ORIGINAL ARTICLE

Outcomes of abdominal false lumen embolization for chronic aortic dissection after prior proximal repair with stent-graft

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Abstract

Background: Persistent false lumen (FL) perfusion with aneurysmal formation is common after thoracic endovascular aortic repair (TEVAR) for typical extended aortic dissection and is associated with poor outcomes. Endovascular FL embolization (FLE) has recently been tried for treatment of postdissection aortic aneurysm (PDAA). However, most reports address thoracic rather than abdominal FLE. In this study, we present the results of abdominal FLE in patients with residual patent abdominal FL following stent-graft repair for aortic dissection.

Methods: Between 2015 and 2019, 24 patients (mean age: 56.7 ± 11.8 years, range: 40-84 years, 18 male) received endovascular abdominal FLE using vascular plugs, coils, or candy plugs as the main surgery (5 patients) or auxiliary procedure (19 patients) after earlier stent-graft repair for aortic dissection (Type A: 9, Type B: 15). The medical records were reviewed and aortic remodeling was examined comparing the preembolization computed tomography (CT) and the most recent CT before reintervention.

Results: Technical success was achieved without any intraoperative complications, early morbidity, or mortality. Median follow-up was 34.4 months (range: 12-71). Regarding thoracic FL, 15 patients exhibited complete thrombosis before the procedure and did not change status thereafter except for 1 patient with distal stent-graft-induced new entry. In the other 9 patients, 6 exhibited increased thrombosis. With regard to the abdominal aorta, increased FL thrombosis only occurred in 8 patients with 3 (12.5%) achieving complete thrombosis. The maximal thoracic aortic diameter did not change (1.4 ± 5.6 mm) statistically, but the abdominal diameter increased significantly (4.3 ± 3.7 mm, $p < 0.005$).

Conclusion: From our results, abdominal FLE is a safe procedure. However, covering all the re-entry tears is complex and the possibility of complete FL thrombosis is low. The abdominal aortic diameter appears to become enlarged in these patients. Continuous follow-up is necessary after FLE.

Keywords: Aortic dissection; Embolization; False lumen

1. INTRODUCTION

Thoracic endovascular aortic repair (TEVAR) has become the primary treatment for complicated type B aortic dissections.[1,2] The goal of TEVAR is to eliminate antegrade flow into the false lumen (FL) by covering the proximal aortic tear with stent-graft placed in the true lumen (TL) of the descending aorta. Closure of the primary tear also facilitates thrombosis and the subsequent regression of the FL and re-expansion of the TL, a late effect known as aortic remodeling.[3]

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Favorable aortic remodeling (ie, complete thrombosis and resolution of the FL) is considered the ideal morphological change in the aorta post stent-graft for type B aortic dissection, and it is associated with improved long-term outcomes.[1,3,4] FL thrombosis occurs more effectively in the stented part of the dissected aorta, and favorable remodeling occurs more frequently in patients with limited dissection.[5] In patients with DeBakey IIIb aortic dissection, the abdominal aortic FL usually remains patent post stent-graft repair, even after total thrombosis in the stented segment.[6,7] Persistent retrograde flow into the FL through the remaining distal re-entry tears or intimal fenestrations related to the branch vessels could preclude complete thrombosis and eventually lead to aortic dilatation and postdissection aortic aneurysm (PDAA), which is the main cause of late mortality or other severe complications.[8] An estimated 13.4% to 62.5% of patients have different degrees of PDAA even after successful stent-graft repair.[4,9]

For PDAA, an endovascular approach is regarded as a less invasive treatment with acceptable early outcomes if the patient is unable to tolerate traditional open surgery.[10,11] Endovascular repair can be classified into interventions from the TL side and from the FL side. Although endovascular FL embolization (FLE) has been performed previously, the procedure is generally used for thoracic thrombosis, like a candy-plug technique.[11–14] Abdominal FLE is rarely attempted because of the complexities of the vital visceral branches.[15,16]

Herein, we report the midterm outcomes of endovascular FLE aimed at the abdominal segment for a dissection patient post-thoracic stent-graft implantation with or without FLE for thoracic thrombosis.

