Innovative Application of Available Stent Grafts in Japan in Aortic Aneurysm Treatment—Significance of Innovative Debranching and Chimney Method and Coil Embolization Procedure

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Objective: We here describe our experience with innovative uses of these devices.

Patients and Methods: We reviewed treatment outcomes of 310 endovascular abdominal aortic repair (EVAR) and 83 thoracic endovascular aortic repair (TEVAR) cases performed between August 2007 and February 2012. We separately assessed results in elderly and high-risk patients who had a novel procedure. This group included 94 patients who underwent EVAR with IIA embolization, 10 patients who had EVAR and a renal artery chimney procedure for a short aortic neck, 20 patients who had two de-branching TEVAR or Chimney method for thoracic aortic aneurysms (TAA) and 3 patients who had debranching TEVAR for thoracic abdominal aortic aneurysms (TAAA).

Results: Of the 393 patients given stent grafts (SGs), 3 (0.8%) died in the hospital, including 1 patient with pneumonia who underwent EVAR and IIA embolization and 1 patient with a cerebral infarction who had TEVAR. Four patients (4.3%) who were treated with EVAR with internal iliac artery (IIA) embolization presented with residual buttock claudication 6 months postoperatively, and 3 patients (3.2%) had onset of ischemic enteritis; however, in all 7 patients, the condition resolved without additional intervention. In the 10 patients who had EVAR and a renal artery chimney method, the landing zone (LZ) was ≤10 mm, but neither endoleak nor renal artery occlusion was observed perioperatively or during midterm follow-up. Of the 20 patients who had a 2-debranching TEVAR, including 9 in whom the chimney method was used with the LZ in zone 0, 1 (5%) had a residual endoleak. In 3 patients with TAAA, we used SGs to cover 4 abdominal branches and bypassed the visceral artery; the outcomes were good, with all patients being ambulatory at hospital discharge.

Conclusion: Among innovative SGs treatments, the debranching procedure and the chimney method using catheterization and the coil-embolization technique provided good outcomes, as used in addition to surgical procedures. Aortic aneurysm treatment will become increasingly noninvasive with the continuing development of more innovative ways to use the SGs currently available in Japan. (*English Translation of Jpn J Vasc Surg 2012; 21: 165-173)

Keywords: aortic aneurysm, stentgraft, debranching procedure, chimney method, coil embolization
INTRODUCTION

The number of patients undergoing stent graft (SG) treatment for aortic aneurysms is increasing annually in Japan.\(^1\) This is considered to be due to the increased use of SGs with technical modifications at each facility for elderly patients and patients at high risk of open surgery (OS), not necessarily in compliance with the anatomical indications (instructions for use: IFU), because of the satisfactory therapeutic outcomes in patients to whom the procedure was applied in compliance with the IFU as well as the prolonging of the mean lifespan and an increase in the incidence of the disease.

At Shinshu University Hospital, which is based in Nagano Prefecture, with a high rate of elderly, about 40% of patients undergoing surgery for aortic aneurysms are aged 80 years or above,\(^2\) and the benefit of SG treatment and its modifications is considered to be marked. In this report, the modifications of the stent grafting procedure for aortic aneurysm that we have devised since 2007, when the treatment was first adopted, were evaluated.

SUBJECTS AND METHODS

At Shinshu University Hospital, SG treatment was initiated for abdominal aortic aneurysms (AAA) in August 2007 and for thoracic aortic aneurysms (TAA) in January 2009, and endovascular abdominal aortic repair (EVAR) and thoracic endovascular aortic repair (TEVAR) were performed in 310 and 83 patients, respectively, until February 2012 (Table 1). The mean age of all these patients was 77.4 ± 7.3 years. Debranching stent grafting accompanied by reconstruction of branches of the aorta was initiated in June 2010.

