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Review Article

Midterm Results of Endovascular Treatment for the Patients with Thoracoabdominal Aortic Aneurysms

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Treatment of thoracoabdominal aortic aneurysm (TAAA) remains a challenging pathology. Technologies and innovations of endovascular treatment, in particular the evolution of fenestrated and branched stent graft for complex aortic pathologies such as TAAA have provided excellent short-term results. However, the mid-term and long-term results of endovascular treatment for TAAA including endoleaks and branch patency are still unclear. This article provides an overview of available devices and results of endovascular treatment for TAAAs. (This is a translation of Jpn J Vasc Surg 2019; 28: 67–74.)

Keywords: thoracoabdominal aortic aneurysm, stent graft, fenestrated endovascular aortic repair (FEVAR), branched endovascular aortic repair (BEVAR)

Introduction

Thoracoabdominal aortic aneurysms (TAAA) are extensive aneurysms involving abdominal branches. The gold standard treatment for TAAA is open surgical repair (OSR) of the aneurysm, including branches reconstruction, where the aorta is exposed through a large spiral incision and the aorta is replaced with a prosthetic graft. However, conventional OSR for TAAA with prosthetic graft is associated with many complications, such as paraplegia, visceral ischemia, renal failure, pulmonary hemorrhage, and pneumonia. OSR for TAAA has many other problems, such as decreased activities of daily living and pain control of the wound, even in cases with a good course. According to a survey conducted in 2015 by the Japanese Association for Thoracic Surgery, the intraoperative mortality and in-hospital mortality rates for conventional OSR for TAAA are 5.1% and 9.6%, respectively. OSR for TAAA has similarly poor intraoperative and in-hospital mortality rates in Western countries (estimated 7%–10%). There is room for improvement compared with other diseases.[1)] The Crawford extension (Ext.) or the modified Crawford Ext. with an additional type V is used for TAAA classification. The postoperative paraplegia rate is high in the extensive Ext. II procedure (approximately 10%–14%).[1)] Currently, the endovascular treatment using stent graft is indicated for high-risk patients, such as elderly patients or those with co-morbidity such as respiratory failure. The endovascular treatment using stent graft excludes the aneurysm while preserving branch blood flow; thus, standard stent grafts are not indicated for these patients with TAAA. We reviewed the literature on the outcomes of endovascular treatment using stent graft for TAAA, including middle-term outcomes.

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Endovascular Treatment Using Stent Graft for Thoracoabdominal Aortic Aneurysms

Endovascular treatments for descending thoracic aortic aneurysms and abdominal aortic aneurysms are rapidly gaining popularity in Japan owing to their minimal invasiveness and good short-term outcomes. However, standard devices cannot be used for endovascular treatment of TAAA because they require completing the procedure while maintaining blood flow in the abdominal branches while excluding the aneurysm. Furthermore, the mid- to long-term outcomes are unknown. Fenestrated endovascular aortic repair (FEVAR),[2,3)] branched endovascular aneurysm repair (BEVAR),[4,5)] combined fenestrated and branched (F/BEVAR),[6–8)] physician-modified stent grafts

(PMSG),[9,10] and snorkel techniques[11,12] are used for endovascular treatment of TAAA. Safety, efficacy, and the ability to perform the procedure anytime and anywhere are some characteristics of an ideal stent graft procedure. In that sense, endovascular treatment that can be provided with off-the-shelf devices is ideal. Stent grafts for F/BEVAR are custom made and therefore, take time to be prepared, whereas PMSG[9,10] and snorkel techniques[11] can be performed using off-the-shelf-devices and are suitable for emergency cases. Recent studies have reported using off-the-shelf devices, such as multibranched endografts or t-Branch (Cook Medical, Bloomington, IN, USA)[12–14] and multilayer flow modulator stents (MFMS: Cardiatis, Isnes, Belgium)[15] as well. A hybrid surgery bypasses the abdominal branch and performs thoracic endovascular aortic repair (TEVAR).[16,17] The outcomes of these surgeries are discussed individually below.

