Single stem visceral debranching for complex aortic disease

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What this paper adds

Treatment of complex aortic diseases including thoracoabdominal aortic aneurysms and aortic dissection is highly challenging. Hybrid repair may be useful in some situations wherein anatomy, the need of emergent repair or patient comorbidities preclude the use of total endovascular or direct open reconstruction. This paper details an original hybrid repair in which a single branch is used to reroute all visceral vessels.

Abstract:

Objective: Hybrid treatment of complex aortic disease has been described with various techniques of retrograde visceral bypass. The use of a single branch to revascularize all renal and visceral vessels may be less cumbersome than multiple synthetic branches and may seems to be efficient in terms of patency.

Methods: We retrospectively included 15 patients between 2013 and 2021. Indication was aortic dissection (AD) (type A, acute or chronic type B), thoracoabdominal aortic aneurysms (TAA), visceral occlusive disease. Surgery consisted in median laparotomy, visceral vessel debranching from native aorta or from an aortic graft. In case of AD, surgical fenestration was performed. Additional TEVAR completed the treatment when indicated, during the same procedure or later on.

Results: Mean age was 60 years. 9 (60%) patients were treated for AD, 3 (20%) for TAA, 3 (20%) for occlusive disease. A total of 65 target vessels were debranched through the single stem retrograde vascular graft (SSRVG) technique. Aortic surgical fenestrations were performed in 8 cases and TEVAR in 4 cases. In the postoperative course, 3 TAA patients died, 7 patients developed renal insufficiency (47%), 4 patients presented pneumonia (27%) and 3 colonic ischemia (20%). After a mean follow up of 21 months, all vessels (but 2 IMAs) were patent and no endoleak was noted.

Conclusion: SSRVG technique offers a feasible and safe solution in various complex aortic diseases. The use of a single graft makes the technique straightforward by reducing the volume of multiple branch assembly in the retroperitoneal space with satisfying patency rates Further studies with larger patient sample size and longer follow up are needed to elucidated the efficacy and durability of the technique.

Keywords: Hybrid surgery, visceral vessel debranching, TEVAR, aortic dissection, thoracoabdominal aortic aneurysm

INTRODUCTION

Treatment of complex aortic disease such as thoracoabdominal aortic aneurysm (TAA) or aortic dissection (AD) is a challenge for both patients and surgeons and the best therapeutic option is still subject to controversies. Open repair remains a challenge and even with improvements like distal perfusion and spinal protection, only fit patients with limited comorbid-

ities can undergo such invasive procedure. More and more TAA and AD cases become amenable to a totally endovascular repair due to constant progress of devices and skills[1,2]. Nonetheless, uncertainty of long-term results, limits in technical feasibility and availability of devices still restrict its wide applicability. As a result, there are situations wherein total open surgery is considered a great surgical "insult" and total endovascular repair is not an option. For those patients can hybrid repair, combining both open and endovascular techniques, offer an appealing alternative. Several reports been published since the nineties underlining the role of debranching of the supra aortic trunks and a tubular stent-graft on the treatment of lesions of the aortic arch using[3,4]. The same strategy may be used for the treatment of abdominal or thoracoabdominal lesions. Visceral vessels are bypassed first, paving the way for a synchronous or metachronous exclusion of the aortic lesion by a stent-graft[5,6]. The stemming of visceral debranching from the infrarenal aorta avoids the need for proximal aortic

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clamping, thoracotomy, and limits the duration of and end-organ ischemia. However various techniques of debranching stemming either from the infrarenal aorta or the iliac arteries have been described, they did not reach the same level of popularity as that of arch debranching[5]. This lack of success may be due to several reasons for technical failure including a poor donor artery, the use of multiple grafts in an "octopus" configuration and suboptimal choice of the best tunnels for retrograde visceral grafts. With the disappearing of the skills in open abdominal vascular surgery among (young) vascular surgeons we have found useful to herein report our original technique of abdominal visceral debranching using a single stem retrograde visceral graft (SSRVG). Indications, principles, technical details and outcomes of patients are provided.

