Complete renovisceral debranching and EVAR for thoracoabdominal aneurysm

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Abstract

Open graft repair of thoracoabdominal aortic aneurysms (TAAA) is an incredibly complex and challenging procedure with acceptable results achieved only by a few centers worldwide. Contemporary outcome analysis of TAAA repair performed in the United States showed greater operative mortality and morbidity rates than commonly reported. Moreover, a recent European long-term follow-up study showed that survival remains suboptimal, especially in the early years after TAAA repair. Complete renovisceral debranching combined with EVAR offers many advantages in regard to open surgical repair with comparable or better results, especially in the high-risk patient. Although this hybrid procedure will not replace open surgical repair, the latter will significantly decrease during the next decades, as very experienced surgeons will be lacking, due to the mainly endovascular generation of surgeons being educated nowadays. Similarly, the results of the hybrid TAAA repair will improve, as new techniques will eliminate most barriers still existing today.

Introduction

Open graft repair of thoracoabdominal aortic aneurysms (TAAA) is an incredibly complex and challenging procedure, which is probably surpassed only by very few surgical procedures. Despite this procedure has been introduced more than 50 years ago, acceptable results are achieved only by a few centers worldwide [1, 2]. Contemporary outcome analysis of TAAA repair performed in the United States showed greater operative mortality and morbidity rates than commonly reported [3]. This holds true for patients treated in European countries. Moreover, a recent European long-term follow-up study showed that survival remains suboptimal, especially in the early years after TAAA repair [4]. Overall, the attempts to reproduce the good results of some few centers of excellence mostly fail. In fact, these attempts do produce high mortality, morbidity and costs. Finally, it has to be stated that most patients presenting thoracoabdominal aortic aneurysm rupture who are treated by open graft repair do not survive [5]. Given the lack of significant improvement in TAAA graft repair over the last decades, new techniques of repair are needed. Complete endovascular TAAA repair is a quite appealing method, but remains from a technical point of view probably as challenging as an open graft repair procedure [6]. Besides that, this method requires specific skills and leads to high X-ray exposition. Moreover, fenestrated and/or branched devices have to be customized leading to significant time delay and high material costs. All these points might explain why 10 years after its first description this

highly attractive concept is still performed by only a few centers. A third option, the hybrid technique, was first described 1999 by Quinones-Baldrich [7]. The principle of that procedure is to bypass the renovisceral arteries, generally with grafts attached to the iliac arteries. This first surgical step, renovisceral debranching, is followed by a simultaneous or staged second step, where the TAAA is excluded by implanting aortic stentgrafts. These two steps (surgical and endovascular) allow quite extensive EVAR procedures (i.e. to treat Crawford type II TAAA) to be performed without compromising abdominal organ perfusion. Main advantages of this approach are the avoidance of thoracoabdominal exposure, single lung ventilation, hypothermia, extracorporeal circulation and aortic cross clamping.

The goal of this paper is to review the various surgical options to perform this hybrid technique, to present the latest results from the literature, and finally to discuss potential further improvements.

Surgical options to perform the hybrid procedure

Exposure of the renovisceral arteries

Basically, there are three options to get access to the renovisceral arteries: the transperitoneal approach, the retroperitoneal approach and a combination of the transperitoneal and retroperitoneal approaches.

Transperitoneal approach

Full midline abdominal incision is the most commonly used approach. It allows anterior access to the renovisceral vessels through two limited retroperitoneal incisions: limited retroduodenal (at the level of the ligament of Treitz) dissection allows access to both renal arteries and the superior mesenteric artery and a through a longitudinal short incision of the hepatogastric ligament, the coeliac trunk or hepatic artery are easily reached. The transperitoneal approach offers several advantages. It is well known to all surgeons, simple and fast track, especially in emergency cases. Moreover, its allowing direct visualization and evaluation of the whole abdominal content and the infrarenal aorta as well as the iliac vessels are easily exposed. However, this approach has drawbacks. Reentering the abdomen after prior abdominal surgery might lead to abdominal organ injuries. Ligation of the celiac trunk by this approach might be challenging. Fluid evaporation and body temperature loss are high, when the abdomen is left open for several hours. The respective fluid requirement might be important and preclude primary abdomen closure due to significant bowel swelling possibly resulting in intraabdominal hypertension with forced closure. Finally, in obese patients, respiratory failure may occur quite often.

