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Is Hybrid Procedure the Best Treatment Option for Thoraco-Abdominal Aortic Aneurysm?

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Abstract *Objective:* Hybrid thoraco-abdominal aortic aneurysm (TAAA) repair, consisting in re-routing of abdominal aortic visceral branches followed by TAAA endograft exclusion has been shown to be a feasible strategy, especially appealing in high-risk patients.
Patients and methods: We analysed 31 high-risk patients who underwent hybrid TAAA repair in our centre with a variety of visceral re-routing configuration and of commercially available thoracic endografts. Twenty-three simultaneous (74.2%) and eight staged procedures (25.8%) were performed with a four-vessel re-vascularisation in 10 cases (32.3%), a three-vessel in six (19.4%) and a two-vessel in 15 (48.4%). We also performed a literature review of major single-centre series of TAAA hybrid repair.
Results: No intra-operative deaths were observed in our series, with a technical success in endovascular TAAA repair of 100%, an overall perioperative mortality of 19.4% and a perioperative morbidity of 35.5%, including one case (3.2%) of permanent paraplegia. At a median follow-up of 11.9 months, we observed a visceral graft occlusion rate of 6.8%, one type II endoleak and one endograft migration. From the literature review, six other single-centre series with more than 10 hybrid TAAA repairs were found. From data available of 107 patients, we observed a mean perioperative mortality of 15.6%, the rate of primary endoleaks was 17.9%, paraplegia/paraparesis 7.2% and renal failure 9.9%, with other major perioperative complications reported in the 50.6% of cases. At the follow-up period visceral graft occlusion rate was 5.1%.
Conclusion: Typical complications of conventional TAAA open surgery have been not eliminated by hybrid repair and significant mortality and morbidity have been reported till date. The fate of visceral bypasses and incidence of endoleak and other endograft-related complications need to be carefully assessed. Hybrid TAAA repair should nowadays be limited as alternative to simple observation in patients unfit for the conventional open repair.

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The conventional open surgical treatment of thoraco-abdominal aortic aneurysm (TAAA) through the last decades has been the inclusion technique as proposed by Crawford et al. in 1978.[1] This challenging procedure substantially evolved over the years especially in organ protection strategies enabling experienced surgical centres to have much lower mortality and morbidity rates than previously reported.[2–9] The evolving technology led, in the 'real world', to extend the use of endovascular grafts to off-label indications. Among the latest frontiers of endovascular challenge, the aortic segment giving rise to the abdominal visceral vessels is an appealing field especially for poor surgical candidates. In this critical site the experience with endografts incorporating the visceral vessels with fenestrations or with formal branches is limited to a few highly specialised centres conducting investigational studies,[10,11] few large series have been published and reports suffer from a lack of accurate comparison with similar open surgical procedures.

Wider applicability and reports are available with hybrid TAAA repair providing inflow to visceral arteries by means of extra-anatomic bypass followed by aortic endograft relining.[15–22] Early favourable outcomes encouraged some groups to perform hybrid TAAA repair in patients fit for surgery as well.[15] In this study, we report our single-centre experience and review the major series reported in literature in order to summarise the existing evidence and to define the role of hybrid TAAA repair in our set of patients.

Patients and Methods

Among a total of 374 TAAA repairs carried out between 1988 and 2009, from 2001, 31 high-risk patients (26 male and five female; median age: 72.4 years; range: 35–83 years) underwent hybrid TAAA repair by means of visceral aortic de-branching and endovascular exclusion of the aneurysm (12 type I, three type II, six type III, three type IV Crawford classification and seven aneurysms of the visceral aortic patch). The criteria we used to define these patients as being at high risk for inclusion technique were American Society of Anesthesiologists (ASA) class 3 or 4 associated with forced expiratory volume in 1 s $< 50\%$ or cardiac ejection fraction $<40\%$. One patient out of these clinical criteria was anyway selected for hybrid TAAA repair due to local technical concerns related to a retroperitoneal fibrosis. Of these 31 patients, 26 had a history of previous aortic surgery (16.1% ascending, 22.6% descending, 25.8% abdominal and 29% thoraco-abdominal). These patients' data were prospectively collected in a computerised database (Table 1).

The TAAA median maximum diameter on the short axis was 69 mm (range: 64–89 mm). One patient underwent emergency treatment because of a TAAA rupture. Anatomical inclusion criteria for the hybrid repair were a minimum proximal aortic neck length of 20 mm, the possibility of an aortic visceral de-branching to be effective in lengthening the distal aortic neck in a native or a grafted aorta to a minimum of 15 mm and an aortic neck diameter allowing a 15–20% endograft oversizing in the absence of circumferential thrombus or calcifications.