METHODS

Patients et indication

This is a single center retrospective study. Between 2013 and 2019, 168 patients who were treated for a visceral artery surgery were identified. Patients selection used the French common classification of medical procedure (CCAM) with a specific code, namely EDKA003: «remplacement d'une artère digestive par laparotomie». Decision to perform a hybrid visceral debranching rather than a total open or endovascular treatment resulted from a multidisciplinary consensus. All medical records were reviewed and patients treated with this particular single branch retrograde bypass technique were identified. A total of 15 patients were identified. Data were collected on an Excel spread-sheet on a password-protected computer, including demographics and clinical characteristics, type of the disease (TAA, AD, occlusive disease), emergency or elective cases, symptoms at presentation, preoperative workup, intraoperative data and postoperative course. Target vessel patency was evaluated on most recent postoperative CT scan. Given the nature of the study, a waiver was given by the Sorbonne University review board regarding informed consent of patients.

APPROACH

Patients are operated on under general anesthesia in a supine position with mild lordosis. A transperitoneal median laparotomy is performed in all cases. The retroperitoneum is firstly entered lateral to the duodenojejunal junction after section of the lesser mesenteric vein. The left renal vein (LRV) is mobilized using a large rubber tape, permitting exposure of the abdominal aorta proximal and distal from the renal ostia up to the iliac arteries. The right and left renal arteries (LRA and RRA) and inferior mesenteric artery (IMA) are then dissected distal to any ostial lesion and taped. The superior mesenteric artery (SMA) is exposed through a left lateral approach from its ostium to distal to any ostial lesion. Exposure of the SMA can be demanding while expose of its ostial segment deals with the felting of mesenteric plexus. Approach of the intramesenteric segment necessitates the section of the Treitz ligament. To get a full mobilization of the SMA one or both pancreaticoduodenal branches must be ligated. The
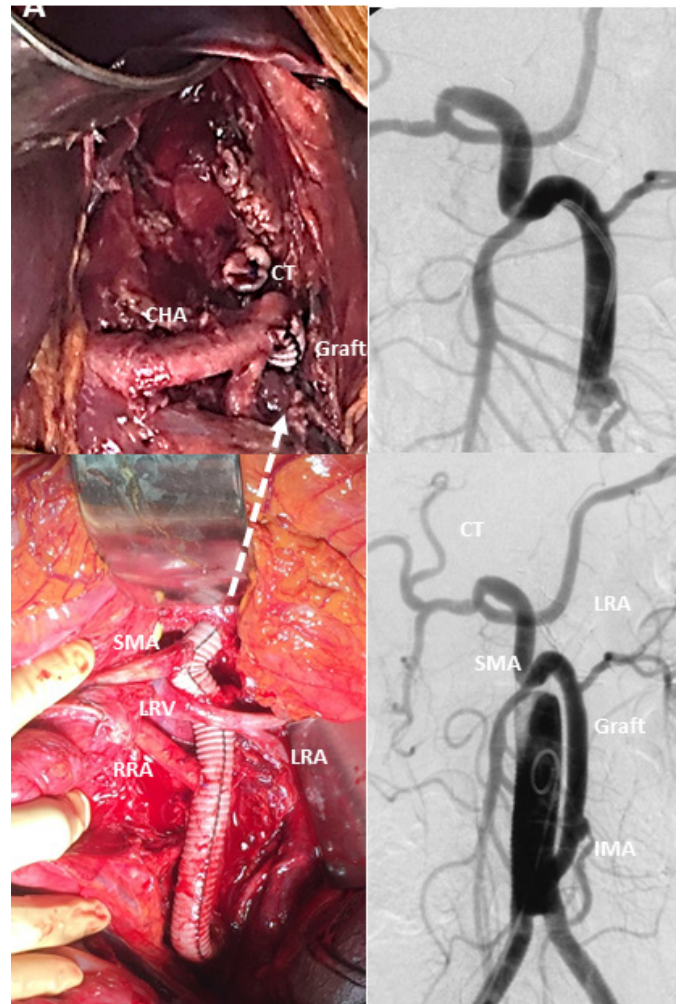

Figure 1: Intraoperative picture illustrating the single branch montage. On the left panel (A), the Dacron graft starts from the main graft (MG), receives the RRA via a small Hybrid Maquet Fusion 7mm diameter graft (so-called « cactus »), is routed behind the LRV and receives on its left the LRA and on its right the SMA. The graft is tuneled retropancreatic (white dotted arrow) up to the CT (middle panel) where an end-to-end anastomosis was performed (CT is ligated, CHA: common hepatic artery). The right panel (B) shows a postoperative arteriography of another patient. Image in the lower right corner is the overall aspect and image in the upper right corner is a magnification of RVG.

celiac trunk (CT) is approached through a section of the lesser omentum. After the taping of the common hepatic and splenic arteries, the coronary gastric artery is ligated and the trunk is dissected from the celiac plexus, through the arcuate ligament and if necessary, the right crux of the diaphragm. A retropancreatic tunnel is quite easy to create at this step from the left lateral side of the suprarenal aorta to the left lateral side of the celiac trunk by severing the left crux of the diaphragm. In cases of increased fragility of aortic wall (i.g. aortic dissection) a too proximal approach of visceral arteries must be avoided.