At our department, treatments have been conducted using devices covered by health insurance, and those requiring fenestrated or branched SGs,\(^3\) which must be privately imported, have not been introduced, although preparations have advanced. We have performed OS for disorders and achieved favorable outcomes by conventional OS with modifications of devices available in Japan primarily for elderly and high-risk patients. Such modifications have been made primarily for the following 4 SG procedures:

1. EVAR accompanied by internal iliac artery (IIA) embolization
2. EVAR accompanied by the renal artery chimney procedure for short-necked aneurysms
3. TEVAR accompanied by debranching of 2 or more of the 3 branches in the aortic arch or the chimney procedure for TAA
4. Debranching TEVAR for thoracic abdominal aortic aneurysms (TAAA)

We have regarded these 4 procedures as a series, considering debranching TEVAR as an applied SG technique based on coil embolization in EVAR with IIA embolization and EVAR with the renal artery chimney graft technique for short-necked aneurysms. In addition, while SG treatment for aortic dissection is attracting attention, we focused on the above 4 procedures in this report as we have not made positive modifications of procedures for aortic dissection except simple TEVAR for entry closure. Presently, the therapeutic principles and techniques employed at our department are as follows:

1. EVAR with IIA embolization

In principle, both uni- and bilateral IIA embolizations are indicated on the condition that the ipsilateral deep femoral artery (DFA) is patent and that informed consent concerning the possibility of buttock claudication is obtained. If these conditions are not fulfilled, we select OS, in principle. Also, regarding the possibility of intestinal ischemia associated with IIA embolization, we considered it desirable to perform some kind of blood flow evaluation, and adopted near-infrared spectroscopic (NIRS) monitoring of the buttock blood flow in OS for AAA\(^4\) in March 2011 as an index of intrapelvic blood

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Device (manufacturer)</th>
<th>No. of patients</th>
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<tbody>
<tr>
<td>EVAR (n = 310)</td>
<td>Excluder (^1)</td>
<td>174</td>
</tr>
<tr>
<td></td>
<td>Zenith (^2)</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>PowerLink (^3)</td>
<td>5</td>
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<td></td>
<td>Endurant (^4)</td>
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</tr>
<tr>
<td>TEVAR (n = 83)</td>
<td>TAG (^1)</td>
<td>67</td>
</tr>
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<td></td>
<td>Talent (^4)</td>
<td>11</td>
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<tr>
<td></td>
<td>TX2 (^2)</td>
<td>5</td>
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EVAR: endovascular abdominal aortic repair; TEVAR: thoracic endovascular aortic repair. * Including 3 TAAAs. \(^1\): WL Gore, Flagstaff, Arizona, USA; \(^2\): Cook Medical, Bloomington, Indiana, USA; \(^3\): Endologix, Irvine, California, USA; \(^4\): Medtronic, Minneapolis, Minnesota, USA
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As shown in Fig. 2A, when the proximal hook is applied with the slow deployment method at a position corresponding to the renal artery bifurcation angle, covering 1/2 or more of the renal artery orifice, the lumen of the renal artery is secured by placing a bare stent (Fig. 2B), and a proximal cuff is also positioned, if necessary, to increase the radial force. As renal artery stents, primarily balloon expandable bare stents of 4–5 mm in diameter, which fit the diameter of the renal artery, are used. In some patients with a difference in the bifurcation level between the left and right renal arteries, a landing zone (LZ) is determined to the lower margin of the higher-level bifurcation, and the chimney technique is performed, placing a stent in the lower renal artery. Recently, the Endurant Stent Graft System (Medtronic, Minneapolis, Minnesota, USA) with an IFU requiring an LZ of 10 mm or longer on the proximal side has become available, and either Endurant or Excluder with the chimney graft technique of the renal artery, placing a bare stent in the distal renal artery, is used selectively in consideration of flow (Fig. 1).