Fenestrated and branched endovascular aneurysm repair (F/BEVAR, Table 1)

The two broad categories are: (1) FEVAR, in which a Zenith type stent graft with some fenestrations is placed, and a covered stent is placed over the fenestration and abdominal branch to create the branches and (2) BEVAR, in which the branched stent graft has some branches at the waist part of the main body of the stent graft, and branches have sleeves for overlapping portions to prevent type III endoleaks (side branches; **Table 1**). Another type is the multibranched endograft (t-Branch) with multiple branches. Because the branching part of t-Branch has a waist, the blood flow of visceral arteries is never occluded after the deployment of t-Branch even if the visceral arteries and sleeve positions are not exactly matched; thus, it can be used as an off-the-shelf device. Here we reviewed the techniques and early and mid-term outcomes of FEVAR and BEVAR. Though many reports exist on the short-term outcomes of FEVAR and BEVAR,[2–10] cautions are required because many articles are including the FEVAR/BEVAR for the pararenal abdominal aortic aneurysm (PRAAA).[3,7,8] In particular, PRAAA has good outcomes when compared with TAAA, and early outcomes for TAAA Ext. I–III, particularly Ext. II, are poor.[2,3] Few reports focus only on TAAA and few report on mid- and long-term outcomes (**Table 2**).[2,5,6,9,14,18]

The characteristics of the devices and operative techniques are described to understand these outcomes. FEVAR is performed using custom-made devices (CMD) that are customized to each patient's anatomy, or PMSGs for emergency surgeries.

Bilateral femoral arteries are surgically exposed to insert a stent graft for the thoracic aorta and premade fenestrated stent graft from one femoral artery and deployed. Next, several catheters are inserted from the brachial or opposite femoral artery to reconstruct the visceral branches of the abdominal aorta, often using the Atrium ADVANTA V12 covered stent (Maquet, Getinge group, Gothenburg, Sweden). However, branches that do not align with the fenestrations can cause branch occlusion and prolong occlusion time of the lower limbs, as well as type III endoleaks because of existence of many connec-

Table 1 Pros and cons of fenestrated and branched endovascular aortic repair for thoracoabdominal aortic aneurysms

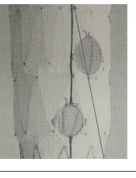
	Fenestrated EVAR (FEVAR)	Branched EVAR (BEVAR)
		
Advantages	•preferred for right angle take off visceral branches •possible when the stent graft body is against the aortic wall •minimal coverage of normal aorta	•shorter limb ischemia time because the main device is removed after deployment •main device has sleeves to prevent type III endoleaks •off-the-shelf device is available
Disadvantages	•longer limb ischemia time •possibility of type III endoleak from the attachment site of fenestration and stent graft for visceral branches •no off-the-shelf device need physician modified stent graft (PMSG) for emergent or urgent operation •frequent re-intervention after FEVAR using PMSG	•difficult when the stent graft body is against the aortic wall •longer coverage of normal aorta (increasing risk of spinal cord ischemia?) •longer reconstructed branches (higher incidence of renal occlusion?) •possibility of occlusion for right angle take off visceral branches→tortuosity of reconstructed branch is one of the risks of branch occlusion •possibility of cerebral infarction due to brachial access

Table 2 Midterm results of fenestrated and branched endovascular aortic repair for TAAA