2. METHODS

2.1. Patient population

This retrospective study was approved by the Institutional Review Board of the Taipei Veterans General Hospital (approval number: 2022-02-011CC). Informed written consent to access medical records was obtained from each patient.

The indications for surgery were similar to those for open surgery, such as aneurysms >5.5 cm in diameter or a rapidly expanding aorta (>1 cm/y) with the persistent opacification and enlargement of the FL. High-risk patients with severe radiographic malperfusion[17] and distal stent-graft–induced new entry (SINE) were also included.[18] FLE may be performed as the main or auxiliary procedure.

2.2. Embolization technique

Under general anesthesia, the patient was placed in a supine position and draped in a routine manner. The bilateral femoral arteries were cannulated using cutdown or predeployed with vascular closure devices (ProGlide; Abbott Vascular, Santa Clara, CA, USA). Two.035-inch Terumo wires were inserted, one advanced toward the TL and the other advanced FL through the distal reentry tear. An angiocatheter followed the wire, and an angiogram was performed to confirm the TL and FL. If the visceral artery was originally from the FL, the TL wire was cannulated nearby tear from the TL to the branch. A supporting catheter followed this wire, and an Amplatz extra-stiff wire replaced the Terumo wire. Subsequently, a stent-graft (Atrium Advanta V12, Getinge, Merrimack, NH, USA or Viabahn, W.L. Gore & Associates, Flagstaff, AZ, USA; LifeStream, balloon expandable vascular covered stent, Bard Medical, GA, USA) was deployed between nearby tear and visceral branch for rerouting or stenosis. Subsequently, plug, coil, or candy-plug was inserted. For plug deployment (Amplatzer Vascular Plug or Vascular Plug II; Abbott, or Zenith iliac plug, Cook, Bloomington, IN, USA), a guiding catheter followed the FL wire was setup at desired position. The plug catheter was inserted guided by the catheter and was deployed in the FL after rotating the delivery wire. Coils (Nester or Tornado Embolization coil, Cook) were deployed in the same manner as the plug. For the handmade candy plug (Fig. 1), a Medtronic (Valiant Captivia, Minneapolis, MN, USA) or Cook (Zenith TX2) stent-graft was applied. The Medtronic stent-graft was completely deployed on the side table. A 10-mL

