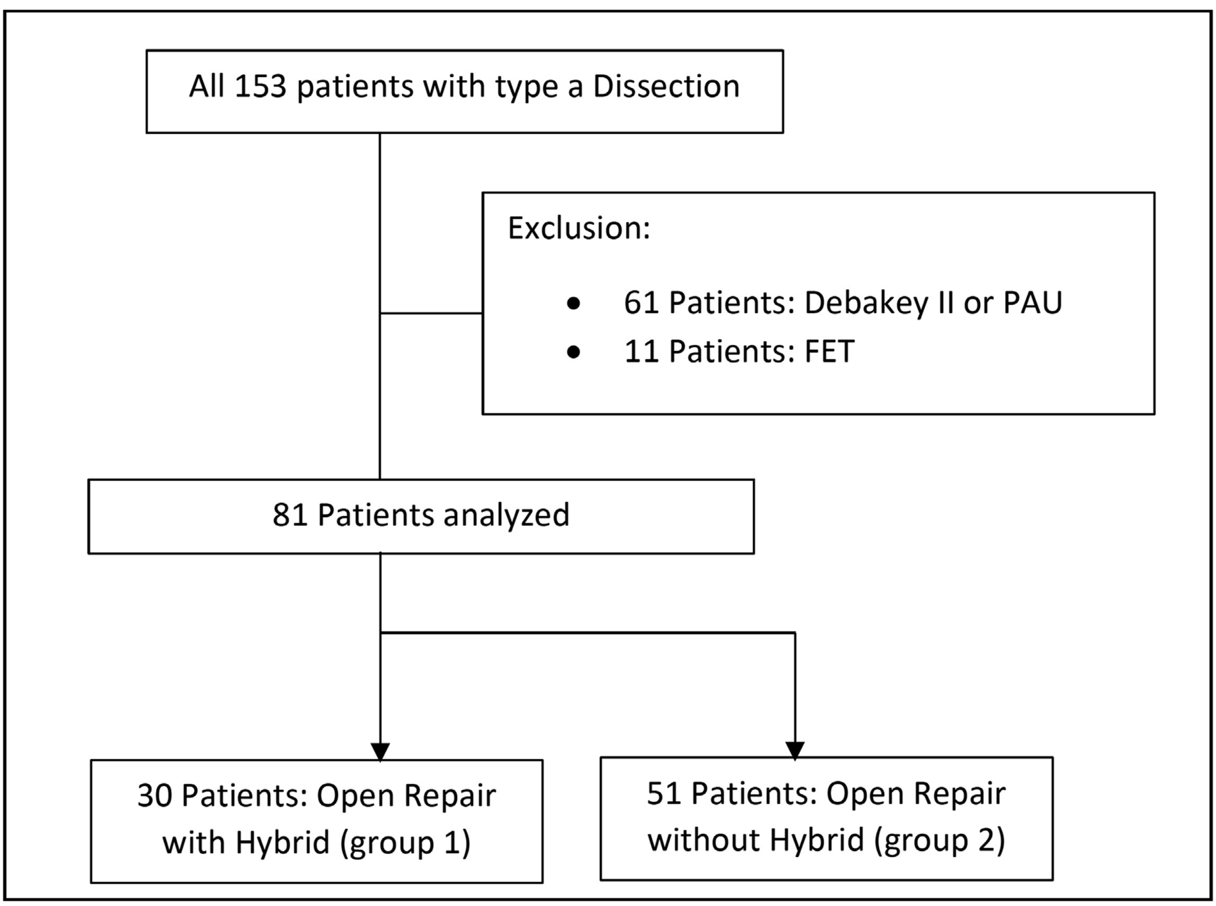

Fig. 1 Study groups. FET, frozen elephant trunk; PAU, penetrating aortic ulcer.

with retrograde TEVAR of the DTA was applied on 30 patients (group 1). The indication for a hybrid surgical procedure was based on the computed tomographic (CT) findings of a true lumen collapse to less than 50%, whereas the realization of the hybrid procedure was based on the surgeon's preference and availability of the vascular surgeon (responsible for TEVAR) over a wide range of time until it became routine in our institution. During surgery, an interventional vascular surgeon forwarded the guide wire into the true lumen with ultrasound or fluoroscopy support and released a covered stent via femoral approach under direct vision in group 1 patients. The control group included 51 patients who underwent only replacement of the ascending aorta or hemiarch, without stent placement in the DTA (group 2).