Choice of the donor artery

Many failures of retrograde debranching derive from a bad

choice for the donor artery like a diseased iliac artery. Our, therefore, best choice is an aorto-aortic, aorto-(bi)iliac or aorto-(bi)femoral prosthetic graft. In AD cases, such a choice offers the opportunity of creating an aortic fenestration.

Preparation of the graft

A custom graft is created by assembling a main graft (MG) with a retrograde visceral graft (RVG). The choice for the MG can be any polyester or PTFE graft but for bifurcations, we prefer asymmetric bifurcations in the aorto(bi) iliac setting (Albograft 18x10mm, 16x9mm or 14x8 Lemaitre Burlington Massachusetts USA). For the RVG, some resistance to kinking is needed, therefore a polyester- coated PTFE graft (Fusion 10mm or 8mm, Maquet Getinge Merrimack, USA) is chosen. An elliptic hole is created on the left lateral side of the body of the MG using a cautery. The hole is positioned two centimeters above the aortic bifurcation or the bifurcation of the graft in order to maximize the length of the MG proximal to the anastomosis with the RVG and subsequently securing an adequate distal landing zone for the thoracic stentgraft. A beveled retrograde anastomosis is then made using a running polypropylene 5/0 suture end of the RVG to side of the MG.

Proximal anastomosis of the main graft

Systemic heparin (100 UI/Kg) is given prior to clamping. Sites of clamping and of anastomosis are carefully planned on preoperative imaging and by intraoperative palpation. Attempts at clamping or suturing diseased, thrombosed or calcified aortic segments must be avoided. Typically, the clamp is applied one centimeter caudal to the most distally arising renal artery. Although our technique is compatible with a side to end anastomosis, we prefer an end to end anastomosis. The infrarenal aorta is then sectioned transversally one to two centimeters distal to the clamp. The proximal aortic section is then anastomosed to the MG end to end using a running 4/0 or 3/0 polypropylene suture. If the MG is bifurcated, it is important to position its bifurcation approximately at the same level as that of the native aortic bifurcation. Doing so leaves a long possible prosthetic landing zone proximal to the arising of the RVG.

Proximal anastomosis whenever dealing with an aortic dissection

When dealing with AD, even if all visceral arteries are repaired using the RVG, there is a major concern regarding the flow to upper lumbar or intercostal arteries, which can be impaired with an eventual spinal injury. In these cases, open fenestration is a solution to preserve perfusion to both lumens. It is then important to leave two to three centimeters between the level of clamping and the proximal anastomosis. Dissected tissues are particularly fragile. Therefore, clamping must be gentle and progressive, under moderate hypotension and using clamps with rubber-protected jaws. After clamping, the proximal section of the aorta is exposed using "stay sutures", allowing for a neat resection of the flap flush to the aortic wall and to the clamp. It is in those cases when it may be useful to

clamp the suprarenal aorta in order to ease the resection of the flap. The proximal anastomosis is then sutured, preferably using a running polypropylene Teflon-felt-reinforced running suture.

Distal anastomosis to the aortic bifurcation or distal anastomoses to iliac or femoral arteries is/are then made to allow flow to the lower limbs and pelvis and provide optimal tension of the MG.