	Reilly LM, et al.[5]	Verhoeven EL, et al.[6]	Eagleton MJ, et al.[2]	Baba T, et al.[18]	Oderich GS, et al.[9]	Silingardi R, et al.[14]
Publish year	2012	2015	2016	2017	2017	2018
Number of cases	N=81	N=166	N=354	N=44	N=185	N=73
Crawford extension (Ext.)	II 19 (23.5%) III 11 (13.6%) IV 19 (23.5%) V 9 (11.1%) PRAAA 23 (28.4%)	I 12 (7.2%) II 50 (30.1%) III 53 (31.9%) IV 41 (24.7%) V 10 (6.0%)	II 128 (36.2%) III 226 (63.8%)	I 7 (15.9%) II 13 (45.5%) III 6 (13.6%) V 18 (40.9%)	I–III 73 (40%) IV 112 (60%)	I 5 (7%) II 28 (38%) III 24 (33%) V 16 (22%)
Technique	MBEVAR 50 (61.7%) custom made 31 (38.3%) standard device	39 (23.5%) FEVAR fenestrations only 57 (34.4%) MBEVAR branches only 70 (42.2%) F/BEVAR Branches and fenestrations •right angle take off branches •stent graft body is against the aortic wall →fenestration	F/BEVAR 80 (22.6%) F/BEVAR 37 CA branch 8 SMA branch 35 CA+SMA branches 274 (77.4%) FEVAR	30 (68.2%) FEVAR 14 (31.8%) MBEVAR (t-Branch)	78 (42%) PMSG 107 (58%) F/MBEVAR	MBEVAR 41 elective 32 urgent/emergent
Technical success	100%	95%	94.1%	97.7% (FEVAR 96.7% MBEVAR100%)	94%	92%
Operative death Hospital death	3.7%	7.8% 9.0%	4.8%	4.5% (FEVAR 3.3% MBEVAR 7.1%)	4.3% (Ext. I–III 8% IV 2%) 8.2%	4%
Spinal cord ischemia Permanent paraplegia	23.5% 3.7%	9% 1.2%	8.8% (Ext. II 16.4% Ext. III 4.4%) 4% (Ext. II 7.8% Ext. III 1.8%)	15.9% FEVAR 6.7% MBEVAR 35.7%	4.8% (Ext. I–III 8.2% IV 2.7%) Early period 5.4% Later period 1.1% 3% (Ext. I–III 5% IV 2%)	3%
Stroke	4.9%	1.2%	2.3%	4.5% (FEVAR 0% MBEVAR 14.3%)	3%	3%
Renal failure Dialysis (permanent)	25.9% 4.9%	5.4%	2.8% (Ext. II 5.5% Ext. III 1.3%) 0%	2.3%	11% 1%	21% 3%
Type I/III endoleak All endoleaks	9 (11.1%) 19 (23.5%)	20 (12.0%) 33 (19.6%)	18 (5.1%) 10 (2.8%)	9 (20.4%) (FEVAR 26.7% MBEVAR 7.1%) 10 (22.7%) (FEVAR 30.0% MBEVAR 7.1%)	18 (10%) 24 (13%)	1% 2%
Early re-intervention	25 (30.9%)	12 (7.2%)	13 (3.7%)	7 (15.9%)	26 (14%)	5 (7%)

Table 2 (continued)