All patients were classified according to the Penn classification. The German Registry for Type A Dissection (GERAADA) score was calculated from demographic data and preoperative characteristics (►**Tables 1** and **2**).

Aortic true lumen collapse was defined empirically as >50% reduction in the luminal cross-section area in CT scans as there is no theoretical basis in the literature available.

Visceral malperfusion was defined as impaired perfusion of the celiac trunk or mesenteric bed secondary to the aortic dissection and evidence of deranged laboratory parameters. Entry location and malperfusion were classified according to the TEM (type of dissection location of the tear of the primary entry and malperfusion) aortic dissection classification (►**Table 3**).

Surgical Procedure

All patients were taken directly to the operating room as soon as diagnosis was confirmed by CT scan. After induction of general anesthesia, transesophageal echocardiography (TEE) was performed to evaluate aortic valve function and to rule out pericardial tamponade. Arterial cannulation was accomplished at the right subclavian artery or a femoral artery according to the surgeon's preference. Direct aortic cannulation was used as bail out if subclavian or femoral cannulation was not possible, or under emergency conditions. A stiff guide wire was advanced into the aortic arch with the aid of fluoroscopy and TEE. Following median sternotomy, venous return was achieved by two-stage cannulation in the right atrium, and cardiopulmonary bypass

Table 1 Baseline patient characteristics and risk factors

	Hybrid ($n = 30$) (group 1)	Standard ($n = 51$) (group 2)	p-Value
Patients			
Male	20 (66.7%)	35 (68.6%)	1.00
Age, mean (±SD), y	57.7 ± 12.2	59.2 ± 10.8	0.57
BMI, mean (±SD) (kg/m^2)	27.4 ± 4.0	29.6 ± 6.5	0.10
Comorbidities			
Arterial hypertension, n (%)	27(90.0%)	38(74.5%)	0.16
Atherosclerotic disease, n (%)	17(56.7%)	31(60.8%)	0.89
Aneurysmal disease, n (%)	7(23.3%)	7(13.7%)	0.42
Nicotine abuse, n (%)	9(30.3%)	16(31.4%)	1.00
Hyperlipidemia, n (%)	20(66.7%)	30(58.8%)	0.64
Mechanical ventilation, n (%)	2(6.7%)	4(9.8%)	1.00
Resuscitation, n (%)	1(3.3%)	6(11.7%)	0.25
ECMO preoperatively	0 (0%)	3 (5.8%)	1.00
Chest pain, n (%)	29(96.7%)	48(94.1%)	1.00
Pericardial effusion, n (%)	1(3.3%)	3(5.8%)	1.00
Neurological deficit, n (%)	7(23.3%)	8(15.7%)	0.50
GERAADA score	31.6 ± 8.8%	28.9 ± 17.1%	0.43
Penn classification			
Aa, n (%)	0 (0.0%)	33 (64.7%)	<0.001
Ab, n (%)	16 (53.3%)	10 (19.6%)	<0.001
Ac, n (%)	2 (6.7%)	3 (5.9%)	0.02
Abc, n (%)	12 (40.0%)	4 (7.8%)	<0.001

Abbreviations: BMI, body mass index; ECMO, extracorporeal membrane oxygenation; GERAADA; German Registry for Type A Dissection; SD, standard deviation.
Data presented as mean ± standard deviation (SD) or n (%).
Penn classification: Class Aa: absence of branch vessel malperfusion or circulatory collapse. Class Ab: localized organ ischemia. Class Ac: circulatory collapse with or without cardiac involvement. Class Abc: localized and generalized ischemia.