In all cases, multislice computed tomography (CT) was performed for planning and sizing. Beginning in 2004, a 16-row multislice CT was used, and from 2006 a 64-row multislice CT was employed. Twenty-three simultaneous (74.2%) and eight staged procedures (25.8%) were performed.

Preoperative cerebro-spinal fluid drainage (CSFD) was instituted in 15 selected patients considered at high risk of spinal cord ischaemia for the long segment of native descending aorta planned to be covered by the endograft, and/or for the planned overstenting of the intercostal artery giving rise to the Adamkiewicz artery, identified by building orthogonal and curved multiplanar reformation (MPR) based on preoperative AngioTC imaging, and/or for a prior surgery for abdominal aortic aneurysm (AAA). The CSFD was instituted emergently in two patients when delayed postoperative symptoms of spinal cord ischaemia developed. A portable digital C-arm image intensifier with road-mapping capabilities (series 9600, OEC Medical System or Moonray, Simad Medical Technology, Modena, Italy) was used in all cases. All patients were operated on under general and epidural analgesia. Re-routing of the visceral aortic branches was performed by means of 85 retrograde bypasses through a median laparotomy and transperitoneal access and three antegrade visceral bypasses from the ascending aorta through a median sternotomy associated with a median laparotomy.

Inflow site

The choice of inflow site for retrograde visceral artery bypass grafting was based on the extent of the TAAA, the presence of prior abdominal aortic repair and the quality of the walls of the native aorta and iliac arteries.

Patients with pre-existing abdominal aortic graft (17 cases)

In 13 out of 17 cases with pre-existing abdominal aortic grafts for prior AAA repair ($n = 8$) or TAAA repair ($n = 9$), the retrograde grafts were anastomosed to the previous aortic graft.

In three cases, a pre-existing abdominal aortic graft was not used as the inflow site because of the good quality and favourable anatomical features of the common iliac arteries that were used as the donor vessels.

In the last case with pre-existing abdominal aortic graft, due to a retroperitoneal fibrosis, three antegrade bypasses from the ascending aorta were performed.

Patients without pre-existing abdominal aortic graft (14 cases)

Among the 14 patients who had not undergone prior abdominal aortic grafting, the native aorta represented the donor vessel in four cases, while the common iliac artery was used as the inflow vessel in six cases.

In the other four patients, the infrarenal aorta was grafted for synchronous AAA during hybrid TAAA repair, with a tube graft in three patients and with an aorto-biiliac bypass in one patient. The visceral bypasses were then anastomosed to the distal parts of the tube grafts and the main body, and to the origins of the iliac branches in the patient with aorto-biiliac reconstruction (Fig. 1).

Table 1 Table showing ASA class, site of previous aortic surgery, TAAA extent, visceral arteries rerouted and endografts used in our series of 31 patients underwent in our center hybrid TAAA repair from '01 until '09.

Patient	ASA	Previous aortic surgery	TAAA Crawford extent	Visceral vessels management	Endoprosthesis
#1	4	AAA	Type II	CT, SMA, RRA, LRA	Old Gore TAG
#2	3	TAAA type II	VAP aneurysm	CT, SMA, RRA	Valiant Medtronic
#3	3	Asc aorta, TAAA type III	VAP aneurysm	CT, SMA, RRA	Talent Medtronic
#4	4	DTAA	Type I + dissection	CT, SMA	Zenith TX1 Cook
#5	3	DTAA	Type I	CT, SMA	Zenith TX2 Cook
#6	3	DTAA	Type I	CT, SMA	Zenith TX1 Cook
#7	3	AAA	Type IV	CT, SMA	New Gore TAG
#8	4	Ascending aorta, DTAA	Type I	CT, SMA	New Gore TAG
#9	4	Ascending aorta	Type II	CT, SMA, RRA, LRA	Zenith TX1 Cook
#10	3	AAA	Type I	CT, SMA	Zenith TX2 Cook
#11	3	AAA	Type IV	CT, SMA	New Gore TAG
#12	3	Ascending aorta, AAA	Type I	CT, SMA	Zenith TX2 Cook
#13	4	AAA	Type I	CT, SMA	New Gore TAG
#14	4	TAAA type II	VAP aneurysm	SMA, RRA, LRA	Zenith TX2 Cook
#15	4	TAAA type III	VAP aneurysm	CT, SMA, RRA, LRA	Zenith TX2 Cook
#16	4	AAA	Type I	CT, SMA	Zenith TX2 Cook
#17	4	/	Type III + AAA	CT, SMA, RRA, LRA	Bolton Relay
#18	4	TAAA	Type I	CT, SMA, RRA, LRA	Zenith TX2 Cook
#19	4	TAAA type II	VAP aneurysm	CT, SMA, RRA, LRA	Bolton Relay
#20	4	TAAA type III	VAP aneurysm	CT, SMA, RRA, LRA	Valiant Medtronic
#21	4	TAAA	Type III	CT, SMA, RRA	Zenith TX2 Cook
#22	4	AAA	Type III	CT, SMA, RRA	Zenith TX2 Cook
#23	3	TAAA type II	VAP aneurysm	CT, SMA, RRA, LRA	Zenith TX2 Cook
#24	3	DTAA	Type I	CT, SMA	Bolton Relay
#25	4	DTAA	Type IV + dissection	CT, SMA, RRA, LRA	Zenith TX2 Cook
#26	3	/	Type I	CT, SMA	Zenith TX2 Cook
#27	4	/	Type I	CT, SMA	/
#28	4	/	Type III + AAA	CT, SMA	/
#29	3	/	Type II	CT, SMA, RRA, LRA	Bolton Relay
#30	3	Ascending aorta, DTAA	Type III	SMA, RRA, LRA	Zenith TX2 Cook
#31	4	/	Type III + AAA	SMA, RRA	Bolton Relay