IIA embolization is performed primarily using 0.035-mm coils. Minimal branch embolization is performed in the proximal part of the IIA for common iliac artery aneurysms and at the base of the aneurysm when there is also an IIA aneurysm. As modifications of the procedure, we advance the sheath to a point near the embolization site, promote winding and prevent straightening of the coil by advancing and withdrawing the catheter, and tangle additional coils with the first coil.

2. EVAR with renal artery chimney grafting for short-necked aneurysms

EVAR for proximal short-necked aneurysms in the IFU borderline region is based on different principles among facilities, because it is difficult to standardize the indications, device selection, and SG procedure.5,6) At our department, Excluder® (WL Gore, Flagstaff, Arizona, USA) was primarily used for short-necked aneurysms particularly in elderly and OS-high-risk patients. As shown in Fig. 2A, when the proximal hook is applied with the slow deployment method at a position corresponding to the renal artery bifurcation angle, covering 1/2 or more of the renal artery orifice, the lumen of the renal artery is secured by placing a bare stent (Fig. 2B), and a proximal cuff is also positioned, if necessary, to increase the radial force. As renal artery stents, primarily balloon expandable bare stents of 4–5 mm in diameter, which fit the diameter of the renal artery, are used. In some patients with a difference in the bifurcation level between the left and right renal arteries, a landing zone (LZ) is determined to the lower margin of the higher-level bifurcation, and the chimney technique is performed, placing a stent in the lower renal artery. Recently, the Endurant Stent Graft System (Medtronic, Minneapolis, Minnesota, USA) with an IFU requiring an LZ of 10 mm or longer on the proximal side has become available, and either Endurant or Excluder with the chimney graft technique of the renal artery, placing a bare stent in the distal renal artery, is used selectively in consideration of flow (Fig. 1).
of the conditions around the renal artery.

3. **TEVAR with debranching of 2 or more of the 3 branches of the aortic arch or the chimney graft technique for TAA**

In elderly and OS-high-risk patients, mostly those aged 80 years or above, we have performed 2-vessel debranching TEVAR, debranching the left subclavian artery (SCA) and the left common carotid artery (CCA), since June 2010. Initially, TEVAR with a right-left axillary artery (Ax)/left CCA bypass using an 8-mm ePTFE T-shaped artificial vessel was performed in all patients. However, as the left SCA was not reconstructed in patients treated in compliance with the IFU by debranching the left SCA alone if there was no stenosis in either the left or right vertebral or basilar artery or hypoplasia of the basilar artery system,7 we have recently begun to perform TEVAR by either right-left CCA bypass + left SCA embolization (Fig. 3A) or the 2-vessel chimney graft technique covering 3 branches of the aortic arch setting the LZ in Zone 0 (Fig. 3B). TAG (WL Gore, USA) was used for the chimney graft technique in all patients. Since the maximum diameter of TAG presently available in Japan for the chimney graft technique with the LZ in Zone 0 is 40 mm, a diameter of the ascending aorta thinner than the usual indication (≤35 mm) is presently adopted as the anatomical indication.