Table 2 Clinical laboratory analyses

	Hybrid (*n* = 30) (group 1)	Standard (*n* = 51) (group 2)	*p*-Value
D-dimers (µg/L)	14.3 ± 12.9	17.3 ± 14.1	0.50
Serum creatinine (mg/dL)	1.0 ± 0.4	1.2 ± 1.1	0.37
GFR (mL/min/1.73 qm)	76.8 ± 20.6	73.0 ± 22.1	0.44
Platelets (/nL)	184 ± 78.1	188.4 ± 59.9	0.79
CK (U/L)	144.7 ± 115.3	835 ± 4227.4	0.38
CKMB (ng/mL)	3.0 ± 4.6	14.2 ± 47.7	0.21
GOT (U/L)	612.8 ± 2088	50.6 ± 94.2	0.12
GPT (U/L)	474.1 ± 1650	57.4 ± 84.3	0.14
Serum lactate (mg/dL)			
Preoperative	17.9 ± 23.8	22.9 ± 34.6	0.65
Intraoperative	61.3 ± 33.3	66.0 ± 36.0	0.52
Postoperative	22.0 ± 38.0	42.9 ± 57.3	0.08

Abbreviations: CKMB, creatine kinase muscle-brain type; GFR, glomerular filtration rate; GOT, glutamat-oxalacetat-transaminsae; GPT, glutamat-pyruvat-transaminase.
Data presented as mean ± standard deviation or *n* (%).

Table 3 Morphological characteristics of the aortic dissection

	Hybrid (*n* = 30) (group 1)	Standard (*n* = 51) (group 2)	*p*-Value
Location of proximal entry			
Aortic root, *n* (%)	5 (16.7%)	7 (13.7%)	0.72
Sinotubular junction, *n* (%)	7 (23.3%)	13 (25.4%)	0.82
Ascending aorta, *n* (%)	7 (23.3%)	10 (19.6%)	0.90
Proximal arch, *n* (%)	6 (20.0%)	10 (19.6%)	1.00
Descending aorta, *n* (%)	1 (3.3%)	3 (5.9%)	1.00
True lumen occlusion in the DTA, *n* (%)	30 (100%)	40 (78.4%)	0,57
TEM score			
Ta	30 (100%)	51 (100%)	–
E0	4 (13.3%)	7 (13.7%)	0.96
E1	19(63.3%)	30 (58.8%)	0.69
E2	6 (20.0%)	10 (19.6%)	0.97
E3	1 (3.3%)	3 (5.9%)	1.00
M0	0 (0.0%)	33 (64.7%)	<0.001
M1	1 (3.3%)	6 (11.8%)	0.25
M2	12 (40.0%)	6 (11.8%)	<0.001
M3	17 (56.7%)	6(11.8%)	<0.001

DTA, descending thoracic aorta; E1, entry was in the ascending aorta; E2, entry was in the arch; E3, entry was in the descending aorta; EM Score, E0, no entry; M0 if malperfusion was absent; M1, if coronary arteries were malperfusion; M2, if supra-aortic vessels were malperfusion; and 3, if visceral/renal and/or a lower extremity was affected. Plus (+) was added if malperfusion was clinically present and minus (-) if it was a radiological finding.
Data presented as mean ± standard deviation or *n* (%).