Visceral debranching and repair

Visceral debranching and repair is then performed in a sequential caudal to cephalad order: IMA if considered necessary, most distal renal artery, most proximal renal artery, SMA and CT. Except for the IMA, every visceral artery to be treated is ligated or clipped at its ostium and sectioned at its most healthy level. The distal stump is beveled if smaller than 4mm or to give a good direction and transposed side to end to a hole punched on the RVG using a running suture of 5/0 or 6/0 polypropylene. If the IMA is treated, it is transposed via a small Carrel button of adjacent aortic wall. The best anastomotic position for the IMA is on the left lateral aspect of RVG one centimeter above its anastomosis with the MG. The best position for the renal arteries is the ipsilateral aspect of the RVG behind the taped LRV. The RVG must therefore be tunneled behind the LRV. Anastomosis to the LRA is in general easier than to the RRA. For the RRA, especially if its level of arising from the aorta is close to the ostium of the SMA, it is practical to sever firstly the SMA to facilitate the access to the RRA. All anastomoses to the visceral arteries must be performed without tension. For this reason, it is important to free a sufficient length of the artery to allow for its coming to the RVG without tension. If this is not possible due to anatomical or pathological reasons, it is advisable to interpose a short segment of prosthetic graft of an adapted size between the target artery and the RVG. This is particularly important for the SMA, which is optimally transposed on the frontal aspect of the RVG, either caudal or well proximal of the crossing of the RVG by the LRV, in order to avoid the creation of a nutcracker syndrome. The RVG is then tunneled behind the pancreas and anastomosed end to end to the distal section of the CT. Flow to every target artery is then checked using a continuous sterile doppler probe. In fat or normally adipose patients After completion of the visceral debranching the RVG can be covered using the left mesocolon and the pre-aortic tissue, whereas a trans-mesocolic omentoplasty can often be necessary to secure the graft.

Postoperative course and follow up

All patients were admitted in ICU during the first postoperative days then cleared to the ward in the absence of a complication. Major neurological, respiratory, renal, cardiac and digestive adverse events occurring until discharge were collected. Patients had duplex and CTA before discharge. After discharge, patients were followed up at 1 month, 6 months and yearly thereafter, clinically, with duplex or CTA.

Table 1: Demographic and comorbidities

Patients (N=19)	N (%) or mean±SD
Age	55±34y
Male	11(68%)
Women	5(32%)
BMI	24.7±5.1
Comorbidities	
Diabetes	1 (6%)
Hypercholesterolemia	6 (37%)
Smoking	3 (18%)
Renal insufficiency	1 (6%)
Hypertension	11 (69%)
Coronary artery disease (n, %)	6 (37%)
Peripheral artery disease (n, %)	4 (25%)
ASA, median	2 (1-3)

RESULTS

Intraoperative

From January 2015 to December 2019, fifteen patients were treated using this technique.

Mean age was 60 years old [38-78]. Other demographics and cardiovascular risk factors are given in Table I. Table II details indications and outcomes. The indication was an AD in 9 (60%) cases, a TAA in 3 (20%) cases, and mesenteric occlusive disease in 3 cases (20%). Nine patients had prior vascular interventions, two of whom including abdominal aorta replacement, providing a suitable MG at the time of debranching.

A total of 65 target arteries were debranched and repaired through a single-stemmed-RVG: 5 target arteries were treated in 8 (53%) cases, 4 in 4 (27%) cases and 3 in three (20%) cases. Aortic fenestration was performed in 8 (53%) cases. Four (27%) procedures included the insertion of a tubular aortic stent-graft, two in a single-stage operation and two in a second procedure. Mean operative time was 354±72 minutes.

Out of the four patients who received TEVAR, 3 had spinal fluid drainage. One, who was operated on an emergency setting and was under 2 antiplatelet agents, had no drainage and experienced secondary paraplegia.

Treated pathologies

Type A aortic dissection: patients #1 and 2

These two patients had both open repair of their AD (Bentall procedure). The first patient developed a type 1 dissecting TAA during follow up. The second patient presented later on with a 45mm left common iliac artery dissecting aneurysm and all of the visceral arteries were dissected. His descending thoracic aorta was 42mm in diameter.

Chronic type B aortic dissection: patients #3-6

These patients were previously treated medically (#5), with TEVAR (#4) or open surgery (#3,6). Later on, they developed various degree of visceral/ renal malperfusion along with enlargement of their descending thoracic aorta or abdominal aorta requiring aneurysm exclusion and visceral/ renal vessels revascularization.

Acute type B aortic dissection: patients #7-9

Indication was persistent hypertension, visceral/ renal malperfusion and/ or rapid enlargement of their aorta.

Thoraco-abdominal aortic aneurysm: patients #10-12

These patients had TAA and were deemed unfit for total open repair, not amenable for total endovascular repair for anatomic reasons, or were treated in emergency.