4. **Debranching TEVAR for TAAA**

TEVAR with debranching of 4 abdominal branches was performed in 3 patients, who were basically emergent cases, and in whom the risk of OS was considered high, and revascularization by bypassing 4 abdominal branches using SGs was considered a better choice. We aim to reconstruct the superior mesenteric artery (SMA), celiac artery (CEA), and right renal artery through the right external iliac artery (EIA) with a retroperitoneal approach (using an 8-mm ePTFE artificial vessel) without detaching the aneurysm from the surrounding tissues, place SGs after similarly reconstructing the left renal
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emia due to PAD. He underwent common femoral artery (CFA) thromboendarterectomy and EVAR accompanied by bilateral IIA embolization under general anesthesia. Postoperatively, ischemic enteritis occurred, and, as hospitalization for conservative treatment was prolonged, the patient developed pneumonia and died on the 69th hospital day. The two who died after TEVAR were a patient who died due to acute retroperitoneal bleeding that occurred on the 2nd day after discharge from the ICU to the general ward, and a patient who died on the 22nd hospital day due to intraoperative multiple cerebral infarctions including those in the brainstem. Also, among all patients, 1 (0.3%) suffered aneurysm-related death a long time after treatment, which was caused by AAA rupture due to a delayed type III endoleak (EL) after EVAR. No patient required OS for aneurysms after the initial SG treatment even on long-term follow-up. Concerning OS for complications, after EVAR, femoral-femoral bypass surgery for leg ischemia was performed in 3, and enterectomy/colostomy for SMA embolization was performed in 1; after TEVAR, intraoperative repair of EIA damage was performed in 2 (using a 24 Fr sheath in both), enterectomy/colostomy for SMA embolization was performed in 1, ascending aorta replacement for proximal aortic dissection was performed in 1 who received TEVAR for a dissecting aortic aneurysm of the artery through the left EIA, and embolize the bifurcation of the SMA and CEA with coils, but the reconstruction method varies with the patient, as mentioned below.

Generally, also, we perform coil embolization in debranched SG treatment for aortic aneurysms using coils of 0.035 mm in diameter under flow control with a balloon to prevent coil migration and using 0.018-mm coils only at necessary sites.

Results

1. Results of all SG treatments

The ratio of the number of patients undergoing OS and SG treatment changes every year. In 2011, SG treatment was performed in 68.9% (71/103) and 42.3% (33/78) of all patients who underwent elective surgery for AAA and TAA, respectively. As a result of evaluation of indications in consideration of various factors, the frequency of SG treatment in EVAR decreased compared with 82.8% (101/122) in 2010, but that in TEVAR increased compared with 33.3% (25/79) in 2010. Of the patients who underwent SG treatment, hospital death was observed in 1 (0.3%) after EVAR and 2 (2.4%) after TEVAR. The patient who died after EVAR was a 91-year-old male with an 8-cm iliac artery aneurysm complicated by severe pulmonary emphysema and severe limb ischemia due to PAD. He underwent common femoral artery thromboendarterectomy and EVAR accompanied by bilateral IIA embolization under general anesthesia. Postoperatively, ischemic enteritis occurred, and, as hospitalization for conservative treatment was prolonged, the patient developed pneumonia and died on the 69th hospital day. The two who died after TEVAR were a patient who died due to acute retroperitoneal bleeding that occurred on the 2nd day after discharge from the ICU to the general ward, and a patient who died on the 22nd hospital day due to intraoperative multiple cerebral infarctions including those in the brainstem. Also, among all patients, 1 (0.3%) suffered aneurysm-related death a long time after treatment, which was caused by AAA rupture due to a delayed type III endoleak (EL) after EVAR. No patient required OS for aneurysms after the initial SG treatment even on long-term follow-up. Concerning OS for complications, after EVAR, femoro-femoral bypass surgery for leg ischemia was performed in 3, and enterectomy/colostomy for SMA embolization was performed in 1; after TEVAR, intraoperative repair of EIA damage was performed in 2 (using a 24 Fr sheath in both), enterectomy/colostomy for SMA embolization was performed in 1, ascending aorta replacement for proximal aortic dissection was performed in 1 who received TEVAR for a dissecting aortic aneurysm of the
distal arch, and lavage/drainage for cervical bypass graft infection was performed in 1 who underwent debranching TEVAR for an infected aneurysm of the ascending aorta. Paralysis of the lower body due to spinal cord ischemia was noted in 4, and while 2 showed almost complete recovery with conservative treatment including spinal cord drainage, paralysis persisted in the other 2 (2.4%). EL that occurred after EVAR was type Ia in 4 patients (1.3%), type Ib in 2 (0.6%), type II in 78 (25.2%), and type III in 5 (1.6%). It disappeared in all patients with additional treatment for types I and III. Of the 6 patients (7.7%) who showed 10-mm or greater enlargement of the aneurysm due to type II EL, embolization of the feeding artery was added in 5. Of these 5 patients, 2 underwent lumbar artery embolization through the IIA, 2 underwent inferior mesenteric artery (IMA) embolization through the SMA, and 1 underwent embolization by small-incision laparotomy, because percutaneous transcatheter embolization was unsuccessful. Embolization succeeded in all these patients, with a clear decrease in the aneurysm size in 4. Additional SG treatment in the leg was necessary in 3 due to type III EL. After TEVAR, type Ia EL was observed in 8 (9.6%), of whom EL resolved spontaneously in 4, but the additional treatments described below were carried out in the remaining 4. Enlargement of an aneurysm considered to have been due to type II EL of the intercostal artery (78→83 mm: 2 years and 2 months after SG treatment) was noted in only 1, additional TEVAR was performed in consideration of the possibility of type V EL, and the patient is presently being followed up.