was instituted. The patients were cooled to 22 to 28°C tympanic temperature, and cardioplegic arrest was induced by antegrade and/or retrograde infusion of Bretschneider's cardioplegia via the coronary sinus. The ascending aorta and hemiarch, if necessary, were resected, and the aortic root was reconstructed with the aid of gelatin-resorcinol-formaldehyde-glutaraldehyde (GRF) glue, whenever possible. The ascending aorta was replaced by an appropriately sized Dacron tube, leaving the distal graft anastomosis to be done. Deep hypothermic circulatory arrest (DHCA) with continuous unilateral or bilateral antegrade cerebral perfusion was then initiated. In the group 1 patients, a percutaneous endovascular covered stent was placed in the proximal DTA under direct vision utilizing the already inserted guide wire. Conform TAG and Gore TAG (W.L. Gore & Assoc., Flagstaff, Arizona, United States), Navion (Medtronic, Minneapolis, Minnesota, United States), Zenith Diss and Zenith TX2 (Cook Inc, Bloomington, Indiana, United States) stents were used according to availability. An oversizing of 10 to 15% was aspired. The target landing zone for TEVAR was zone 2 or 3 according to the anatomical findings and the surgeon's discretion.[4] Basically, the offspring of the left subclavian artery was covered if the situs was very deep and aortic suturing too cumbersome, whereas the left subclavian artery was not closed. In case of overstenting of the left subclavian artery, later revascularization of the former was guided only by a clinical need due to obvious malperfusion of the left arm. In both groups, the remaining false lumen within the aortic arch was additionally treated with GRF glue, and the distal anastomosis with the glued native aorta finally completed.

Follow-Up

Follow-up data were obtained through repetitive postoperative outpatient visits and serial visits in our institution. Clinical data including information on quality of life and causes of death were also obtained from the respective family doctor.

Study Approval

The study was approved by the institutional review board of the University Medical Center of Regensburg, Germany (approval number 21–2325–104). Written informed consent was waived based on the retrospective nature of the study.

Statistical Analysis

Statistical analysis was performed with SPSS version 25.0 (IBM SPSS Statistics, United States, IBM Corp, Armonk, NY). Continuous variables are presented as mean (standard deviation) or median with min–max range depending on the underlying distribution; categorical data are reported as absolute and relative frequencies. The clinical preoperative parameters of group 1 and group 2 were not significantly different, that is, the two groups were appropriately matched and met the statistical requirements. For long-term survival, a Kaplan–Meier curve was developed. *p*-Values <0.05 were considered statistically significant. The logistic regression was used to estimate the independent odds ratios of factors related to in-hospital mortality.

Results

Demographic Data

Demographic data and putative risk factors were similar in both groups, that is, there were no significant differences between the two groups in terms of age, comorbidities, and clinical status. GERAADA score was comparable in both groups (group 1 vs. group 2: $31.6 \pm 8.8\%$ vs. $28.9 \pm 17.1\%$, $p = 0.43$). With regard to the Penn classification, the distribution of patients was mixed. While class Aa (absence of branch vessel malperfusion or circulatory collapse) was the dominant finding in group 2 (33 patients, 64.7%), class Ab (branch vessel malperfusion with localized organ ischemia) and class Abc (both branch vessel malperfusion and circulatory collapse) were seen more often in group 1 (16 patients/53.3% vs. 10 patients/19.6% and 12 patients/40% vs. 4 patients/7.8%) (►**Tables 1** and **2**).

The dissection entry was located in the ascending aorta in most patients (group 1 vs. 2: 63.3 vs. 58.8%), whereas an entry in the proximal aortic arch was seen in 20 and 19.6%, respectively. An entry in the descending aorta was noted in 3.3% and 5.9%, whereas no entry was identifiable in 13.3 and 13.7% of patients in groups 1 and 2.

All patients in group 1 presented with malperfusion, while malperfusion was absent in 64.7% of cases in group 2 ($p < 0.001$). In group 1, supra-aortic malperfusion was present in 40%, and visceral or iliac malperfusion seen in 56.7% of patients; both incidences were less than 12% in group 2 ($p < 0.001$). Symptomatic coronary malperfusion was infrequent (►**Table 3**).