	Reilly LM, et al.[5]	Verhoeven EL, et al.[6]	Eagleton MJ, et al.[2]	Baba T, et al.[18]	Oderich GS, et al.[9]	Silingardi R, et al.[14]
Follow-up period (months)	21.4±17.6M	29.2±21M	22±19M	27.3±18.9M	22±20M	18M (1–43M)
Overall survival	1 month 93.4% 6 month 93.4% 2 year 74% 4 year 52%	1 year 83±3% 2 year 78±3.5% 5 year 66.6±6.1%	Ext. II Ext. III 1 year 78% 71% 81% 2 year 68% 60% 72% 3 year 57% 46% 62% 4 year 45% 32% 53% 5 year 40% 32% 43%		Ext. I–III Ext. IV 1 year 81±5% 92±3% 3 year 65±8% 72±6% 5 year 59±9% 56±10%	1 year 88% 2 year 86% 3 year 82% 100% in elective cases
Freedom from ARD	1 month 96% 6 month 93.4% 1 year 93.4% 2 year 93.4%		Ext. II Ext. III 1 year 94% 90% 96% 2 year 93% 90% 95% 3 year 91% 87% 94% 4 year 91% 87% 94% 5 year 89% 87% 90%	FEVAR MBEVAR 1 year 96.7% 92.9% 3 year 88.8% 92.9%		
Target vessel patency	94.8% CA SMA RA 97.4% 100% 93.9% stenosis/occlusion 3.9% 2.5% 14.2%	1 year 98±0.6% 2 year 97±0.7% 3 year 95.1±1.2% 4 year 94.2±1.5% 5 year 94.2±1.5%	CA SMA LRA RRA 1 year 98% 98% 97% 97% 2 year 98% 97% 94% 93% 3 year 94% 95% 94% 92% 5 year 96% 5% 94% 91%	FEVAR SMA occlusion 2/30pt (6.7%) RA occlusion 2/30pt (6.7%) MBEVAR RA occlusion 1/14pt (7.1%)	1 year 94±0.9% 5 year 93±2% Re-intervention in 13 cases (7%)	30 days 99% 1 year 96.5% 2 year 96.5% 3 year 96.5%
Freedom from re-intervention	1 year 66.1% 2 year 50% 3 year 50%	1 year 88.3±2.7% 2 year 82.7±3.5% 3 year 78.4±4.5% 5 year 70.4±7.0%	Ext. II Ext. III 1 year 76% 68% 80% 2 year 64% 52% 70% 3 year 54% 45% 58%	FEVAR MBEVAR 1 year 85.7% 92.9% 2 year 77.4% 92.9% 3 year 71.5% 92.9%	Ext. I–III Ext. IV 1 year 62±7% 80±4% 3 year 62±7% 58±8% 5 year 53±10% 50±9%	1 year 86% 2 year 83%
Remarks	Staged closure of branch to prevent spinal cord ischemia in 2 cases	Sac shrinkage 69% No change 26% Sac expansion 5%	Poor short- and mid-term results in Ext. II	Single stage treatment in all cases Frequent re-intervention after FEVAR High incidence of spinal cord ischemia and low incidence of re-intervention after MBEVAR	Type III endoleaks in 12 cases (6%)	43 (59%) staged 35 (81%) two steps 8 (19%) three steps Favorable results in staged procedure

PRAAA: pararenal abdominal aortic aneurysm; MBEVAR: multi-branched endovascular aneurysm repair; PMSG: physician modified stent graft; CA: celiac artery; SMA: superior mesenteric artery; RA: renal artery (RRA: right renal artery; LRA: left renal artery); SCI: spinal cord ischemia tions between the fenestrations of stent graft and branch stents with no overlaps.[19,20]

Multibranched endovascular aneurysm repair (MBEVAR) is a branched stent graft technique using the Cook Zenith t-Branch. Multibranched endografts (t-Branch) are devices developed for TAAA, in which the waist portion of the tube-shaped stent graft is narrowed and is prefitted with sleeves for the abdominal branches.[4,5,12] The covered stents are attached to these sleeves for incorporation of visceral vessels and provision of blood flow into these vessels. Though off-the-shelf t-Branches are available, they can be custom made with 18- or 21-mm overlap lengths and 6- or 8-mm diameters depending on patient anatomy.[12–14]

First, unilateral femoral artery is exposed, and the thoracic stent graft and t-Branch device are adjusted in clock positions, placed, and deployed. At this time, because the branch portion of the stent graft is tapered, there is no ischemia even if the t-Branch is deployed. Unlike FEVAR, strictly accurate positioning is not required because there is passable distance between the sleeves for the abdominal branches and the orifices of abdominal branches. Once the stent graft of the t-Branch is deployed, additional stent grafts can be deployed as needed, and the femoral artery is closed to restore blood flow of lower limb. Next, a 10-French guide sheath is inserted from the left brachial artery to the thoracic descending aorta to complete the branches to the abdominal branches. A self-expanding stent is placed after bridging an 8–10 mm diameter Fluency covered stent (Bard peripheral vascular; Bard, Inc., Tempe, AZ, USA) or Viabahn stent (W. L. Gore & Associates, Flagstaff, AZ, USA).