2. EVAR with IIA embolization

IIA embolization was performed in 94 (30.3%) of the 310 patients who underwent EVAR. It was unilateral in 61 and bilateral in 33. Buttock claudication of 200 m or less was noted in 9, and although improvements were observed after surgery in all patients, it persisted in 4 (4.3%) on a follow-up over 25.8 ± 16.1 months. Of those in whom the bilateral DFAs were patent, ischemic enteritis was observed in 3 (3.2%), i.e., 2 and 1 who underwent uni- and bilateral IIA embolization, respectively, but could be managed conservatively in all patients. Since we had encountered the hospital death of a patient who had PAD and underwent bilateral IIA embolization but subsequently developed ischemic enteritis and pneumonia, we began to evaluate the intrapelvic blood flow by NIRS gluteal blood flow monitoring in March 2011. Of the 38 patients who underwent IIA embolization under gluteal blood flow monitoring, IIA reconstruction was performed in 1 (2.6%) who showed no recovery of the blood flow, and ischemic enteritis developed in 1 of the 37 patients who showed recovery.

3. EVAR for short-necked renal artery aneurysms

EVAR was performed for short-necked aneurysms of the renal artery not in conformity with the IFU in 32 (10.3%). In 10 of these patients, the LZ was 10 mm or shorter, and the treatment was performed using renal artery stents. None of these patients have developed type I IL, enlargement of the aneurysm, or renal artery occlusion based on postoperative follow-ups over 9.8 ± 6.2 months.

4. TEVAR with debranching of 2 or more of the 3 branches of the aortic arch or the chimney graft technique for TAA

Of the 20 patients who underwent debranching of 2 or more of the 3 branches of the aortic arch, the brachiocephalic artery was preserved by setting the LZ in Zone 1 in 11, and the blood flow of the arch branches was secured by the chimney graft technique by setting the LZ in Zone 0 in the remaining 9.

The branches of the aortic arch were reconstructed with bypasses in 16. Of these patients, right-left CCA/SCA bypass was also performed in 10, only the left SCA was preserved, and bypass surgery of the laterally reversed pattern was similarly performed to reconstruct the neck branches in 2 with aneurysms of the ascending aorta (DeBakey II dissecting aneurysm and infected cystic aneurysm) (Fig. 3C). In 4 recent cases, right-left CAA bypass grafting was performed without reconstruction of the left SCA.