Legend: ASA: the American Society of Anesthesiologists, TAAA: thoraco-abdominal aortic aneurysm, AAA: abdominal aortic aneurysm, DTAA: descending thoracic aortic aneurysm, TAAA: thoraco-abdominal aortic aneurysm, VAP: visceral aortic patch, CT: coeliac trunk, SMA: superior mesenteric artery, RRA: right renal artery, LRA: left renal artery.

Visceral re-routing

Four-, three- and two-vessel re-vascularisation were performed in 10 (32.3%), six (19.4%) and 15 cases (48.4%), respectively. Overall, 88 visceral retrograde bypass were performed (28 to the coeliac axis, 31 to the superior mesenteric artery and 29 to the renal arteries). Diameters of visceral bypasses were 6—8 mm (86 Dacron and two expanded polytetrafluoroethylene grafts). Customised Y graft and single bypass were the preferred configuration. Reversed bifurcated or trifurcated grafts and single bypasses with sequential graft technique were used as well.

For coeliac trunk re-vascularisation, ante-pancreatic graft routing was preferred (Fig. 2), an arteriotomy was made in the common hepatic artery and an end-to-side anastomosis was usually made. An end-to-end anastomosis was usually preferred for the superior mesenteric arteries and for the renal arteries (Fig. 3). In all reconstructions, the grafted vessels were ligated proximally to prevent type II endoleaks. The grafts were then covered with retroperitoneum or omental flap whenever possible.

Access site for endograft insertion

The access vessel for endograft insertion was the common femoral artery (exposed through an inguinal incision) in 16 patients, an iliac approach was used in 5 patients and the device was inserted through the infrarenal aorta or an aortic graft in 7 patients. In these patients the access sites were repaired by purse-string suture, continuous direct suture or by a synthetic patch according to the size and the quality of the access site. A prosthetic conduit has been attached to a previous vascular graft or to the native aorta in three cases of staged procedure, routed to the groin and then used for endograft deployment.

Aneurysm exclusion

Thoraco-abdominal endovascular exclusion was achieved by means of different commercially available CE-marked thoracic endografts (Cook in 16 patients, Gore & Associates