Stent graft therapy for TAAA includes methods such as FEVAR, BEVAR, and F/BEVAR, which combines fenestrated and branched grafts. In F/BEVAR, the branches are at near perpendicular angles, and FEVAR is often selected for branches close to the aortic wall, whereas BEVAR is often selected for caudally directed branches that are far from the aortic wall.[2,6]

Initial and short-term outcomes

Many reports exist on the initial and short-term outcomes of F/BEVAR. Good initial outcomes are reported with limited sample sizes. According to these outcomes, technical success rates in elective surgeries are 90%–97%, and 30-day mortality rates are approximately 0%–9%. Spinal cord ischemia (SCI) occurs in 4%–12%, and results for target vessel patency were good at 90%–100%.[2,4–10,12–14] SCI is a serious complication to be prevented in TAAA treatment. The risk of SCI increases with the extent of TAAA. Compared with a rate of 4.8% SCI in Ext. III (complete paraplegia 1.8%), the rate is 16.4% in Ext. II (complete paraplegia 7.8%).[2] As mentioned earlier, MBEVAR stent grafts have sleeves on the t-Branch portion. Although the incidence of postoperative type III endoleak is low, a high incidence of SCI is reported with MBEVAR either because it completely excludes the aneurysm, a longer extent of the aorta is covered or it is indicated for extensive aneurysms, such as Ext. II.[18] According to this report, MBEVAR was a risk factor of postoperative SCI next to aneurysm diameters of ≥65 mm, treatment lengths of ≥36 cm, and coverage of ≥5 intercostal arteries.[18] However, lower extremity weakness after MBEVAR occurred in 24 of 116 patients (20.6%), of which 15 were transient (62.5%) and approximately 80% occurred not in the operative room but followed a hypotensive event. The need for postoperative cerebrospinal fluid drainage and rigorous postoperative blood pressure management is also reported.[19] According to this report, there were no relationships among postoperative lower extremity weakness, Crawford Ext., staged surgery, and extent of the aneurysm or endoleaks.[19] Furthermore, a lower rate of SCI is associated with staged rather than single procedures. At the staged surgery of Ext. II TAAA, stent graft is deployed proximally to the visceral branches first and treatment of the branches is performed 2–3 months later. With this staged procedure, the 30-day mortality rates improved from 10.3% to 0%, incidence of SCI also improved from 37.5% to 11.1%, and incidence of complete paraplegia improved from 21.9% to 0%.[20]

In recent years, t-Branch has been used during emergency surgeries as an off-the-shelf devices with good overall results: intraoperative mortality rate is low at 4% and paraplegia rate at 3%, including emergency surgery cases.[14] As mentioned above, the t-Branch stent grafts are tapered, and the blood flow in the branches is maintained after deployment. The low paraplegia rate is also explained by the fact that second- and third-stage surgeries are possible when they are hemodynamically permitted.[14,20] Good outcomes have been reported in emergency surgery as well by not completing one branch (usually celiac artery [CA]) immediately but completing it 1–2 weeks later in the second-stage surgery. However, the treatment length of MBEVAR for Ext. III and IV, in particular, is significantly longer than that of open repair and consequently increases the number of intercostal arteries to cover; thus, caution is required.[21]

Mid- and long-term outcomes

Few reports exist on mid- and long-term outcomes of F/BEVAR (**Table 2**). The Cleveland Clinic has reported on mid- and long-term outcomes[2] (30-day mortality, 4.8%; SCI, 8.8%, and complete paraplegia, 4%) in 354 patients who underwent F/BEVAR for TAAA Ext. II and III. As mentioned previously, SCI occurs in 16.4% cases (complete paraplegia in 7.8%) of Ext. II TAAA but in 4.8%

cases (1.8%) of Ext. III. The mean follow-up period was 22 ± 19 months, and 1-, 2-, 3-, and 5-year survival rates were 78%, 68%, 57%, and 40%, respectively. The survival rates were also poorer for Ext. II. The 1-, 2-, 3-, and 5-year freedom rates from aneurysm-related death were good at 94%, 93%, 91%, and 89%, respectively. However, freedom rates from secondary intervention at 1, 2, and 3 years were 76%, 64%, and 54%, respectively, and the rates for Ext. II were poor at 68%, 52%, and 45%, respectively.