Retroperitoneal approach

The retroperitoneal space can be accessed by a *median* or *paramedian abdominal incision* as proposed by Ljungman [8]. This technique has several advantages. It offers excellent access to the whole retroperitoneal space and the renovisceral arteries. The peritoneal sack remains closed, eliminating most problems of the transperitoneal approach. However, it can be a time consuming procedure, as the peritoneal sack has to be mobilized away from the abdominal wall and the diaphragm, especially when access the celiac trunk is

needed. Moreover, as the dissection area is extensive, quite important blood loss can occur over time, especially in cases where hemostasis and/or coagulation are suboptimal and procedure time long. Finally, long lasting and/or uncontrolled or careless retraction of the peritoneal sack using self-retracting systems may lead to visceral ischemia and/or spleen injury.

Combined transperitoneal and retroperitoneal approach

The peritoneal sac is opened through a midline abdominal incision. This is followed by a paracolic incision to access the retroperitoneal space and a medial rotation of the mesenterium. This technique allows getting optimal exposition of the celiac trunk and superior mesenteric artery, especially in case of previous abdominal visceral surgery of the upper abdomen.

Endoscopic assisted exposure of the renovisceral arteries

Ralf Kolvenbach reported successful hand assisted laparoscopic exposure and bypass surgery to the hepatic artery (1) [9] and renal artery (3) [10].

Revascularization of the aortic branches

Bypass grafts to the renovisceral vessels originate generally from the common or external iliac artery or the distal aorta and supply the aortic branches in a retrograde way. In some cases, bypass grafts are anastomosed to the ascending aorta or the distal descending aorta leading to antegrade perfusion. In patients previously operated for AAA or type IV TAAA, blood supply to the renovisceral arteries can be derived from the existing aortic graft material. Some patients with iliac occlusive disease or huge iliac tortuosity might require the implantation of an iliac or iliofemoral conduit. That graft allows aortic stent-grafts to be introduced smoothly into the aorta and may at the same time be used for the attachment of the bypassgraft(s) to the renovisceral arteries. Bypass graft fabric can be polyester (Dacron) or polytetrafluoroethylene (PTFE) with or without ring support. In some instances, the superficial femoral vein has been used [11]. Usually, separate grafts (one for each recipient artery) are sewed together to form an "octopus graft" tailored to the patient's anatomy. Graft positioning and/or tunneling can be challenging. The grafts should not compress any structures (e.g. the ureter), nor should they be in contact with the bowel in order to prevent secondary graft-enteric fistula. Tunneling should be performed meticulously to avoid retroperitoneal bleeding. Grafts to celiac trunk can be routed behind or above the pancreas. Creating a retropancreatic route may lead to severe bleeding or pancreatic (duct) lesions, which might degenerate into pseudocysts with recurrent septic episodes and fatal hemorrhage [8]. In our center, all the grafts targeting the celiac artery or one of its branches are routed ventrally to the pancreas when using the transperitoneal approach. In general, anastomoses to the renovisceral arteries are made in an end-to-side antegrade fashion with the graft maintained short, to prevent kinking, twisting or bulking. The anastomosis to the superior mesenteric artery can be more challenging, as the mesentery is generally rotated to the right and slightly upwards in order to expose the mesenteric artery and perform the anastomosis. This renders fitting the graft to the correct length and position more difficult. Therefore, some authors recommend tailoring the graft a bit

longer and arranging it in a "C-loop configuration" [12]. In our experience, performing a retrograde end-to-side anastomosis with the graft reaching the mesenteric artery from caudally allows maintaining the graft short thereby avoiding any graft kinking or twisting. At the conclusion of an end-to-side reconstruction, flow interruption by clipping or ligating the renovisceral arteries at their origin is necessary to prevent retrograde aneurysm sac perfusion after stent graft deployment (type II endoleak). In cases where surgical interruption deems to be hazardous or dangerous, secondary coiling of the origin of native artery can be performed later. The bypass grafts can generally be covered directly by retroperitoneal tissue, an omentum flap or by using a biological membrane (e.g. a xenopericard patch). In challenging cases (i.e. scar tissue after redo aortic surgery, obesity), the VORTEC (Viabahn Open Revascularisation TEChnique), a vascular connection technique based on the Viabahn stentgraft, has been described to reduce anastomosis and ischemia time and overall procedure duration. In a series of 246 branch revascularization with VORTEC, 30-day and 5-year patency rates of such vascular connections were 94% and 91%, respectively [13].