Surgical Procedure

Isolated ascending aortic replacement, hemiarch, and aortic root remodeling were performed in 46.7, 36.7, and 16.5% of patients in group 1 and 49.0, 43.1, and 9.8% of patients in group 2. Bentall's procedure and additional coronary artery bypass grafting were performed in 6.6 and 3.3% of patients in group 1, and 9.8 and 11.8% of patients in group 2. The extracorporeal perfusion was mostly achieved via cannulation of the right subclavian artery (70.0% of patients in group 1 and 53.0% of patients in group 2), whereas femoral cannulation and direct aortic cannulation were preferred in 16.7 and 13.3% in group 1 and 37.0 and 10% in group 2. Intervals of DHCA time were comparable in both treatment groups too (group 1 vs. group 2: 48.8 ± 17.1 vs. 47.3 ± 18.8 min, $p = 0.73$). Likewise, bypass time (192.5 ± 52.1 vs. 196.2 ± 76.3 min, $p = 0.82$), aortic clamp time (98.0 ± 25.1 vs. 105.9 ± 38.7 min, $p = 0.32$), and nadir of tympanic temperature (23.7 ± 2.6 vs. 23.0 ± 3.1°C, $p = 0.28$) were similar (►**Table 4**).

Stent Grafts

Conform TAG stents were used in 20 (66.6%) patients, Gore TAG in 5 (16.7%) patients, Navion in 2 (6.6%) patients, Zenith Diss in 2 (6.6%) patients, and Zenith TX2 in 1(3.3%) patient. The median proximal and distal stent diameter were 28.7 and 28 mm, respectively. The median treatment length was 127 mm. Stent elongation was performed in 4 (13.3%) patients (►**Table 5**).

Outcome

Overall, in-hospital mortality rate was 25.9%, including 4 patients in group 1 and 17 patients in group 2 (13.3 vs. 33.3%, $p = 0.04$) (►**Table 6**).

Postoperative visceral malperfusion developed only in group 2 patients and thus was significantly higher in as in the group 1 (0 vs. 15.7%, $p = 0.02$). Five patients suffered acute intestinal ischemia, one patient had ongoing acute liver ischemia after surgery, and two patients developed liver ischemia with a transaminase rise 3 weeks later.

Table 4 Surgical procedures

	Hybrid ($n=30$) (group 1)	Standard ($n=51$) (group 2)	*p*-Value
Extent of aortic replacement			
Ascending aorta (%)	14(46.7%)	25(49.0%)	0.70
Ascending aorta+ root (%)	2(6.7%)	5(9.8%)	1.00
Ascending aorta+ hemiarch (%)	14(46.7%)	22(43.1%)	0.76
Associated procedures (%)			
AVR (%)	4(13.3%)	1(1.2%)	0.07
Bentall operation (%)	2(6.6%)	5(9.8%)	1.00
Coronary arteries compromised with CABG (%)	1(3.3%)	6(11.7%)	0.23
Carotid bypass (%)	8(23.3%)	7(13.7%)	0.23
Arterial cannulation:			
Right subclavian artery	21(70.0%)	27(52.9%)	0.13
Femoral artery	5(16.7%)	19(37.2%)	0.05
Ascending aorta	4(13.3%)	5(9.8%)	0.63
ECC time (min)	192.5 ± 52.1	196.2 ± 76.3	0.82
Cross-clamp time (min)	98.0 ± 25.1	105.9 ± 38.7	0.32
DHCA time (min)	48.8 ± 17.1	47.3 ± 18.8	0.73
SCP duration (min)	47.1 ± 28.1	40.4 ± 20.6	0.23
Hypothermia temperature (°C)	23.7 ± 2.6	23.0 ± 3.1	0.28
Transfusion intraoperative (red blood cells, mL)	934.3 ± 660.7	993.7 ± 738.2	0.76

Abbreviations: AVR, aortic valve replacement; CABG, coronary artery bypass grafting; DHCA, deep hypothermic circulatory arrest; ECC, extracorporeal circulation; SCP, Selective cerebral perfusion.
Data presented as mean ± standard deviation or *n* (%).

Table 5 Stent graft systems

	Hybrid ($n=30$)
Device type	
Zenith Tx2, *n* (%)	1(3.3%)
Zenith Diss, *n* (%)	2(6.6%)
Navion, *n* (%)	2(6.6%)
Gore TAG, *n* (%)	5(16.7%)
Conform TAG, *n* (%)	20(66.6%)
Proximal oversizing diameter, mm	28.7(22–34)
Distal oversizing diameter, mm	28(22–36)
Treatment length, mm	127(90–200)
Elongation, *n* (%)	4(13.3%)
Zone 3 or above, *n* (%)	30(100%)

Data presented as median with min–max range or *n* (%).