Endoleaks, branch patency rates, and secondary interventions

Incidence of endoleak after endovascular treatment for TAAA vary widely between 3% and 20%. Type III endoleaks are a characteristic after FEVAR. According to the aforementioned report by the Cleveland Clinic, of 67 patients (18.9%) requiring endoleak treatment, 42 (11.9%) had type III endoleaks.[2] A study of F/BEVAR on 123 patients lasting for a mean of 25 months reported 54 total additional therapies (1–6 times per patient), which were required for type III endoleaks, branch stenosis, and occlusion, in 32 patients (25%).[22] A report comparing CMD and PMSG, also from the Cleveland Clinic, found that the 1-year freedom rate from secondary intervention was 68% for PMSG, which was poorer, compared with 88% for CMD.[23] Of these 82 patients, 26 (31.7%) underwent secondary treatment during the 6-year follow-up period. Only seven patients underwent procedures with CMD (17%) compared with 19 who underwent procedures with PMSG (46.3%), that were required to treat type III endoleaks, branch stenosis, and occlusion.[23] This is believed to be because fenestrations are often created too widely because their positions are not accurate with respect to PMSG and because fenestrations have no reinforcement. Although PMSG can be used in emergency surgeries, the disadvantage is that many additional treatments may be required. Furthermore, the branch patency rates with FEVAR were 95.7% at 1 year and 88.6% at 4 years.[24]

There was an increase in patency rates with MBEVAR (t-Branch) depending on branches: the patency rates of the superior mesenteric artery (SMA), CA, and renal arteries were 100%, 97.9%, and 90.4%, respectively, in the 25.6-month mean follow-up period. Longer stent grafts are associated with higher occlusion rates for renal artery reconstruction.[25] The patency rate of the renal arterial branch at the 8-month follow-up period has been reported at 88.9%, and the tortuosity of the renal artery covered stent (length of the bridged covered stent/direct distance between the end of the sleeve and distal end of the covered stent) was the only risk for occlusion.[26] Furthermore, the mid-term outcomes of 81 patients who underwent MBEVAR in 2012 were characterized by a surprisingly high number of secondary interventions (42 times) in the 32 patients; however, 13 were related to endoleaks, 4 to branches, and only 1 to type III endoleak in the junction.[5] Unpredicted freedom rate from secondary intervention at 6 months and 1 year were both 82% for MBEVAR including emergency surgeries, but type III endoleaks only occurred in 1 of 17 patients.[13] As such, the operative technique has become very stable, as seen in the stable prevention of endoleaks.

F/BEVAR summary and futures

Currently, reliable methods to prevent SCI with certainty, whether to perform a single or staged procedure, and long-term outcomes, including TAAA sac shrinkage, are all matters requiring continuous investigation. Although many challenges remain to be overcome, F/BEVAR for TAAA has become more stable owing to improved devices and techniques and is starting to achieve stable initial outcomes and mid-term durability. BEVAR is superior for preventing endoleaks, but this advantage is limited to Ext. II or III. Furthermore, BEVAR requires upper limb access, therefore increasing the risk of cerebral infarction.[18] In contrast, long-term endoleaks are the challenges associated with FEVAR. Therefore, in the present study, F/BEVAR is indicated for high-risk patients, in whom a conventional OSR is difficult. Higher medical costs owing to increased device costs and secondary treatments are anticipated with the increase in F/BEVAR use. Higher F/BEVAR costs and rehospitalization rates were reported for PRAAA in one study,[8] whereas in another that compared conventional OSR with a prosthetic graft to F/BEVAR for TAAA, the costs of conventional OSR with a prosthetic graft were higher even after accounting for the cost of specialized stent grafts[27] and rates of rehospitalization were also more common after OSR.[28] Because conventional OSR is highly invasive, more patients required rehospitalization owing to postoperative pneumonitis and other complications. Invasiveness of the OSR for TAAA was proven, despite the fact that patients undergoing conventional OSR were younger and were assessed to have tolerance to surgery. Conventional OSR and F/BEVAR for TAAA warrant further improvement.