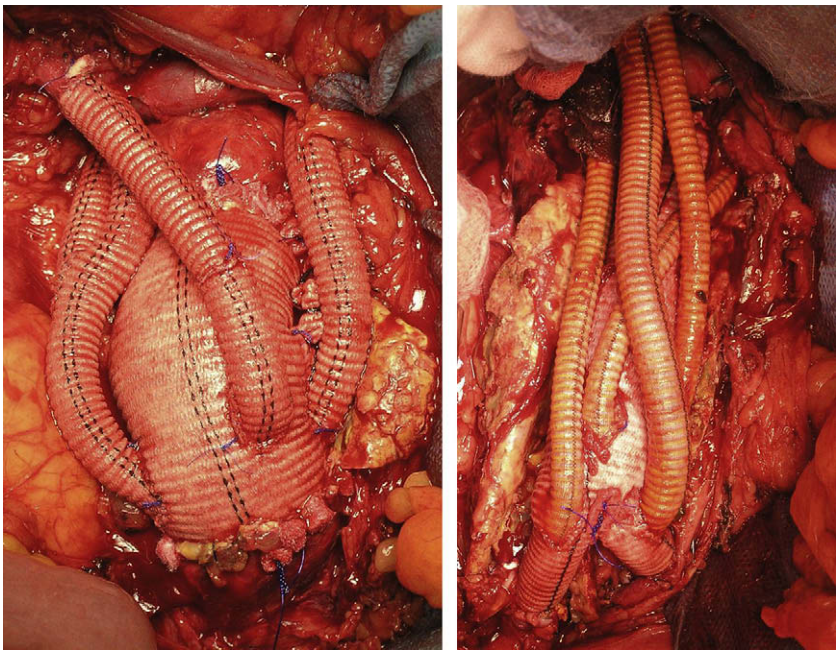

Figure 1 Intra-operative images showing 2 cases in which the infrarenal aorta was grafted for synchronous AAA during hybrid TAAA repair, with a tube graft (left) and with an aorto-biiliac bypass (right). Visceral bypasses were anastomosed to the distal part of the tube graft (left) and to the distal part of the main body and to the origins of the iliac graft branches in aorto-biiliac reconstruction (right).

in five patients, Bolton Medical in five patients and Medtronic in three patients) and a median of 1.5 stent grafts (range, 1—3) were deployed in each patient.

A completion aortography was always done after deployment of the endografts to assess the absence of endoleak and the good patency of visceral bypasses. Endograft ballooning was performed selectively.

Follow-up

The patients were evaluated with post-procedural contrast CT scans at scheduled follow-up imaging at 1, 6 and 12 months and yearly thereafter. Clinical follow-up was also done at regular intervals of 6 months.

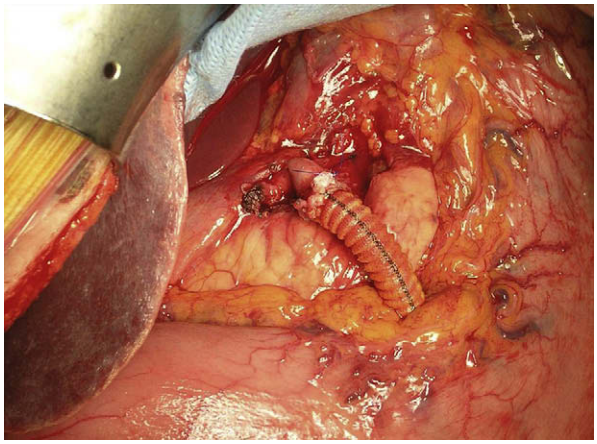

Figure 2 Intra-operative image showing visceral graft antepancreatic routing for revascularization of the coeliac trunk.

Results

Perioperative results

No intra-operative deaths were observed. Perioperative mortality in the inter-surgical interval before endograft deployment was observed in 2 patients (one visceral graft thrombosis leading to a fatal mesenteric infarction and another to a myocardial infarction). Primary technical

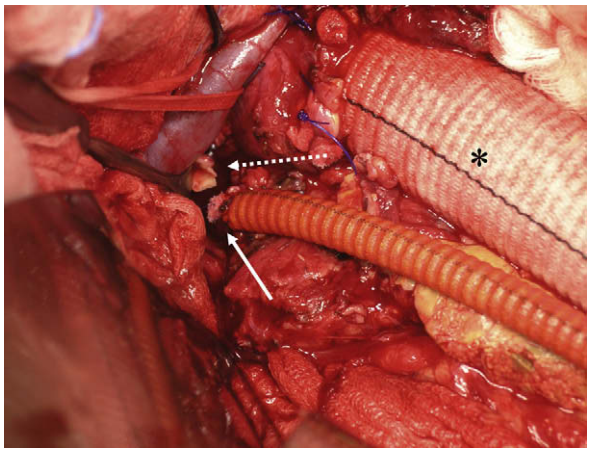

Figure 3 Intra-operative image showing the infrarenal grafted aorta (asterisk) and the end-to-end anastomosis of a visceral graft directed to the right renal artery (continuous arrow) during a hybrid TAAA repair. The dashed arrow indicates the proximal stump of right renal artery clipped and ligated below the left renal vein.