Occlusive disease: patients #13-15

Patients in this group presented with chronic mesenteric ischemia and aorto-iliac occlusive disease and retrograde bypass was favored over antegrade reconstruction.

Postoperative course

There were three (20%) postoperative deaths recorded. Two patients succumbed on the 2nd and 45th day due to multi-organ failure (MOF) whereas the third patient deceased on 51st postoperative day after discharge to a rehabilitation center due to aspiration associated pneumonia and respiratory failure. No death was related to RVG occlusion. Among survivors, acute renal insufficiency was the most frequent complication; 7 (47%) patients, two of which requiring temporary dialysis. There were four (27%) pneumonias and three (20%) cases of colonic ischemia, one requiring colectomy. One septicemia was treated with antibiotics. Overall two patients did not experience any complication, 7 patients experienced 1, 2 experienced 2, 1 experienced 3 and 1 experienced 5 complications (Table II).

Table 2: Preoperative, intraoperative and postoperative (immediate and during follow up) details of the patients. Indication for visceral debranching (VD), previous surgery, intraoperative and postoperative details are given. ARF: Acute renal failure. ARDS: Acute respiratory distress syndrome.

| 80	Sex, age	Initial disease	Indication of VD	Previous surgery	Technique	Debranched arteries	Postoperative period	ICU stay	Hospital stay	FU (days) Status	Target vessel occlusion / endoleaks
1	M, 34	Type A AD	Type 2 TAA	Bentall surgery	VD, TEVAR 2 months later	IMA, LRA, RRA, SMA, CT	ARF, no dialysis	8	26	1273 well	IMA/ No
2	M, 63	Type A AD	45mm left CIA aneurysm, visceral artery dissection.	Bentall surgery	VD + Surgical fenestration,	AMI, LRA, RRA, SMA, CT	Pneumonia, ARF- no dialysis Ischemic colitis medically treated	12	42	858 well	No/ NA
3	F, 69	Chronic Type B AD	Juxta-renal AAA, visceral artery dissection.	Type 1 TAA 6 years before	VD + Surgical fenestration	IMA, LRA, RRA, SMA, CT	Pneumonia	2	6	400, well	No/ NA
4	M, 57	Chronic type B AD	Persistent visceral/ renal malperfusion following TEVAR, Right kidney infarction, 50mm AAA aneurysm	TEVAR	VD + Surgical fenestration	IMA, LRA, SMA, CT	ARF, no dialysis	11	19	1465, well	IMA/ NA
5	M, 75	Chronic type B AD	Mesenteric ischemia + lower limb claudication	-	VD + Surgical fenestration	IMA, LRA, RRA, SMA, CT	ARF, temporary dialysis	12	20	1943, well	No/ NA