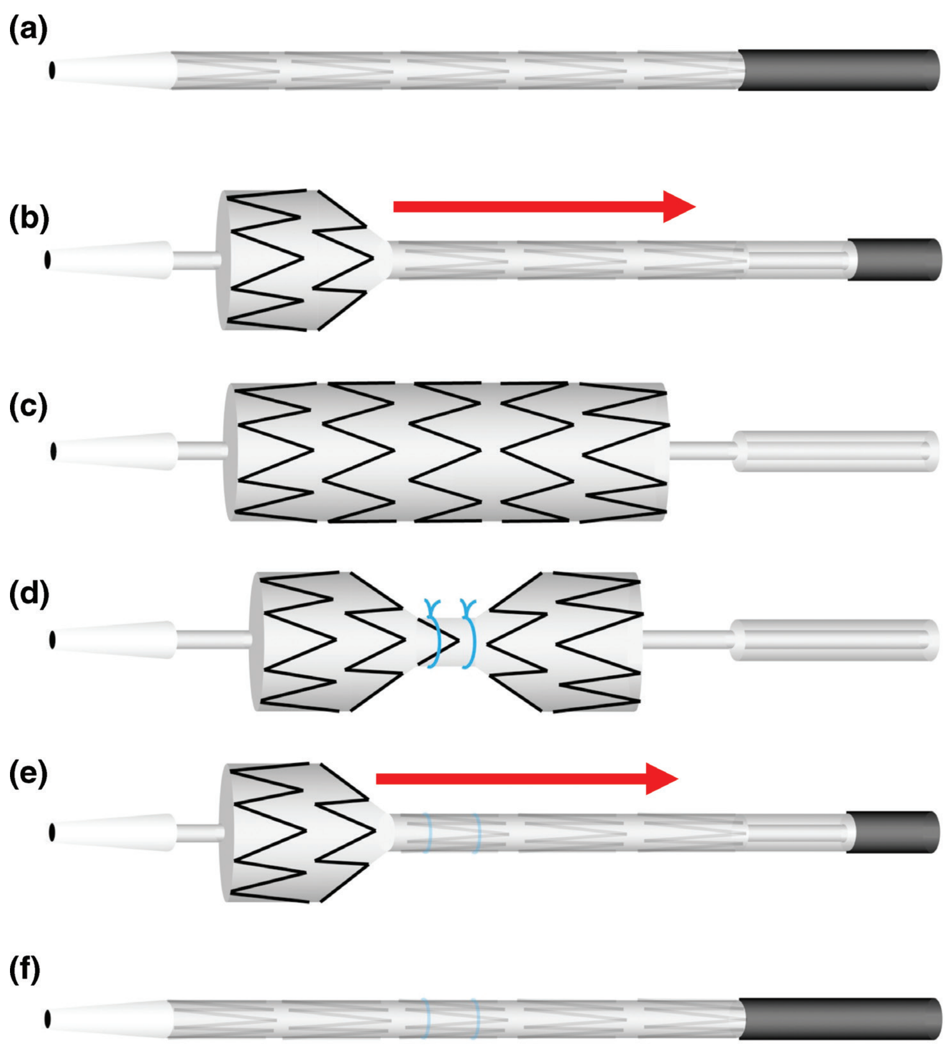

Fig. 1 Technique of handmade candy-plug. (a) A medtronic (Valiant Captivia, Minneapolis, MN, USA) or Cook (Zenith TX2) stent-graft was applied. (b, c) The Medtronic stent-graft was completely deployed on the side table. (d) A 10-mL syringe was placed in the middle of the stent-graft and compressed and then fixed with 5-0 Prolene. This fixation gives the stent-graft a wrapped candy shape. (e, f) This candy plug was reloaded to deliver the catheter.

syringe was placed in the middle of the stent-graft and compressed and then fixed with 5-0 Prolene. This fixation gives the stent-graft a wrapped candy shape. This candy plug was reloaded to deliver the catheter.[19] The Cook stent-graft was partially deployed on the side table and fixed with 5-0 Prolene in the middle. Subsequently, the stent-graft was reloaded. The reloaded candy plug was delivered to the FL and deployed completely. An additional Amplatzer vascular plug was delivered to the waist of the candy plug to complete the occlusion.

2.3. Associated procedures (TEVAR and EVAR)

Before the FLE, either TEVAR or endovascular aneurysm repair (EVAR) was performed. The wire was advanced to the ascending aorta and an angiocatheter followed the wire. An aortogram was performed. A thoracic aortic aneurysm (TAA; Zenith TX2, Cook; TAG, Gore) or abdominal aortic aneurysm (AAA) main-body stent-graft (Excluder, Gore) was delivered and deployed. A TAA stent-graft cannot deploy beyond the T8 level. However, bare metal stent (Zenith Dissection Endovascular Stent, Cook) can extend until the aortic bifurcation, if necessary. As for the AAA stent-graft, an ipsilateral and contralateral iliac stent-graft can extend from the AAA main body individually. A final aortogram and endoleak check were performed.

2.4. Measurement and follow-up

All patients received computed tomography (CT) surveillance, according to their schedule. The patients were required to visit our clinic regularly every 3 months after discharge. The scan images were uploaded and saved for further evaluation. CT was performed using a Hi-Speed Advantage scanner (GE Healthcare, Waukesha, WI, USA) with a 5-mm collimation setting, 10-mm/s table speed, pitch = 2, and a 120-kV, 230 to 250-mA tube current. The entire aorta from the aortic arch to the bilateral iliac arteries was divided into thoracic and abdominal segments at the celiac trunk level. The diameters of the abdominal and thoracic aorta were measured at axial view using SmartIris software. All the diameter measurements were performed perpendicular to the center lumen line.[7] The status of the FL on the imaging was classified as patent if a flow was present in the absence of thrombus, partially thrombosed if both a flow and thrombus were present, or completely thrombosed if no flow was present.[20]

2.5. Statistical analysis

Continuous variables are presented as mean ± standard deviation, and a *t* test was used for the aortic remodeling analysis. A p value <0.05 was considered statistically significant. Data were analyzed using SPSS statistical software (Version 22.0; IBM, Armonk, NY, USA).