Of the 9 patients who underwent the chimney graft technique, 1 chimney was made for the brachiocephalic artery (BCA) in 5, and 2 chimneys were made for the BCA and left CCA in 4. Type I EL persisted postoperatively in 4 who underwent the chimney graft technique among all 20 patients. EL was resolved in 2 after the placement of additional TAGs, and EL disappeared on aortography in the other 2 after transcatheter coil embolization for the gaps between the TAGs and chimney grafts (Fig. 4A, 4B, and 4C). Minor EL persisted on CT in 1 of these patients, additional embolization is planned if it is not resolved spontaneously, although EL persists on contrast-enhanced CT in 1 (5%) of all 20 patients who underwent debranching of 2 vessels. Since February 2012, intraoperative coil embolization has been planned...
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Fig. 4  Postoperative coil embolization to treat type I endoleak after two de-branching thoracic endovascular aortic repair (TEVAR) with chimney for arch aneurysm. (A) To treat an arch aneurysm, we preserved blood flow in the brachiocephalic artery (BCA) by using the chimney method and bypassed the left common carotid artery (CCA)/left subclavian artery (SCA) from the right SCA with an 8-mm T-shaped expanded polytetrafluoroethylene (ePTFE) graft. A type 1 endoleak from the inner curve of the leg of the Excluder device into the aneurysm sac was subsequently detected; it had not been observed on imaging of the aortography during the procedure. The arrows show the route of the endoleak and an accumulation of contrast agent in the sac. (B) Image obtained from the inner side of the leg shows the aneurysm sac and the proximal end of the ligated left CCA before coil embolization. The arrows show the route of the endoleak and an accumulation of contrast agent in the sac. (C) The aorta at coil embolization. Embolization with a coil (arrow) was performed throughout the garter between the two stent grafts (SGs). The patient was under local anesthesia during the procedure, and the site was accessed subcutaneously through the femoral artery.

Fig. 5  Two de-branching thoracic endovascular aortic repair (TEVAR) with chimney method. (A) Coil embolization was done in the garter (demarcated area) between the two stent grafts (SGs) through the left subclavian artery (SCA) to the ascending aorta. A catheter was then inserted into the garters on the left and right sides of the chimney graft, and coil embolization was done in each garter separately. (B) Embolization of the left SCA was not done initially because of the possible need for embolization of the garters if an endoleak developed postoperatively. However, postoperative computed tomography (CT) imaging showed occlusion of the aneurysm sac and left SCA (arrow) and no endoleaks; therefore, embolization of the left SCA was not required. (C) Blood flow in the left common carotid artery (CCA) was preserved with use of the chimney method (arrow); and the left SCA was bypassed from the left CCA.
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Another patient was transported to our hospital with a right hemothorax due to rupture of the residual TAAA. It was decided to perform SMA reconstruction as the minimum necessary procedure and to place SGs throughout the entire thoracoabdominal aorta, and the surgery resulted in the reconstruction of the SMA and right renal artery. The semi-emergent case was under hemodialysis for chronic renal failure, with imminent rupture of the dissecting TAAA, and showed enlargement of the false lumen. The SMA and CEA were reconstructed, and SGs were placed throughout the entire thoracoabdominal region (there was a history of Y-shaped artificial blood vessel replacement). The 3 patients showed an uneventful course, and were discharged in an ambulatory state.

**Discussion**

Indications of SG treatment for aortic aneurysm tend to be widening not only in Japan but also internationally. 1) to be performed prophylactically for garters of chimney grafts if EL is observed or considered possible (Fig. 5A). Nineteen patients except the 1 (5%) who died in the hospital due to cerebral infarction showed a favorable postoperative course and were discharged in an ambulatory state.

**5. Debranching TEVAR (EVAR) for TAAA**

SG treatment for TAAA covering 4 abdominal branches was performed in 3 patients (1 for rupture, 1 as semi-emergent surgery, 1 as elective surgery). The arteries reconstructed with bypasses were the SMA and right renal artery in the rupture case (the left renal artery was chronically obstructed due to aortic dissection; Fig. 6A), CEA and SMA in the semi-emergency case under hemodialysis (Fig. 6B), and all 4 abdominal branches in the elective case (Fig. 6C). The rupture case had a history of replacement of the aortic arch, descending aorta, and abdominal branches using a Y-shaped artificial blood vessel for an extensive dissecting aneurysm performed at another hospital, and was transported to our hospital with a right hemothorax due to rupture of the residual TAAA. It was decided to perform SMA reconstruction as the minimum necessary procedure and to place SGs throughout the entire thoracoabdominal aorta, and the surgery resulted in the reconstruction of the SMA and right renal artery. The semi-emergent case was under hemodialysis for chronic renal failure, with imminent rupture of the dissecting TAAA, and showed enlargement of the false lumen. The SMA and CEA were reconstructed, and SGs were placed throughout the entire thoracoabdominal region (there was a history of Y-shaped artificial blood vessel replacement). The 3 patients showed an uneventful course, and were discharged in an ambulatory state.