Moreover, patients of group 2 suffered more low cardiac output failure with a need of extracorporeal membrane oxygenation (ECMO) support (3.3 vs. 19.6%, $p=0.04$). While three patients in group 2 underwent ECMO placement before surgery and remained on support postoperatively, another seven patients required ECMO support after surgery as compared with only 1 patient in group 1.

The acute kidney injury rate was comparable in both groups (23.3 vs. 43.1%, $p=0.11$). New postoperative stroke was similar in both groups too (26.7 vs. 25.5%, $p=1.00$) (►**Table 6**).

At a mean follow-up of 32 months, late mortality was 2 out of 26 for group 1 versus 6 out of 32 for group 2. One-year, 2-year, and 3-year survival were 83.3, 83.3, and 62.5% in group 1, and 58.7, 58.7, and 52.6% ($p=0.05$) in group 2 (►**Fig. 2**). At the latest follow-up, one (3.3%) and two (6.7%) patients in group 1 required secondary endovascular stents and surgical aortic reintervention versus four (7.8%) and one (2.0%) patients in group 2 ($p=0.65$; $p=0.55$) (►**Table 7**).

At logistic regression analyses identified four significant prognostic factors for in-hospital mortality: body mass index, lactate, delayed sternum closure, and visceral malperfusion.

Discussion

Aortic dissection remains one of the most lethal cardiovascular diseases. A detrimental complication is end-organ malperfusion, which occurs in approximately one-third of patients.[5,6] Surgery for acute aortic dissection should consider a risk-adjusted surgical strategy during the emergency situation as well as provide the patient with the best long-term result, which is possible under these conditions. However, controversy remains over aortic repair versus with

Table 6 Postoperative data

	Hybrid ($n = 30$) (group 1)	Standard ($n = 51$) (group 2)	*p*-Value
In-hospital mortality, *n* (%)	4(13.3%)	17(33.3%)	0.04
Delayed sternum closure, *n* (%)	3(10%)	6(11.8%)	0.80
Reoperation for bleeding, *n* (%)	6(20%)	10(19.6%)	0.96
New postoperative stroke, *n* (%)	8(26.7%)	13(25.5%)	1.00
Acute kidney injury (transient RRT), *n* (%)	7(23.3%)	22(43.1%)	0.11
Pneumonia, *n* (%)	6(20.0%)	10(19.6%)	1.00
Visceral malperfusion, *n* (%)	0(0.0%)	8(15.7%)	0.02
Acute intestine ischemia	0(0.0%)	5(9.8%)	–
Acute liver ischemia	0(0.0%)	1(2.0%)	–
Later liver ischemia	0(0.0%)	2(4.0%)	–
Low cardiac output with ECMO, *n* (%)[a]	1(3.3%)	10(19.6%)	0.04
Preoperative	0(0.0%)	3(5.9%)	–
Intraoperative	1(3.3%)	7(13.7%)	–
ICU stay (d)	10.2 ± 10.6	7.0 ± 6.1	0.09
Hospital stay (d)	19.9 ± 12.9	13.8 ± 9.4	0.02

Abbreviations: ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; RRT, renal replacement therapy.
Data presented as mean ± standard deviation or *n* (%).
[a]ECMO was used in 3 patients in group 2 preoperatively.

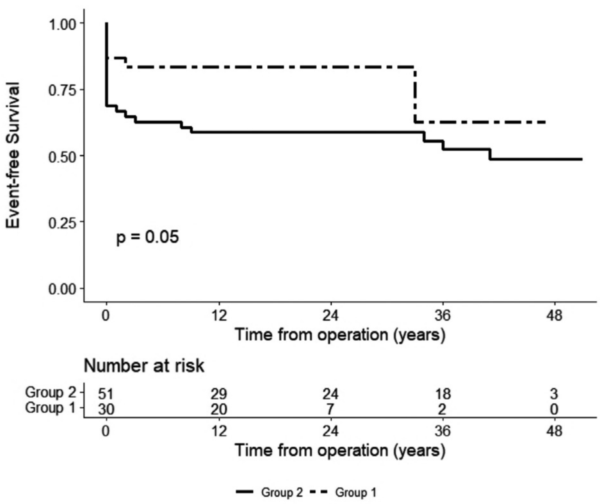

Fig. 2 Postoperative survival and follow-up data, Kaplan–Meier survival estimates and patients at risk.