TEVAR with celiac artery coverage

Certain Ext. I or V TAAA can be treated by TEVAR with covering the CA, stent graft should be deployed just proximal to SMA. A stent also can be placed in SMA to secure a longer distal neck. This TEVAR with CA coverage method is considered safe and effective as long as there is connection between SMA and CA.[29] However, complications, such as cholecystitis, necrosis of the gallbladder, and pancreatitis, have been reported with this methods. A review of these reports found a high 30-day mortality rate of 9.7%, and approximately 30% of the deaths were owing to ischemia of abdominal organs.[29] This review included reports on cases with complications and therefore, the outcomes may represent worse rates than the actual. However, because the distal neck is compromised, secondary intervention is required in approximately 30% of cases due to endoleaks in the mid-term outcomes even if initial outcomes are good, and this condition requires careful observation.[29]

Chimney and sandwich techniques

The chimney technique extends the neck by inserting a covered stent in the abdominal branch parallel to the main stent graft. This method is used relatively often in stent graft treatments for PRAAA. The reverse chimney (periscope graft) method from the distal side also can be used.[11] A review of 176 PRAAA and 58 TAAA patients found a 5.1% mortality rate, 11.5% type I endoleak rate, and chimney stent occlusion in seven of 376 reconstructed branches (1.9%) at 12-month follow-up. Good mid-term outcomes have been reported as well: the branch patency rate was 98%, and aneurysm enlargement occurred in only four patients (5.2%) during the 25-month mean follow-up period.[11]

The sandwich technique is also considered when the distance between the abdominal branch and stent graft edge is long in TAAA.[30] The most important benefit of these treatments is that they can be used as off-the-shelf devices in emergency surgery. A study on 32 patients who underwent TEVAR using the sandwich technique, approximately half of which were emergency surgeries, reported technical success and operative mortality rates of 87.5% and 6.25%, respectively, which were decent; however, type I and III endoleaks occurred in seven patients (21.9%), and this rate was not negligible.[30] Furthermore, endoleaks were common when 3–4 chimney stents were used, and occlusion of the chimney stents also increased with the number of chimney stents. Furthermore, chimney stent occlusions occurred more frequently in chronic dissecting aortic aneurysms. Thus, the sandwich technique can be considered an option for emergency surgery.

Multilayer flow modulator stent (MFMS)

MFMS are multilayered cobalt alloy, self-expandable bare stents without a prosthetic graft, and their three-dimensional structures temporarily flow directly in one direction to embolize the aneurysm while preserving the branch blood flow.[15] MFMS require a very simple technique and have very good initial outcomes, such as low operative mortality and paraplegia rates, which have been reported even for high-risk cases. Branch patency is also good. However, some studies report room for improvement, such as measures for aneurysm enlargement, rupture, and stent migration.[15]

Hybrid surgery (abdominal branch bypass+stent graft) outcomes

Because conventional branched stent grafts are custom made and require at least 3–4 weeks for completion. Because of limitation of covered stent use in Japan, this method allows for securing blood flow after open operations by placing bypasses in abdominal branches through the common or external iliac artery, followed by inserting stent grafts that covers entirely up to the abdominal branch. This requires open surgery but was considered as minimally invasive because it does not require clamping the aorta or thoracotomy, so that organ ischemia time can be kept short. One study reported good short- and long-term outcomes with a 0%–2.3% operative mortality rate.[16] However, operative death rates are not satisfactory and are estimated to range from 8.5% to 34.2%. In terms of long-term outcomes, one-third of patients have been reported to experience some type of bypass-related complication[17]; thus, this procedure requires careful selection of candidates.

Conclusion

First line therapy for TAAA involves OSR. However, perioperative death and complication rates are high for OSR, and it is not indicated for "inoperable" TAAA patients who are advanced age or have cardiopulmonary co-morbidities or history of thoracotomy or abdominal surgery. Fenestrated/branched stent grafts are an option for these patients, in whom repair with OSR is difficult. However, many of these devices are not presently covered under Japanese national insurance and therefore require some time until they can be considered true therapeutic options.

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Additional Note

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