3. RESULTS

Between August 2015 and July 2019, a total of 24 patients underwent endovascular abdominal FLE at our hospital. The mean age was 56.7 ± 11.8 years (40-84) with a predominance of male patients (18, 75%). The median follow-up was 34.4 months (range: 12-71 months).

The basic characteristics of the patients and previous operative information are summarized in Tables 1 and 2. Twenty-two patients had hypertension and 2 had Marfan syndrome. Four patients had cerebrovascular attack before abdominal FLE, and stroke was related to previous aortic surgery in 3 of them. Of these patients, 9 had an operational history of type A aortic dissection and the other 15 had undergone TEVAR or open surgery with frozen elephant trunk (FET) implantation through sternotomy for type B aortic dissection.

Before abdominal FLE, these patients had undergone an average of 2.2 ± 0.99 aortic operations or interventions. Patient 7 received aortic root reconstruction due to severe aortic regurgitation and root aneurysm one year before onset of type B aortic dissection. Thirteen patients had undergone a provisional

Table 1

Basic characteristics of the patients before false lumen embolization

Patient	Age	Sex	HTN	Marfan	Smoking	DM	CVA	eGFR	Dissection
1	52	M	+	−	+	−	−	123	Type A
2	60	M	+	−	+	−	+	79.35	Type A
3	48	M	+	−	+	−	−	51.9	Type A
4	43	F	−	+	−	−	−	107	Type B
5	79	M	+	−	+	−	−	HD	Type B
6	64	M	+	−	+	−	−	84.14	Type A
7	55	F	−	+	−	−	−	61.39	Type B
8	75	F	+	−	+	−	−	22.86	Type B
9	52	M	+	−	+	+	−	120	Type B
10	54	M	+	−	+	+	−	113.5	Type B
11	50	M	+	−	+	+	+	80.81	Type A
12	69	F	+	−	−	+	−	40.23	Type B
13	48	M	+	−	−	−	−	76.04	Type B
14	40	M	+	−	−	−	+	98.25	Type B
15	57	M	+	−	−	−	−	63.13	Type A
16	71	M	+	−	+	+	−	34.47	Type B
17	42	M	+	−	−	−	−	82.76	Type B
18	50	M	+	−	−	−	−	191.22	Type A
19	55	M	+	−	+	−	−	78.37	Type B
20	44	M	+	−	+	+	+	70.21	Type A
21	50	M	+	−	−	−	−	77	Type B
22	81	M	+	−	−	−	−	HD	Type B
23	73	F	+	−	−	−	−	80	Type B
24	52	F	+	−	−	−	−	79.87	Type A

The eGFR unit is mL/min.

eGFR = estimated glomerular filtration rate; HTN = hypertension; DM = diabetes mellitus; CVA = cerebrovascular accident.