Table 7 Follow-up survival and secondary interventions

	Hybrid ($n = 26$) (group 1)	Standard ($n = 34$) (group 2)	*p*-Value
Follow-up (mo)	26.0 ± 11.8	31.0 ± 15.0	0.64
Mortality, *n* (%)	2(7.7%)	6(18.8%)	0.05
Endovascular stent	1(3.3%)	4(7.8%)	0.65
Surgery	2(6.7%)	1(2.0%)	0.55

Data presented as mean ± standard deviation or *n* (%).

malperfusion-directed interventions. One of the most entrenched principles of aortic dissection surgery is to perform the simplest and shortest operation that will have the least adverse impact on the patient. Groups favoring immediate aortic repair have demonstrated resolution of malperfusion syndrome with aortic repair alone in up to 75 to 80% of patients,[7–9] while repairing the dissected DTA only when postoperative clinical complications occur. The problem with this approach is that most of the patients are postoperatively left with residual dissection in the aortic arch and descending aorta. Floating membranes, however, may cause vessel occlusion, which may ensue disastrous complications. There is some suggestion that mesenteric revascularization prior to definitive aortic repair may improve outcome.[10–12] Our group followed that strategy for many years until we introduced the hybrid approach to reduce complications related to the residual dissection in the DTA.

Our data show that differences in the hospital mortality rate and the follow-up at mid-term survival between group 1 and group 2 (13.3 vs. 33.3%, $p = 0.04$, 62.5 vs. 52.6%, $p = 0.05$) were statistically significant. Furthermore, the hybrid technique (group 1) reduced the incidence of postoperative visceral malperfusion and low cardiac output failure with ECMO support rate (0 vs. 15.7%, $p = 0.02$, 3.3 vs. 19.6%, $p = 0.04$). The Penn classification of the patient groups clearly underlines our findings. More than half of the group 1 patients suffered branch vessel malperfusion with localized organ ischemia with no postoperative malperfusion, whereas about two-thirds of patients in group 2 had no malperfusion, but obviously a high incidence of malperfusion after surgery. Hence, the presented results demonstrate that supplemented TEVAR of the DAT significantly enhances distal branch vessel flow and prevents malperfusion, and also reduces periprocedural morbidity and mortality rates.

The benefit of TEVAR can also derived from patients with type B aortic dissection. Numerous clinical data report a relevant fraction of early failures following medical treatment (12.4–58%) with a need of early intervention, such as open surgery or TEVAR procedures.[13,14] Thus, there is a significant proportion of patients with uncomplicated type B dissection who gain a clear survival benefit when undergoing stent placement on time.[13] Keeping the aforementioned arguments in mind, we attempted to combine the straightforward strategy of ascending/proximal hemiarch replacement with a simultaneous treatment of the descending aorta in TAAD patients. Several groups have previously conducted studies on this concept. In 2013, the group of Bavaria et al demonstrated the feasibility of a hybrid approach in an elective patient cohort with aortic arch aneurysms. This study analyzed two separate strategies (with/without ascending aorta replacement and subsequent TEVAR of the arch) and derived promising results with low in-hospital mortality (8%) and low rates of neurologic events (paraplegia 5%, stroke 8%). Despite relevant long-term mortality (all causes, 52% after 5 years), aortic reintervention rate (2.7%) was low and endoleaks were not seen during follow-up.[15] In 2017, Matt et al compared a cohort of patients with ascending/hemiarch replacement with a cohort with additional antegrade stent graft placement after type A aortic dissection also conveying promising results. Even though circulatory arrest intervals were slightly longer in case of stent graft placement, rates of stroke, paraplegia, visceral ischemia as well as mortality were significantly lower in the TEVAR group.[16] Likewise, operative strategies of extended arch repair including antegrade TEVAR of the descending aorta report effective closure of descending false lumen and offer significantly lower rates of patent false lumen in the distal descending aorta compared with “conventional” extended arch repair including antegrade TEVAR of the descending aorta report effective closure of descending false lumen and offer significantly lower rates of patent false lumen in the distal descending aorta compared with “conventional” extended arch repair without use of stents.[17,18] In this regard, the Ascyrus Medical Dissection Stent Hybrid Prosthesis (AMDS) stent may also have great potential for the future.[19]