success in endovascular TAAA repair was 100%, with a perioperative mortality of 12.9% (four patients operated in a single-stage procedure died and one each operated for multiple organ failure, coagulopathy, pancreatitis and respiratory failure). The overall major perioperative morbidity was 35.5%. Three cases of pancreatitis (9.6%) were reported, with one patient who died of acute myocardial infarction few days after percutaneous drainage of a huge peri-graft fluid collection performed in another centre. Three cases of renal failure (9.6%) resolved without dialysis, and one case of respiratory failure (3.2%) was recorded as well. Delayed transient paraparesis was observed in two patients (6.4%) on postoperative day 2; the condition resolved after CSFD positioning. One case (3.2%) of irreversible paraplegia was observed. Another patient developed dysphagia and regurgitation after the endovascular procedure; oesophageal imaging showed a marked endoluminal stenosis related to aneurysm compression, suggesting the development of a secondary achalasia. The patient was submitted to botulinum toxin endoscopic injections at the lower oesophageal sphincter, obtaining a complete resolution of symptoms (Table 2).

Visceral arteries management

Among the total 88 planned visceral bypasses (85 retrograde and three antegrade from the ascending aorta), only two target vessel re-vascularisation (left renal artery in both cases) failed for technical issues.

One patient undergoing long-term dialysis had intentional overstenting of both renal arteries, and three patients with a right solitary functioning kidney had intentional overstenting of the left renal arteries without re-vascularisation. One patient had the common hepatic artery originating from the superior mesenteric artery, with a small anomalous coeliac trunk that was intentionally overstented without re-vascularisation. In one patient with previous left nephrectomy and coeliac trunk occlusion, only the right renal artery and the superior mesenteric artery were grafted. One patient with previous type IV TAAA conventional repair by aortic grafting with bevelled proximal anastomosis developed severe retroperitoneal fibrosis and type III TAAA; the left kidney was not functioning. Antegrade re-vascularisation of coeliac trunk, superior mesenteric artery and right renal artery was chosen in this case by means of a trifurcated graft attached to the ascending aorta and routed through the diaphragm (Fig. 4).

Patency of two (2.3%) visceral grafts was intra-operatively assisted with stenting: a peri-anastomotic initial dissection of the right renal artery in the first case and a moderate stenosis with an angulation of the anastomosis with the superior mesenteric artery in the second case were detected at intra-operative angiography and immediately corrected. An initial dissection with a mild stenosis of the right iliac artery representing the donor vessel for visceral re-routing was also intra-operatively stented distally to the proximal anastomosis of a 'Y' graft because of intra-operative detection of a reduced femoral pulse after declamping.

Mid-term results

At a median follow-up of 11.9 months (range: 1–69.5 months), visceral graft occlusion rate was 6.8% (six out of 88) leading to bowel infarction and death in two patients and to loss of one kidney in one. Four non procedure-related deaths (one each of aortic arch aneurysm rupture, myocardial infarction, cerebral aneurysm rupture and a head trauma) were recorded.

Among the 19 survivors (61.3%), one small type II endoleak from an aberrant left gastric artery originating directly from the aorta in a dissecting TAAA is carefully followed and until recently no aneurysm enlargement has been observed. One case of endograft migration leading to a type I endoleak required an emergency complete visceral aortic de-branching and endograft relining in another centre (we gratefully acknowledge Dr MP Jenkins – St Mary's Regional Vascular Unit, Imperial College Healthcare NHS Trust, London, United Kingdom – for performing this successful operation). No other cases of aneurysm growth or other procedure-related complications were reported (Table 2).

Literature review

From literature review, six single-Center series with more than 10 hybrid TAAA repairs with a variety of operative indications and patients' risk factors were found and analysed (excluding our previous reports and current series). In these series, the mean perioperative mortality was 15.6% and primary endoleaks were reported in the 17.9% of cases. Paraplegia/paraparesis was reported in 7.2% of cases, renal failure in 9.9% and other major complications in 50.6%. At the follow-up, visceral graft occlusion rate was 5.1% (Table 3).

Discussion

Although open surgical repair of TAAA has evolved significantly over the last decades,[2–9] technical challenge and current morbidity and mortality of the inclusion technique are still significant especially in extensive aneurysms, with prior aortic surgery and in poor surgical candidates.[12,21–23]

Hybrid TAAA repair is currently an appealing technique, largely feasible in any centre experienced in abdominal vascular surgery and aortic endovascular procedures and may represent a 'bridge' solution waiting for larger series and reproducible results from evolving experience with totally endovascular TAAA repair with fenestrated and branched endografts.[10–14]

By avoiding thoracotomy, hybrid TAAA repair may be hypothesised to be particularly advantageous in patients with previous thoracic surgery, especially with 'frozen chest', in which a redo left-sided thoracotomy may be associated with major bleeding and increased post-operative complication rate, such as respiratory and organ failure.[24–28] Hybrid repair may also have some advantages in cases of previous cardiac surgery and cannulation, in which pericardial or proximal aortic adhesions may increase the technical challenges and risk if an inclusion technique with distal perfusion through a left heart bypass is required. Furthermore, by avoiding thoracic aortic cross-clamping,

Table 2 Table showing perioperative and mid-term results of our series of 31 hybrid TAAA repair from 2001 to 2009.