Table 2

Previous aortic operations before false lumen embolization

Patient	Surgery 1	Surgery 2	Surgery 3	Surgery 4
1	AVR + TAR + FET	TEVAR (Petticoat)		
2	Ascending aortic replacement	TEVAR	TAR + FET	Rt renal stent-graft
3	Ascending aortic replacement	Aortic root reconstruction + TAR + FET	TEVAR (Petticoat)	
4	TAR + FET	TEVAR	TEVAR (Petticoat)	Rt renal and Rt EIA stent-graft
5	TEVAR (Zone 2) + Lt CS bypass	TEVAR		
6	Ascending aortic replacement	RCCA-LCCA bypass + TEVAR (Zone 1)	TEVAR	TEVAR (Petticoat) + Rt renal stent-graft
7	Aortic root reconstruction	TEVAR (Petticoat) (Zone 2) + Lt CS bypass + LSCA embolization		
8	TAR + FET	LSCA embolization	Lt CS bypass	
9	TEVAR (Zone 3)	TEVAR (Petticoat) + Rt renal and celiac trunk stent-graft		
10	Distal arch replacement + FET	Lt CS bypass		
11	TAR + FET	EVAR		
12	TEVAR (Zone 1) + LCCA stent (chimney) + LSCA embolization			
13	Ascending aortic replacement	TAR + FET + TEVAR (Petticoat)	LSCA embolization	
14	TAR + FET + TEVAR (Petticoat)			
15	TAR + FET	TEVAR (Petticoat)	Lt renal stent-graft + EVAR	
16	Aorto-bilateral carotid bypass + TEVAR (Petticoat) (Zone 0) + Lt CS bypass			
17	TEAVR (Zone 4)			
18	Ascending aortic replacement	TEVAR (Zone 2) + Lt CS bypass	TEVAR (Petticoat)	
19	TEVAR (Zone 2) + Lt CS bypass + LSCA embolization			
20	TAR	TEVAR (Petticoat) (Zone 2) + Lt CS bypass + LSCA embolization		
21	TEVAR (Petticoat) (Zone 2) + thoracic FL embolization			
22	TEVAR (Zone 1) + LCCA and LSCA stent-graft (chimney)			
23	TEVAR (Zone 3)	TEVAR (Zone 4)		
24	Ascending aortic replacement	TEVAR (Zone 2) + LSCA embolization		

AVR = aortic valve replacement; CS bypass = common carotid artery-subclavian artery bypass; EIA = external iliac artery; EVAR = endovascular aneurysm repair; FET = frozen elephant trunk; FL = false lumen; LCCA = left common carotid artery; LSCA = left subclavian artery; Lt = left; RCCA = right common carotid artery; Rt = right; TAR = total arch replacement; TEVAR = thoracic endovascular aortic repair.

extension to induce complete attachment (PETTICOAT) procedure for severe TL compression. Four patients had received renal artery stent-graft (patients 2, 4, 6, and 15) for rerouting, and 1 patient had received renal artery and celiac trunk stent-graft for malperfusion (patient 9). Patient 11 had previously undergone an EVAR procedure for degenerative infrarenal abdominal aortic aneurysm, and patient 15 had undergone EVAR and rerouting of the left renal artery for PDAA after total arch replacement with FET and PETTICOAT procedure for type A dissection. Patient 21 had also previously undergone thoracic FLE (candy-plug technique). No type 1 or 2 endoleak from the left subclavian artery were identified in these patients during abdominal FLE.

The operative procedures and device implantation and information are summarized in Table 3.

Vascular plugs, coils, and handmade candy plugs were used for embolization. Abdominal FLE was performed as the main surgery (5 patients, patients 2, 5, 7, 11, and 21) or auxiliary to other procedures simultaneously (19 patients), including extension using the TEVAR or PETTICOAT procedure for severe TL compression (8 patients), EVAR for PDAA (2 patients), stent-graft implantation in the visceral branch for compression (7 patients), or rerouting to seal the fenestration (left kidney in patient 20). Extension using the PETTICOAT procedure requires implantation with aortic bare stents only. Four patients received thoracic FLE (candy-plug) simultaneously (patients 6, 9, 15, and 16). Patient 12 received external iliac artery stent-graft to cover the fenestration hole in addition to embolization. Technical success was achieved in all patients without any intraoperative complications. Thirty-day morbidity and mortality were also 0.

The aortic remodeling was examined through a comparison with the preembolization CT and most recent CT before the reintervention after FLE (Table 4). Regarding thoracic FL, 15 patients exhibited complete thrombosis before the procedure without changing their thrombotic status thereafter with the exception of 1 patient who had distal SINE (patient 13). In the other 9 patients, 6 exhibited increased thrombosis after the procedure (1 from patent to partial thrombosis, 2 from patent to complete thrombosis, 3 from partial to complete thrombosis). Only 1 (patient 16) of the 4 patients who underwent thoracic FLE (candy-plug) experienced a change in their thrombotic condition.