**Discussion**

Indications of SG treatment for aortic aneurysm tend to be widening not only in Japan but also internationally. 1)
At our department, also, OS is often indicated for patients aged 70 years or less from the viewpoint of the long-term outcome, but the frequency of SG treatment is increasing primarily in elderly patients. Of the 393 patients who underwent SG treatment at our department, 3 died in the hospital all due to SG-related causes, and the avoidance of pitfalls of endovascular manipulations in SG treatment including reevaluation of its indications is recognized afresh as extremely important for improving the therapeutic outcomes. There is no method for the complete prevention of cerebral infarction other than sufficient attention to the position of the SG stump and balloon occlusion of branches as well as careful manipulation. One patient died due to acute retroperitoneal bleeding on the 2nd postoperative day, but the treatment for this patient was postoperatively judged to have been in compliance with the IFU on the reevaluation of preoperative CT images by the Investigation Division of WL Gore. These problems will be resolved with the advent of hydrocoating and low-profile devices, but our present policy is to perform iliac artery puncture with a retroperitoneal approach after a small incision when necessary. Also, blood vessel prosthesis implantation was performed simultaneously for pararenal AAA in 1 of the 2 patients who postoperatively developed lower body paralysis, being in agreement with the report that blood vessel prosthesis implantation for the AAA is a risk factor for lower body paralysis after TEVAR. Since lower body paralysis markedly affects the QOL, the careful selection of procedures in consideration of various risk factors is also considered necessary for TEVAR. The overall incidence of EL after EVAR was in agreement with those in the literature, but the treatment for type II EL, in particular, is controversial. We performed embolization of the lumbar artery or IMA, which is a major cause of EL, in 5 patients by percutaneous catheterization and could reduce the aneurysm size. In addition, 1 patient died after a prolonged period due to rupture of the aneurysm associated with delayed type III EL, and we reaffirmed the importance of long-term follow-up after stent grafting.

Since the point of modifications of the stent grafting procedure is considered to lie in hybridization of endovascular manipulation and OS, we evaluated 4 procedures involving debranching, the chimney graft technique, and coil embolization in this study.

We treat buttock claudication, which may be caused by IIA embolization at EVAR, conservatively, in principle, because it often disappears shortly after surgery, and because, if it occurs, secondary reconstruction with bypass is possible. None of the patients treated at our department wished to undergo two-stage IIA reconstruction bypass surgery, possibly because of their lifestyle in Nagano Prefecture, in which daily life is largely dependent on automobiles. After we had encountered 3 cases of ischemic enteritis, we began to evaluate the intrapelvic blood flow by NIRS monitoring of the gluteal blood flow for assessing the risk, primarily, of intestinal ischemia. We are presently analyzing the data, but our policy is not to perform IIA reconstruction if clear improvement in the blood flow from the minimum level after IIA embolization due to collateral blood flow from the DFA is confirmed after sheath extraction. Since whether or not intestinal ischemia is caused by IIA embolization depends on the degree of development of collaterals from the SMA or bilateral DFAs, the severity of arteriosclerosis of branches of the IMA and IIA, which are collaterals, is considered more important.