Endovascular exclusion of the thoracoabdominal aortic aneurysm is performed as a second step, which can be performed simultaneously with the debranching procedure. There are obvious advantages of all-in-one procedure. The aortic aneurysm is completely treated within a single procedure, and therefore the risk of aortic rupture is ruled out. Moreover, this approach offers technical advantages. In case an iliofemoral conduit for stentgraft introduction becomes necessary, an open abdomen makes this procedure easier. Finally, bypass graft failure eventually recognized during angiography control can be corrected without time delay. On the other hand, arguments to perform these two steps as distinct operations are predominant. Complete renovisceral debranching is generally a long-lasting procedure with significant impact on patient's homeostasis and postoperative systemic inflammatory response syndrome (SIRS) develops in most patients. Performing EVAR simultaneously to the debranching step increases the procedure time potentially resulting in an even more severe SIRS. This syndrome may lead to critical illness and induces different levels of unstable hemodynamics, generally necessitating catecholamine support to maintain sufficient and stable blood pressure. During this period, the risk for TAAA rupture remains low, as hypertension is not usual. Usually, this inflammatory syndrome decreases in intensity within a few days and EVAR can then be performed with little risk of spinal ischemia. Considering that thoracoabdominal stentgraft deployment significantly reduces spinal blood flow reserve, critical spinal perfusion might develop if hemodynamic becomes unstable. In our center, most EVAR procedures are performed under local anesthesia and without CSFD, as our patients are treated with therapeutic doses of heparin combined with antiplatelet regimens (Aspirin 100 mg/day) after the debranching procedure. Local anesthesia allows direct neuro-monitoring and early/immediate treatment of a potential acute neurologic deficit. However, we did not experience any primary acute neurologic deficit in hybrid procedures, when EVAR was performed under local anesthesia so far.

The *access site* for stentgraft introduction is generally the common femoral artery. Direct access or introduction through a conduit on the iliofemoral arteries or aorta has been described to overcome access vessel complications in cases with heavily calcified or tortuous and/or stenotic iliofemoral arteries. Some of these remote access techniques require general anesthesia and might influence the decision to perform the hybrid procedure as a one stage procedure.

Type and number of stentgrafts used for endovascular exclusion is tailored on a patient-to-patient basis. Crawford TAAA types II-IV require landing into the iliac vessels and using a AAA device to complete the procedure. Crawford TAAA types I and V can be treated with exclusive use of thoracic devices. Generally, these cases do not need complete renovisceral debranching, but only bypassing one or both visceral arteries. In Crawford TAAA types I and II, stentgraft devices will eventually land into the arch and therefore additional bypass surgery to maintain intact blood flow to the left subclavian artery and the internal mammary artery, the most important sources of spinal blood supply, is highly recommended.

Literature review and meta-analysis of various treatment options for TAAA

The surgical repair of TAAA has a high mortality and morbidity in most centers. Some high volume centers [1, 2] do show a 30-day mortality of about 7-9%, but generally perioperative mortality remains clearly above the 10% benchmark, and this despite major advances in operative techniques (left heart bypass, spinal cord protection, mild hypothermia and selective visceral perfusion). In an analysis of 1010 patients who underwent repair of TAAA in California (797 elective and 213 ruptured), elective mortality was 19% at 30 days, and 31% at one year. In the subset of patients older than 80 years, one-year mortality reached 40%. 30-day mortality for ruptured TAAA was 48.4%. Overall mortality rate was 61.5% after 12 months and highest in old patients [14]. In a single centre series from Boston with 445 consecutive TAAA patients operative mortality was 8.2%, and was associated with intraoperative hypotension, intraoperative transfusion requirements, postoperative spinal cord ischemia and postoperative renal failure [15]. The authors concluded that despite the favorable impact of different adjuncts on perioperative mortality and spinal cord ischemia, major morbidity after TAAA remains an unsolved challenge.

The hybrid technique has been introduced to reduce invasiveness of conventional open thoracoabdominal graft repair more than 10 years ago. In the mean time several centers have published their experience (Tab. 6.I). A collaborative study of three European vascular centers showed in a series of 107 consecutive patients (85 elective and 22 emergency) a 30-day mortality rate of 14.95% (16/107). Complete and permanent spinal cord ischemia occurred in 8.4% (9/107), terminal renal failure requiring dialysis in 4%, and mesenteric ischemia followed by bowel resection in 2.8% of the patients [16]. A systematic literature review of 108 TAAA treated with hybrid open/endovascular repair showed a 30-day mortality in elective cases of 10.4% (10/108), while total 30-day mortality including emergency cases was 14.8% (16/108). Permanent neurological deficit occurred in 2.7% (3/108) of the patients, and renal failure was reported in 11.1% (12/108). Overall mortality during a follow-up of 10.6 months was 24.1% [17]. Patel described a comparative series of 23 patients (mean age of 77 years) treated by the hybrid technique and 77 patients (mean age of 73 years) treated by open thoracoabdominal surgery. The 30-day/in-hospital mortality rate of the hybrid repair group was 26% and permanent paraplegia rate was 4% whereas the 30-day mortality of the open TAAA repair group was 10% and the paraplegia rate was 4%. Comparing both groups, it has to be stated that patients treated by the hybrid technique were older and showed a higher extent of Crawford types I-II (61%), compared with somewhat younger patients having a lesser extent of Crawford types I-II (31%) in the open TAAA group [18]. Our meta-analysis on hybrid TAAA procedures covers