With regard to the abdominal aorta, increased FL thrombosis only occurred in 8 patients (5 from patent to partial thrombosis and 3 [12.5%] from partial to complete thrombosis), and no change was identified in 16 patients. In terms of aortic diameter change, the thoracic diameter increased in 15 patients and the abdominal diameter increased in 22 patients. Only patients 4 and 24 exhibited a decreased abdominal diameter. Statistically, the abdominal diameter increased significantly (4.3 ± 3.7 mm, $p < 0.005$) but not the thoracic diameter (1.4 ± 5.6 mm).

Table 3

Surgical procedures and device implantation

Patient	Procedures	Embolization device in false lumen	Device in true lumen
1	FL embolization + extension TEVAR	AVP2-020, -022	Gore TGU313110 + TGU312610
2[a]	FL embolization	AVP2-022	Nil
3	FL embolization + extension TEVAR	AVP2-018, -022	Gore TGU313110 + PLA320400 + PLA230300*2
4	FL embolization + EVAR	PLUG-012, -014, -016*5 & AVP2-018, -020, -022	Gore RMT281212 + PXC141000 + PXL161007
5[a]	FL embolization	PLUG-010, -014, -016*4	nil
6	FL embolization (including candy-plug for thoracic FL) + SMA stent-graft	Candy-plug (Medtronic VAMC3232C150TE with AVP2-022 + VAMC2222C100TE with AVP2-020) AVP2-016, -018 & Plug 016; Nester 14 mm*3	Bard LSMU131238 **+** extended with Medtronic SC1040LG
7[a]	FL embolization	AVP2-022 and PLUG-016*2	Nil
8	FL embolization + extension with Petticoat	AVP2-020, -022*2	Cook ZDES-36-180
9	FL embolization (including candy-plug for thoracic FL)	Candy-plug: Zenith iliac plug 16 × 30 mm, 20 × 30 mm, 24 × 30 mm AVP2-020, -022	Nil
10	FL embolization + extension with Petticoat	PLUG-016*3	Cook ZDES-36-180x2
11[a]	FL embolization	AVP2-022	Nil
12	FL embolization + right EIA stent-graft	PLUG-008, -012, -016*2	Bard LSMU1350837
13	FL embolization + Rt renal stent-graft	PLUG-012, -014	Atrium V12 5 × 38 mm
14	FL embolization + Lt renal stent-graft	PLUG-012, -014, -016*2	Atrium V12 6 × 38 mm
15	FL embolization (including candy-plug for thoracic FL)	Candy-plug (Medtronic VAMC2222C100TE with PLUG-016) PLUG-016*5 & AVP2-018, -020, -022	Nil
16	FL embolization (including candy-plug for thoracic FL)	Candy plug (COOK TBE-32-80-PF with PLUG-016) PLUG-016	Nil
17	FL embolization + extension with Petticoat + Rt renal stent-graft	AVP2-020	Petticoat: ZDES-36-120+ZDES-36-180 Renal artery: Atrium V12 8 × 38 mm
18	FL embolization + Rt renal stent-graft	PLUG-016*5	Gore Viabahn 8 × 50mm
19	FL embolization + extension TEVAR with Petticoat	PLUG-014, -016	Cook ZDEG-PT-36-28-159, ZDES-36-180
20	FL embolization + extension with Petticoat + Lt renal stent-graft	PLUG-016*5	Petticoat: ZDES-36-180 x2 Renal artery: Atrium V12 5 × 38 mm
21[a]	FL embolization	PLUG-016*2, -018; Nester 10 mm*2, 12 mm*8	Nil
22	FL embolization + extension TEVAR and EVAR	AVP2 -020, -022	TEVAR (Gore TGU313115 + TGU454520) EVAR (Gore TGU 262610, Viabahn 9 × 50 mm*2)
23	FL embolization + Rt renal stent-graft	PLUG-012, -014*2	Atrium V12 6 × 38 mm
24	FL embolization + Rt renal stent-graft	PLUG-016	Atrium V12 6 × 22 mm

EIA = external iliac artery; FL = false lumen; LSCA = left subclavian artery; Lt = left; Rt = right; TL = true lumen.
[a]Abdominal FLE was performed as the main surgery (5 patients, patients 2, 5, 7, 11, and 21).
*Number used.