6	M, 69	Chronic type B AD	Extension of dissection to visceral artery, 40mm diameter DTA	Aortic arch surgery 7 years before	VD + Surgical fenestration	IMA, LRA, RRA, SMA, CT	Septicemia	8	22	827, well	No/ NA
7	M, 67	Acute type B AD	Hypertension (4 drugs) Visceral/ renal malperfusion	-	VD + Surgical fenestration + Aortic arch surgery (Thoraflex) 24 months later	IMA, LRA, RRA, SMA, CT	Uneventful	1	8	1310, well	No/ NA
8	M, 38	Acute type B AD	Hypertension (3 drugs) Visceral/ renal malperfusion	-	VD + Surgical fenestration	IMA, LRA, RRA, SMA, CT	Pneumonia	7	20	292, well	No/ NA
9	M, 75	Acute type B AD	Dissection down to SFA, 67mm diameter type 1 TAA	-	VD + Surgical fenestration + Aortic arch surgery (Thoraflex) 1.5 months later + TEVAR 6 months later	LRA, RRA, SMA, CT	Ichemic colitis (left colon resection), ARF no dialysis	10	80	194, well	No/ No
10	F, 77	Type 1 TAA Surgery delayed due to coronary stenting	Emergency (chest pain, left pleural effusion)	-	VD TEVAR during same procedure	LRA, RRA, SMA, CT	Pneumonia, secondary (day 3) paraplegia, MOF	45	45	45 Death	NA/ NA
11	M, 69	Type 3 TAA	Severe comorbidities, Kidney cancer (left nephrectomy)	AAA open repair, 8 years before	VD from previous aortic graft	RRA, SMA, CT	ARDS, Ischemic colitis, MOF, Death before second stage	2	2	2 Death	NA/ NA
12	M, 78	Type 2 TAA	60mm Visceral patch aneurysm	Open repair of type 2 TAA 8 years before	VD from previous aortic graft, TEVAR 14 days later	LRA, RRA, SMA, CT	ARF, no dialysis	24	31	51, Death (food swallowed the wrong way)	No/ No
13	F, 65	Occlusive disease	Chronic mesenteric ischemia and lower limb claudication	Iliac and SFA stenting	VD	IMA, SMA, CT	Uneventful	1	7	145, well	No/ NA
14	M, 71	Occlusive disease	Chronic mesenteric ischemia and lower limb claudication	Kissing Iliac senting CT stenting	Median laparotomy, aortobifemoral by-pass, visceral debranching	LRA, SMA, CT	Pneumonia, Acute renal In-sufficiency, ACS (stent), duodenal bleeding, confusion	26	47	85, well	No/ NA
15	F. 68	Occlusive disease	Chronic mesenteric ischemia and lower limb claudication	No	Median laparotomy, aortobifemoral by-pass, visceral debranching	IMA, LRA, RRA, SMA, CT	ARF, no dialysis Ischemic colitis (medical ttt)	4	8	523 Well (visceral herniation)	No/ NA
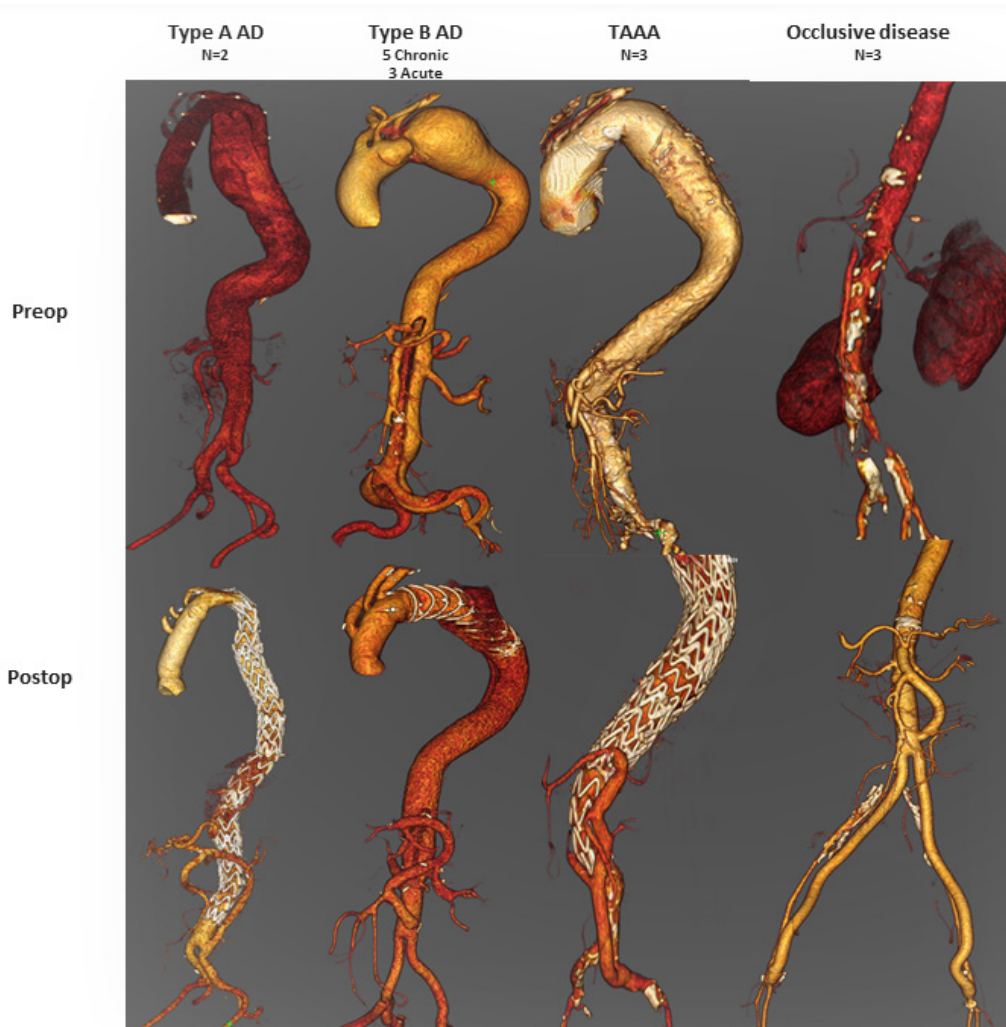
Figure 2: Representative preoperative and postoperative CT scan of the different categories of patients.