Patient	TAAA Crawford extent	Perioperative mortality	Perioperative morbidity	Follow-up
#1	Type II	no	no	lost from FU
#2	VAP aneurysm	no	yes (spinal cord ischemia)	aortic arch rupture
#3	VAP aneurysm	no	yes (transient renal failure[a])	death (visceral graft thrombosis)
#4	Type I	no	no	endograft migration
#5	Type I	yes (coagulopathy)	no	—
#6	Type I	no	yes (respiratory failure)	alive
#7	Type IV	no	no	unrelated death (cerebral aneurysm rupture)
#8	Type I	yes (respiratory failure)	no	—
#9	Type II	no	no	alive
#10	Type I	no	yes (pancreatitis)	alive
#11	Type IV	no	yes (transient renal failure[a])	alive
#12	Type I	yes (pancreatitis)	no	—
#13	Type I	no	no	alive
#14	VAP aneurysm	no	no	alive
#15	VAP aneurysm	no	no	pancreatitis
#16	Type I	no	yes (pancreatitis)	unrelated death (myocardial infarction)
#17	Type III + AAA	no	no	alive
#18	Type I	no	no	alive
#19	VAP aneurysm	no	no	alive
#20	VAP aneurysm	yes (MOF)	no	—
#21	Type I	no	yes (spinal cord ischemia)	alive
#22	Type III	no	yes (dysphagia)	unrelated death (head trauma)
#23	VAP aneurysm	no	yes (transient renal failure[a])	alive
#24	Type I	no	no	alive
#25	Type IV + dissection	no	no	type II endoleak
#26	Type I	no	yes (spinal cord ischemia)	alive
#27	Type I	yes (visceral graft thrombosis)	no	—
#28	Type III + AAA	yes (myocardial infarction)	yes (pancreatitis)	—
#29	Type II	no	no	kidney loss (visceral graft thrombosis)
#30	Type III	no	no	alive
#31	Type III + AAA	no	no	alive

[a] Not requiring dialysis.

hybrid TAAA repair should be particularly appealing in patients with poor cardiac function and valvulopathy.

However, although some authors,[15] based on their experience of a mortality rate of >30% in patients undergoing conventional open repair of extensive TAAA, encourage the use of hybrid TAAA repair in preference to conventional surgery in patients fit for surgery as well, we did not note in our series or literature review, probably due to the usual poor clinical conditions of the patients, a remarkable protective effect of hybrid treatment from typical complications of major surgery such as respiratory failure, coagulopathy and cardiac and renal complications. Furthermore, we observed the onset of new threatening complications specific to hybrid procedure especially related to the visceral grafts such as bowel infarction, pancreatitis and renal arteries thrombosis.

Spinal cord ischaemia

With regard to the problem of spinal cord ischaemia, if the risk of paraplegia during endovascular thoracic aortic procedures is lower compared to the open thoracic aortic surgery, it is a debated concern. During hybrid TAAA repair, the avoidance of supracoeliac clamping and the shortened duration of visceral ischaemia should lead to greater perioperative haemodynamic stability compared to