With regard to the reintervention, patient 2 received a thoracoabdominal aortic replacement because a large hematoma was diagnosed using CT at the posterior mediastinum after sudden respiratory embarrassment (Fig. 2). Thoracic FL rupture was confirmed during surgery. Patient 20 suffered from sudden chest and back pain with bloody pleural effusion 3 years after FLE. Blood extravasation from thoracic FL was suspected based on CT imaging although the thoracic aortic diameter was <5 cm, and the stent-graft was extended to above celiac level. Complete thoracic FL thrombosis was identified 1 year later. The stent-graft was also extended above the celiac level in patient 13 because of a distal SINE, which occurred despite bare stents implantation. During follow-up, patient 9 was suspected of having type III endoleak. Implantation of the stent-graft was performed with balloon angioplasty. Auxiliary FLE with 2 vascular plugs (AVP2-020 and 022) was performed through fenestration near the renal artery.

4. DISCUSSION

In this study, we evaluated the midterm outcomes of FLE in patients with residual patent abdominal FL after prior aortic repair for extended aortic dissection. Although technical success was achieved without any complications in all patients, the abdominal and thoracic aortic diameter appeared to become enlarged, and the rate of complete FL thrombosis was low. The results revealed unfavorable aortic remodeling in both the abdominal and thoracic segment. Many literatures about case report or case series treated with FLE could be searched in the Pubmed, and it would encourage more vascular surgeons to perform similar work. The outcomes may not as positive as the published results suggest. Our results are reported for balance because "survivorship bias" has a considerable influence on the decision-making of surgeons.

A patient who has survived type A aortic dissection might undergo a redo total arch replacement for an enlarged dissected arch if only the ascending aorta was replaced in the previous operation. Currently, total aortic arch replacement using FET implantation is relatively safe even in a redo operation because of the simplicity and effectiveness of FET.[21,22] The descending aortic configuration of the replaced ascending and arch aorta extended with FET is similar to chronic type B aortic dissection after TEVAR. Both FET and TEVAR aim to cover the proximal tear, but the distal re-entry tears are often left for monitoring if

Table 4

Aortic remodeling after false lumen embolization

Patient	Thoracic		Abdominal		Maximal thoracic diameter (cm)	Maximal abdominal diameter (cm)
	Before/after embolization		Before/after embolization		Before/after embolization	Before/after embolization
1	Patent	CT	Patent	Patent	4.52/3.90	3.22/3.96
2	CT	CT[a]	PT	PT	8.24/10.20	6.33/6.50
3	PT	CT	PT	PT	4.96/4.38	4.98/5.32
4	CT	CT	Patent	PT	3.34/3.21	6.65/6.52
5	CT	CT	Patent	PT	5.04/4.20	5.14/5.55
6	CT	CT	PT	PT	7.17/6.99	6.44/6.70
7	PT	CT	Patent	PT	3.73/3.89	4.04/4.23
8	PT	PT	PT	PT	6.22/7.28	5.81/6.59
9	PT	PT[a]	PT	PT	6.96/7.38	4.25/4.54
10	CT	CT	PT	PT	4.84/5.08	4.84/5.08
11	CT	CT	PT	PT	3.64/3.58	3.44/3.81
12	CT	CT	PT	CT	4.29/4.27	3.37/3.42
13	CT	PT[a]	PT	PT	6.3/6.33	4.09/4.92
14	CT	CT	Patent	PT	2.92/3.02	3.26/3.86
15	CT	CT	PT	PT	4.98/5.02	4.71/5.33
16	Patent	CT	Patent	Patent	5.16/4.94	4.11/4.52
17	CT	CT	PT	PT	2.91/3.01	5.27/5.39
18	Patent	PT	Patent	Patent	6.11/6.04	5.54/6.54
19	CT	CT	PT	CT	4.81/5.47	4.76/4.91
20	PT	PT[a]	Patent	PT	4.25/4.56	3.94/4.47
21	PT	CT	PT	PT	4.07/4.10	4.54/4.62
22	CT	CT	PT	PT	5.75/6.05	3.52/4.94
23	CT	CT	PT	PT	4.18/4.70	4.95/5.79
24	CT	CT	PT	CT	5.49/5.66	3.37/3.27