Follow-up

The mean ICU/ hospital stay was 11/ 25 days. Among the four patients with endograft, one had residual type 1B endoleak distal to his thoraflex arch hybrid prosthesis. This endoleak was sealed with TEVAR 6 months later. Over a mean follow-up of 21 months, no additional death was noted, all target vessels were patent except from two IMAs (97% of patency). One patient developed visceral herniation. The four patients received a stent-graft remained free from any endoleak. (Figure 2)

DISCUSSION

Technique

Single-stemmed RVG (SSRVG) is a safe and efficient method for abdominal debranching. All target vessels but two IMAs of our series remained patent to the last follow up. IMA is notoriously known to be provided with backflow from collaterals stemming from the SMA or the hypogastric arteries. We retrospectively believe that repair of the two occluded IMAs was probably redundant. To our knowledge, the use of a SSRVG to revascularize all four (LRA, RRA, SMA and CT) even five (IMA) visceral arteries is original. In the literature, visceral rerouting techniques include customized Y-grafts, reversed bifurcated grafts, trifurcated grafts or even four-vessel visceral debranching graft as previously described by others[5,7-11]. All these techniques inherit the disadvantages of the "octopus" technique: several retrograde small conduits with questionable hemodynamics, complex routing and a definite risk of visceral fistula formation. Our single-stemmed set-up has on the contrary the following advantages: There is only one healthy donor artery, only one proximal anastomosis between two prosthetic grafts and only one main conduit with a patency maintained by the united flow to all target vessels. The graft is short and large while optimizing its room in the abdomen and well-protected against a visceral fistula behind the LRV and the pancreas. We indeed had no visceral fistula in the series. Finally, after a learning curve, this technique is considered easier than the complex multiple-branches technique. All our major target vessels (IMA excluded) remained patent to the last follow-up, comparing favorably with patency rates ranging between 90-97% reported elsewhere[12,13,8]. To our opinion, this is the result of the hemodynamic optimization brought by the single-stem concept: a high flow in a large conduit. This provides our solution with the lowest possible hemodynamic impedance and

is supported by a recent computational fluid model work[14]. In this work, Yuan and coll. showed that, from a hemodynamic standpoint, the use of CIA rather than aorta for the inflow site, leads to a dramatic decrease in flow to the visceral organs. Moreover, their hemodynamic model favored the use of less branches to perfuse visceral organs. In our single stem technique, should moreover one target-vessel occlude, this would not impact the patency of the others. Although all our cases have been performed through a transperitoneal approach, the technique is feasible through a retroperitoneal approach. However, such a retroperitoneal approach limits the access to the distal SMA and the distal RRA, even in the pre-renal plane. Moreover, access to the SMA and the RRA through a retroperitoneal route necessitates a thorough and extensive mobilization of the visceral segment of the aorta which should be avoided in this cohort of patients considered for debranching.

Our mortality and morbidity rates are high underlining the severity of the treated disease and the comorbidities of the patients selected for debranching. Of note, the three deaths occurred in the TAA group of patients, who were clearly the most fragile and in one case operated on an emergency setting. Mortality rates range between 10% to 15%[12,13,5] in the literature, but is highly associated with patients comorbidity. However, we would like to underline the fact that none of our complications was due to occlusion of a target-vessel or the presented technique in general.

Despite limitations due to a small number of patients and its retrospective nature, the present work describes a promising technique of abdominal debranching. Comparison of debranching or hybrid surgery between open repair and totally endovascular alternatives is clearly outside of our focus. The high proportion of AD in this series shows the usefulness of our technique in this subgroup of complex aortic patients. Moreover, and as shown above, SSRVG and open aortic fenestration are highly compatible, offering an efficient solution in challenging cases.

Of course, our conclusions deserve confirmation among larger cohorts with a longer follow-up. They stress the importance of maintaining a high degree of open surgical competence among vascular surgeons, even in the endovascular era.

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