TABLE 6.I. – *Mortality and ischemic complications of published case series of renovisceral arteries open debranching with more than 15 patients.*

AUTHOR, YEAR, REFERENCE	SD	PTS.	AGE	ER (%)	UR (%)	30D-M (%)	PP (%)	ARF (%)	TDS	AMI (%)
Wolf, 2010 [19]	SC	20	58	18 (90)	2 (10)	3 (15)	1 (5)	3 (15)	3	1 (5)
Muehling, 2010 [20]	SC	16	67	10 (63)	6 (17)	5 (31)	1 (6)	1 (6)	0	3 (19)
Smith, 2010 [11]	SC	24	74	–	–	3 (12)	2 (8)	4 (17)	–	5 (21)
Patel, 2010 [21]	SC	29	72	25 (82)	4 (8)	1 (3)	1 (3)	22 (76)	5	1 (3)
Kabbani, 2010 [22]	SC	36	71	32 (89)	4 (11)	3 (8)	1 (3)	4 (11)	1	3 (8)
Quinones-Baldrich, 2009 [23]	SC	15	68	-	-	1 (7)	2 (13)	0 (0)	0	1 (7)
Donas-Lachat, 2009 [24]	SC	58	74	49 (85)	9 (15)	4 (7)	1 (2)	0 (0)	0	2 (4)
Chiesa, 2009 [25]	SC	31	72	30 (97)	1 (3)	4 (13)	1 (3)	3 (10)	0	0 (0)
Biasi, 2009 [26]	SC	18	73	14 (78)	4 (22)	3 (17)	1 (6)	0 (0)	0	0 (0)
Van de Mortel, 2008 [27]	SC	16	69	11 (69)	5 (31)	5 (31)	1 (6)	2 (12)	2	3 (19)
Lee, 2007 [28]	SC	17	69	17 (100)	0 (0)	4 (23)	0 (0)	1 (6)	1	1 (6)
Black, 2006 [29]	SC	29	74	26 (90)	3 (10)	7 (24)	0 (0)	4 (14)	2	1 (4)
Zhou, 2006 [30]	SC	18	69	–	–	1 (5)	0 (0)	1 (6)	1	0 (0)
OVERALL		327	67	232 (85)	38 (15)	43 (13)	12 (4)	45 (17)	15 (33)	21 (6)

SD: study design, SC: single centre; MC, multi centre, SR: systematic review; Pts: Patients; ER: elective repair, UR: urgent repair; 30d-M: 30 days mortality; PP: paraplegia; ARF: acute renal failure; TDS: transient dialysis support; AMI: acute mesenteric ischemia.

TABLE 6.II. – *Studies reporting on complete renovisceral open debranching.*

AUTHOR, YEAR, REFERENCE	PTS	COMPL DEB (%)	3V DEB (%)	TOT (%)	30D-M (%)
Wolf, 2010 [19]	20	13 (65)	1 (5)	14 (70)	2 (14)
Muehling, 2010 [20]	16	2 (13)	0 (0)	2 (13)	0 (0)
Smith, 2010 [11]	24	8 (33)	0 (0)	8 (33)	-
Patel, 2010 [21]	29	-	-	-	-
Kabbani, 2010 [22]	36	-	-	-	-
Quinones-Baldrich, 2009 [23]	15	6 (40)	0 (0)	6 (40)	0 (0)
Donas-Lachat, 2009 [24]	58	-	-	-	-
Chiesa, 2009 [25]	31	10 (32)	0 (0)	10 (32)	1 (10)
Biasi, 2009 [26]	18	8 (44)	0 (0)	8 (44)	-
Van de Mortel, 2008 [27]	16	11 (69)	1 (6)	12 (75)	-
Lee, 2007 [28]	17	10 (59)	0 (0)	10 (59)	-
Black, 2006 [29]	29	16 (55)	0 (0)	16 (55)	-
Zhou, 2006 [30]	18	-	-	-	-
OVERALL	327	84 (41)	2 (5)	86(46)	3 (9)