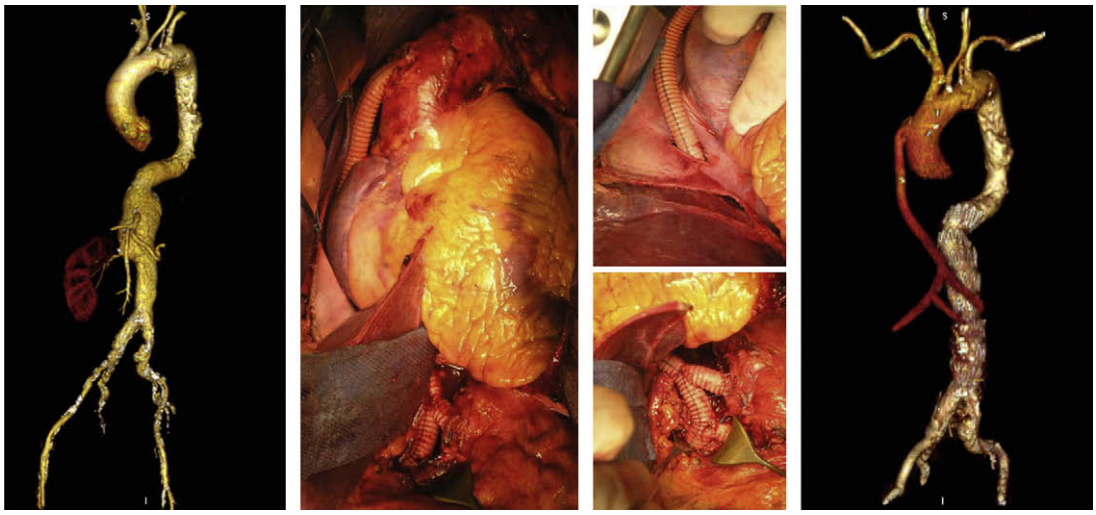

Figure 4 A patient with previous type IV TAAA conventional open repair by aortic grafting with bevelled proximal anastomosis developed a type III TAAA with severe retroperitoneal fibrosis; the left kidney was not functioning (preoperative computed tomography on the left). Revascularization of coeliac trunk, superior mesenteric artery and right renal artery was antegrade by means of a trifurcated graft attached to the ascending aorta and routed through the diaphragm (intra-operative images at the centre). Control computed tomography shows successful aneurysm exclusion (Cook Zenith TX2 ZTEG-2D-36-186) and good patency of the antegrade bypass (image at the right).

conventional open repair, and the risk of spinal cord ischaemia could be assumed to be reduced.[14]

In an animal model, Böckler et al. demonstrated that endovascular repair is associated with lower rates of spinal cord ischaemia and paraplegia than aortic cross-clamping.[29] These findings were confirmed in human by Carroccio et al.[30] This hypothetical advantage was likely balanced in our series by the increased risk of spinal cord ischaemia related to the high incidence of prior descending, abdominal or thoraco-abdominal aortic graft repairs in the patients we selected for hybrid TAAA repair.[25] However, the problem of paraplegia has not been eliminated by hybrid TAAA repair and extensive coverage of the thoraco-abdominal aorta could be identified as the cause of a still significant rate of spinal cord complications.

Greenberg et al.[31] compared total stent-graft length in patients with respect to the development of neurological deficit, demonstrating a significant association with the length of aortic coverage. Spinal cord ischaemia following thoracic endograft repair may be hypothesised to have a different aetiology with a better prognosis compared to open surgery,[32] and in our series we observed cases of delayed onset with a complete resolution after CSFD — a pattern quite unusual in our experience with open surgery.

Simultaneous or staged procedure?

The choice of simultaneous or staged procedure is another debated concern of hybrid TAAA repair and is related to the specific clinical conditions of every single case. The staged strategy reduces the burden of the procedure and theoretically reduces the risk of coagulopathy related to the aneurysmal sac thrombosis associated with the extensive surgical procedure required for visceral arteries re-routing. The one-stage strategy has the advantages to eliminate the risk of inter-surgical TAAA rupture and to offer a prompt iliac or aortic access site when femoral arteries are not adequate.

In case of staged repair in patients with inadequate femoral arteries, we learned that an interesting option is

Table 3 Table showing the major worldwide series of hybrid TAAA published (excluding our previous reports), reported in the current paper* and presented by MP Jenkins at European Society for Vascular Surgery Congress in 2007**.

Author	Pts. (*n*)	30-day mortality (%)	Morbidity (%)	Paraplegia/ paraparesis (%)	Renal failure (%)	Overall mortality (%)
Black et al.[15]	29	13	61	0	15.4	23
Böckler et al.[29]	28	14.3	59	11	11	30
Wolf et al.[17]	20	10	55	10	15	25
Zhou et al.[20]	15	NA	NA	NA	NA	NA
Resch et al.[18]	13	23	53	15	2	38.5
Lee et al.[19]	17	18	25	0	6	24
Chiesa*	31	19.4	35.5	9.6	6.4	35.5
Collaborative Group** (London/Heidelberg/Munich)	89	13	19	8	3	NA