Excluder is the first choice in EVAR for proximal short-necked aneurysms, because, if blood vessel prosthesis implantation by OS becomes necessary due to type Ia EL after EVAR, the same surgery as first-choice OS can be performed after treatment using an SG with no top stent. As a result, we have encountered no type I EL even after a prolonged period following EVAR for short-necked aneurysms, including 10 patients who underwent EVAR with the renal artery chimney graft technique for short necks of 10 mm or less. In treating short-necked aneurysms, which of the left and right approaches should be used must be evaluated more effectively to secure a 3-dimensional area of the LZ, and preoperative designing by 3D-CT is important. However, OS accompanied by suprarenal aortic clamping is a stable procedure, and we regard OS as the first choice for those aged 70 years or less from the viewpoint of the long-term outcome.

Proximal type I EL is a major factor that deteriorates the results of debranching TEVAR using the chimney graft technique for aortic arch-distal aortic arch aneurysms. If debranching TEVAR with bypass surgery is performed in branches of the aortic arch, EL may persist on the final angiography, and anatomical indications of the chimney graft technique are difficult to determine. Also, in the chimney graft technique with the LZ in Zone 0, we set a diameter of the ascending aorta of 35 mm or less as a condition for the use of a TAG of 40 mm in diameter. Actually, however, the aortic diameter is about 35 mm in many patients, and the applicability of
the TAG is often questionable. Since the risk of type I EL is higher in the chimney graft technique with the LZ in Zone 0 than in usual TEVAR, subsequent measures for type I EL are necessary. To cope with this problem, we have recently adopted coil embolization of the garters between SGs and chimney grafts. 21) This procedure has been performed in a total of 5 patients consisting of 3 who showed intraoperative EL, which was minor in some, and 2 in whom EL was confirmed by postoperative CT. Since EL disappeared on aortography in all patients, suggesting the effectiveness of the procedure, we have decided to perform coil embolization when debranching TEVAR using the chimney graft technique is selected until branched SGs become available in the future. The embolization power is vital in coil embolization of the aorta and its branches, and we attach importance to modifications of the manipulation to consistently place 0.035-mm coils. This often allows management of the enlargement of aneurysms associated with type II EL after EVAR and type I EL associated with debranching TEVAR. Presently, we consider the following method to be reasonable for the chimney graft technique with the LZ in Zone 0: After SG placement, performing angiography and, if necessary, coil embolization of the sacrificed left SCA to the garter of SG, and, after confirming the absence of type I EL by postoperative CT, performing embolization of the left SCA percutaneously through the left brachial artery as a second step. We consider this procedure to be reasonable, because the pressure of the left SCA can be reduced by SG implantation with a consequent reduction in the risk of rupture due to not performing embolization. We have encountered a case in which the left SCA scheduled to be embolized as well as the TAA were spontaneously occluded after this procedure (Fig. 5B). In distal aortic arch aneurysms, the blood flow of the left CCA can also be secured by the chimney graft technique similarly to EVAR for short-necked AAA (Fig. 5C), and flexible evaluation of the treatment pattern depending on the location of the aneurysm and the state of branches of the aortic arch is considered important.

In debranching TEVAR for TAAA, various modifications of the bypass procedure to the abdominal splanchnic artery have been devised at many facilities. 22–23) Our method for bypass surgery is a combination of conventional open iliac artery-SMA bypass surgery for SMA occlusion and aneurysmectomy by the retroperitoneal approach. Since the procedure allows the avoidance of tissue detachment around the aneurysm or the pancreas except for Kocher mobilization as an advantage but necessitates widening of the area of detachment as a disadvantage, it is desirable to perform bypass surgery and TEVAR in 2 stages. Further evaluation for improvements in the procedure is considered necessary.

**Conclusion**

Modifications of SG treatment with debranching and the chimney graft technique for aortic aneurysms using commercial devices available in Japan were reported. Mildly invasive treatments for elderly patients, etc., are often possible by combining surgical and catheterization techniques and using commercial devices presently available in Japan in ways not in compliance with the IFU. However, the introduction of; and improvements in, fenestrated or branched SGs and devices effective for the treatment of aortic dissection are awaited in Japan.

**References**