Pts: Patients; Compl Deb: Complete debranching; 3V Deb: 3 vessels debranching in association with celiac trunk occlusion; 30d-M: 30 days mortality; TOT: total. TAAA data are based on a subgroup of 204 patients. 30-day mortality data are based on a subgroup of 32 patients. Percentage data are made on the subgroup population.

the past 5 years and is based on series presenting at least 15 patients [11, 19-30]. Overall, the analysis includes 13 single center articles with a total of 327 patients (minimum: 16, maximum: 58 patients). Of these 327 patients, most (85%) were treated on an elective basis.

TABLE 6.III. – *Studies reporting on thoracoabdominal aortic aneurysm and relative complete renovisceral open debranching and mortality.*

AUTHOR, YEAR, REFERENCE	PTS	TAAA CRAWFORD TYPE (%)			COMPL DEBRANCHING (%)			30D-M		
		II	III	TOT	II	III	TOT	II	III	TOT
Wolf, 2010 [19]	20	11 (55)	7 (35)	18 (80)	6 (55)	7 (100)	13 (72)	1 (17)	1 (14)	2 (15)
Muehling, 2010 [20]	16	3 (19)	1(6)	4 (25)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Smith, 2010 [11]	24	–	–	–	–	–	–	–	–	–
Patel, 2010 [21]	29	12 (41)	16 (55)	28 (96)	–	–	–	–	–	–
Kabbani, 2010 [22]	36	10 (28)	12 (33)	22 (61)	–	–	–	–	–	–
Quinones-Baldrich, 2009 [23]	15	2 (13)	6 (40)	8 (53)	2 (100)	4 (67)	6 (75)	0 (0)	0 (0)	0 (0)
Donas-Lachat, 2009 [24]	58	5 (9)	9 (16)	14 (24)	–	–	–	–	–	–
Chiesa, 2009 [25]	31	3 (10)	6 (19)	9 (29)	3 (100)	1 (17)	4 (44)	0 (0)	0 (0)	0 (0)
Biasi, 2009 [26]	18	8 (44)	7 (39)	15 (83)	–	–	–	–	–	–
Van de Mortel, 2008 [27]	16	1 (6)	1 (6)	2 (13)	1 (100)	1 (100)	2 (100)	–	–	–
Lee, 2007 [28]	17	2 (11)	8 (47)	10 (58)	1 (50)	5 (63)	6 (60)	–	–	–
Black, 2006 [29]	29	18 (62)	7 (24)	25 (6)	–	–	–	–	–	–
Zhou, 2006 [30]	18	0 (0)	8 (44)	8 (44)	–	–	–	–	–	–
OVERALL	327	75 (25)	88 (29)	163 (54)	13 (59)	18 (62)	31 (61)	1 (5)	1 (5)	2 (5)

SD: study design, SC: single centre; MC, multi centre, SR: systematic review; Pts: Patients; ER: elective repair, UR: urgent repair; 30d-M: 30 days mortality; PP: paraplegia; ARF: acute renal failure; TDS: transient dialysis support; AMI: acute mesenteric ischemia. TAAA data are based on a subgroup of 303 patients. Compl Deb data are based on a subgloup of 115 patients. 30-day mortality data are based on a group of 82 patients. Percentage data are made on the subgroup population.

Reported overall 30-day mortality rate was 13% (43/327) (Tab. 6.I). Interestingly, complete renovisceral debranching was reported in only 86 of these 327 patients. In these cases, reported 30-day mortality was 9% (3/32) (Tab. 6.II). Although half of the patients had extensive TAAA (Crawford II, n=75; Crawford III, n=88), complete 4 vessels renovisceral debranching was performed in only 61%. Generally, the reason not to perform complete aortic branch revascularization was that one visceral or renal artery was already occluded or that high-grade stenosis was present. In these latter cases it was deemed reasonable to just occlude the vessel during EVAR. 30-day mortality of the specific subgroup "complete renovisceral debranching and Crawford II or III" was 5.13% (2/23) (Tab. 6.III). Major TAAA in-hospital morbidity was: paraplegia in 4% (12/327), renal failure recovering later in one third of the patients in 17% (45/327), and mesenteric ischemia in 6% (21/327) (Tab. 6.I).