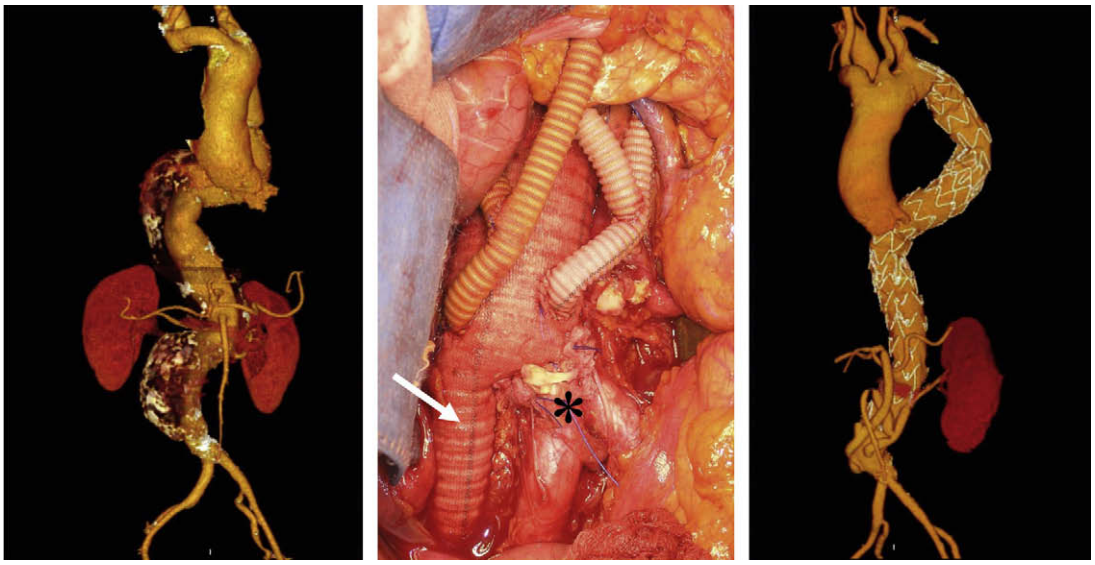

Figure 5 Preoperative TC showing a type II TAAA (left). The surgical stage consisted of infrarenal aorta grafting by means of a bifurcated graft (24 × 12 mm): the left branch was cut at the origin and anastomosed to the aortic carrefour (asterisk); the right branch (arrow) was routed to the groin and used as a conduit. The configuration chosen for retrograde four-vessel revascularization was a double ''Y'' graft (intra-operative image at centre). The control CT scan shows the successful aneurysm exclusion (Bolton Relay 38 − 34 × 190 + 38 − 34 × 145 + 36 − 32 × 190 mm) with right kidney loss due to bypass occlusion (right).

represented by the prosthetic conduits that can be attached to the abdominal aorta during the aortic de-branching and routed to the groin (Fig. 5). These side branches should be used selectively because they may increase the risk of infection and thrombotic embolisation during thrombectomy of thrombosed conduit before endograft insertion.

Ideal inflow site

Regarding the ideal inflow site for visceral bypasses, a previous abdominal aortic graft may be theoretically the best inflow site for the visceral bypasses avoiding clamping and suture on atherosclerotic native arterial wall. However, in our series, we learned that during the endovascular stage the take-off of visceral grafts from native or grafted aorta is not so easy to spot during angiography with a portable 'C-arm' despite lateral site of anastomosis and radiological markers, making it hard to comprehend where the actual distal neck ends. Thus, the common iliac artery can represent an inflow site making the endograft deployment easier and should be used preferably if it is of a good quality and also in absence of other specific concerns.

Visceral bypass outcomes

The long-term patency and safer route of visceral bypass are other matters of concern, and some devastating complications such as visceral graft occlusion and pancreatitis are not so uncommon both in our series and in reports from literature. We currently prefer the ante-pancreatic route for the vascularisation of the hepatic artery in order to reduce the risk of pancreatic injury through a posterior passageway.

We learned to always perform control angiography of the visceral bypasses both in single-stage and staged interventions for prompt correction of technical defects and dissections of visceral arteries and stenosis when required. One patient experienced a fatal bowel infarction in the inter-surgical interval, and no completion angiography was performed after visceral arteries re-routing.

In addition, the risk of late enteric erosion or fistula in their extra-anatomic route will need to be closely monitored with respect to the fate of visceral grafts.

Conclusion

With regard to all of the unsolved concerns discussed in this article and many others such as the long-term durability of endograft materials and the fate of excluded TAAA, we cannot provide any certain answer presently; therefore, larger study cohorts and longer follow-up are needed to make statistically meaningful comparisons and to consider all the biases related to the learning curve, the continuous technical progress and materials improvements typical of the evolving nature of hybrid TAAA repair.

Today, to the question if hybrid procedure is the best treatment option for TAAA, we believe the answer is 'no', because the standard open surgery through the inclusion technique in high-volume centres is the gold standard of treatment in good surgical candidates,[6] and hybrid TAAA repair is still limited as an alternative to simple observation in patients unfit for the inclusion technique.

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