Interestingly, we noticed a 25% higher in-hospital mortality rate as compared with other studies, which is most likely a consequence of multiple factors.[20,21] One explanation could be that the local population has a high-risk profile and usually sees a physician rather late. Also, the preoperative resuscitation rate of 8.6% (3.3% in group 1 and 11.7% in group 2) was extraordinarily high.[22,23] Moreover, 3.7% of our patients required preoperative ECMO support, which corroborates the assumption of a higher operative risk and worse prognosis in our analysis.

In our experience, the additional retrograde TEVAR of the DTA did not increase the cross-clamp time and the DHCA time (►**Table 5**) and did not contribute to higher perioperative stroke rate (►**Table 6**). Furthermore, we found that retrograde passage of a guide wire using interventional techniques enabled accurate placement of the stent in the true lumen.

Despite complete repair with the FET has been nominated the best surgical repair technique for TAAD, FET is a time consuming and complex procedure that cannot be performed on every patient.[24,25] In an analysis of patients from our center operated on for TAADs with FET surgery, we achieved in 82% a proximal closure of the false lumen (data not displayed). Likewise, other studies on postoperative surveillance of the false lumen report clear benefits of extended repair leading to lower rates of patent false lumen in the descending aorta, but not complete obliteration in all aortic sections.[5,22,25] However, this advantage of FET surgery did not translate into a significant lower requirement of reintervention. Five-year freedom from thoracic events or thoracic reintervention is reported to ~80% after extended as well as limited repair. Our own institutional experience for secondary interventions after isolated ascending aortic repair comprises a 10% rate (23 from 228 patients) of late complications after initial emergency surgery for type A dissection with a mean interval of 72 months to secondary surgery. Most common reasons for reintervention are progressive growth of the false lumen or suture line dehiscence.[26] Therefore, we consider the hybrid arch preserving approach with limited ascending /hemiarch repair combined with descending stent placement as a promising alternative strategy in TAAD patients with an unaffected aortic arch. Our results indicate that hybrid repair is a safe procedure with satisfactory in-hospital mortality and complication rates.

Study Limitations

There are few important limitations of the study. A prospective randomized study design would have been superior, as it would have excluded a surgeon bias. Adopting a strict operative protocol would have enhanced comparability of the groups, and a larger sample size of the study cohort would have increased the statistical power.

Conclusions

Hybrid surgical therapy is a feasible method of treatment for patients with TAAD. In survivors, it improves perioperative outcome and mid-term survival.

Abbreviations

CT computed tomography
TAAD type A acute aortic dissection
DTA descending thoracic aorta
ECMO extracorporeal membrane oxygenation
FET frozen elephant trunk
GERAADA The German Registry for Type A Dissection
PAU penetrating aortic ulcer
TEVAR thoracic endovascular aortic repair
TEE transesophageal echocardiography

Authors' Contributions

Jing Li was involved in conceptualization, data curation, formal analysis, investigation, project administration, methodology, and writing of the original draft. Andreas Stadlbauer, Armando Terrazas, Bernhard Floerchinger, Karin Pfister, Marcus Creutzenberg, and Kyriakos Oikonomou have written, reviewed and edited the manuscript. Christof Schmid was involved in conceptualization and writing and editing of the original draft. Leopold Rupprecht was also involved in writing and editing of the original draft.

Conflict of Interest

None declared.

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