Discussion

Overall, experience with the hybrid technique is still limited considering the overall number of patients treated up to now and/or the relatively short follow-up presented in the literature. But so far, results of the hybrid open/endovascular repair technique are quite similar to the results of open repair in high volume experienced centers. The major difference between the open repair group and the patients treated with the hybrid procedure is that most of the candidates of the latter group presented severe co-morbidities,

significantly increasing mortality and morbidity and therefore usually deemed inoperable with open surgery.

There are several explanations for the relatively excellent outcomes of the hybrid procedure. There is basically no need to perform a thoracotomy to expose the thoracic aorta, nor it is necessary to manipulate the lungs and the heart. Therefore, lung reperfusion and arrhythmia, after the lungs and heart have been retracted for a while or canulated, are ruled out. Moreover, the diaphragm remains intact allowing normal respiratory mechanic after weaning. Extracorporeal support intended to protect the visceral organs and spinal cord whilst the aorta is opened is not needed at all. As a consequence, acute hemodilution and major reduction of the afterload, occurring as the priming volume of the cardiopulmonary bypass system enters into the patients circulatory system, is avoided. Therefore, the hemodynamic, blood pressure and spinal circulation are maintained stable. Furthermore, the patients' hematocrit and coagulation factors are not diluted. Additionally, thrombocyte count and function are not altered through the extracorporeal pump and oxygenator. Another advantage is that the blood doesn't get into contact with a huge foreign body surface (extracorporeal system), thus reducing the risk of SIRS during or around the operation. Overall, this incredibly invasive procedure requiring huge incision of eventually more than 100 cm and two-cavities exposition, as well as a whole complex adjunct setting to perform safe open thoracoabdominal aortic repair, might be too much for patients with co-morbidities. This seems to be confirmed by the poorer results of open TAAA repair, even in the high-volume centers, when patients present comparable comorbidity.

Fig. 6.1. – 61 years old patient with Crawford II thoraco-abdominal aortic aneurysm, extending proximally to the aortic arch, and with severe coronary artery disease. Hybrid repair consisted in a multistep procedure. As first step, multiple coronary artery bypass grafting and debranching of the left carotid artery and left subclavian artery, the latter with VORTEC, were performed. Transperitoneal complete renovisceral debranching, using the VORTEC to connect the renal arteries, was performed as second step. Finally, EVAR, extending from the proximal aortic arch to the common iliac arteries was performed under local anesthesia. 4 years later, the patient enjoys excellent life quality and is working regularly.

In conclusion, even if the hybrid surgery remains demanding for the surgeon, especially in obese patients or in redo procedure with scare tissue, avoidance of open thoracoabdominal aortic surgery with its heavily adjunct techniques, seems to be beneficial for the patient. The results of the hybrid procedure compete also very well with the completely endovascular procedure using branched stentgrafts, but has the advantage to be performed just with low x-ray load, necessary for the deployment of usual stentgrafts devices. Actually, the value of the hybrid procedure can be regarded in between the standard open TAAA procedure and the completely endovascular repair and seems most appropriate in the older patient and/or the patient with some comorbid-

ity. The young and fit patient is probably better deserved by conventional open TAAA surgery, but as thoracic and thoracoabdominal procedures are increasing repaired by EVAR, the expertise in open techniques is decreasing and the question arises what will happen once the actual experts in open surgery will be retired. Finally, the patient unfit for surgery is probably better deserved by completely endovascular approach.

As the hybrid procedure is performed without end-organ protection (cardiopulmonary support and hypothermia), sequential ischemia-reperfusion of the renovisceral organs remains an issue. This holds especially true for the high-risk patient, the typical candidate for this procedure. Lastly, the results of the hybrid procedure might further be improved by the VORTEC, a useful anastomotic tool reducing ischemia time to approximately one minute. Ischemia-reperfusion is completely avoided by that technique, especially reducing the rate of renal failure, a prognostic factor for poor outcomes.

Conclusion

Hybrid TAAA repair via complete renovisceral debranching and EVAR offers many advantages compared to open surgical repair with comparable or better results, especially in the high risk patient. Accordingly, TAAA repair might be offered to patients otherwise denied surgery avoiding the risk of fatal aortic rupture in these patients. Although the hybrid procedure does not completely replace open surgical repair, the latter will significantly decrease during the next decades as very experienced surgeons will be lacking due to the mainly endovascular generation of surgeons being educated nowadays. Similarly, the results of the hybrid TAAA repair will improve, as new techniques like the VORTEC will eliminate barriers still existing today.

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