CT = complete thrombosis; PT = partial thrombosis.

[a]Before reintervention.

an extended dissection has been performed. PDAA remains a problem during long-term follow-up.

Open repair remains the gold standard for PDAA. However, it is a challenging procedure, presenting serious technical difficulties for surgeons and a mortality risk for patients. Hence, this procedure is only considered for younger patients with fewer comorbidities. An endovascular approach is regarded as less invasive with acceptable early outcomes for those unable to tolerate open surgery.[10,11]

The PETTICOAT technique was first reported in 2005 by Mossop et al.[23] This technique eliminates the entry tear and increases the true luminal diameter in the distal aorta, resolving dynamic malperfusion simultaneously through a combination of stent-graft and bare stent in the visceral and infrarenal segments. In our study, 13 patients underwent the PETTICOAT procedure before FLE for severe TL compression but not for FL thrombosis. In fact, based on a meta-analysis, complete FL thrombosis at the abdominal level was only observed in 13.5% of the patients at the 1-year follow-up.[24] This low possibility of FL thrombosis can be easily understood because bare stent could not able to cover the reentry tear or fenestration. Furthermore, distal SINE may occur even after the PETTICOAT procedure because the stent-graft and bare stent have different radial forces. Further studies should investigate whether an oversized bare stent[25] or deploying the bare stent before the stent-graft decreases the occurrence of distal SINE.

Therefore, more aggressive endovascular management through the TL to achieve FL thrombosis was attempted. The previous stent-graft could be extended using fenestrated or branched stent-grafts (F/BSG)[26–28] or the parallel stent-graft technique.[29] However, obtaining a customized stent-graft for F/BSG is time-consuming and the procedure is technically demanding if the TL is narrow or tortuous. Gutter-related endoleak is also of concern after performing the parallel stent-graft technique. Other concerns include spinal cord ischemia because of the long-segment coverage of the aorta and health insurance reimbursement in our system. Consequently, these techniques are rarely used in our patients.

Intervention through FL is another way to FL thrombosis. However, most studies have focused on thoracic FL using the candy-plug technique, which has demonstrated acceptable early outcomes.[13,30] By contrast, fewer studies have addressed abdominal FL with only a 1-year follow-up.[15,16] This is why we analyzed the outcomes of our patients who underwent abdominal FLE.

Two previous studies produced different results. Hofferberth et al[15] reported that 60% of patients achieved complete thoracic FL thrombosis, but only 20% achieved improved abdominal FL thrombosis after FLE without selective criteria after a 63-month follow-up. The candy-plug technique was not used in these patients. This is consistent with our results demonstrating that favorable aortic remodeling is difficult through abdominal FLE. However, Zeng et al[16] reported positive outcomes for FLE with a stent-graft. Their results combined both TL and FL procedures, including the deployment of stent-grafts in FL to exclude tears in the visceral segment of the aorta and traditional EVAR or TEVAR to exclude tears and expand the TL in the nonvisceral segment of the aorta. However, several anatomical requirements must be met for this technique to be successful; results relating to highly selected patients cannot be generalized.

Currently, no devices have been produced specifically for FLE except the commercial candy plug. However, this has anatomical requirements and is only suitable for a small number of patients. In some cases, this technique may fail or the thoracic FL patent again during follow-up. Coils, onyx glue, vascular plugs, or handmade candy plugs are used according to the surgeon's preference for both thoracic and abdominal FL in clinical practice.

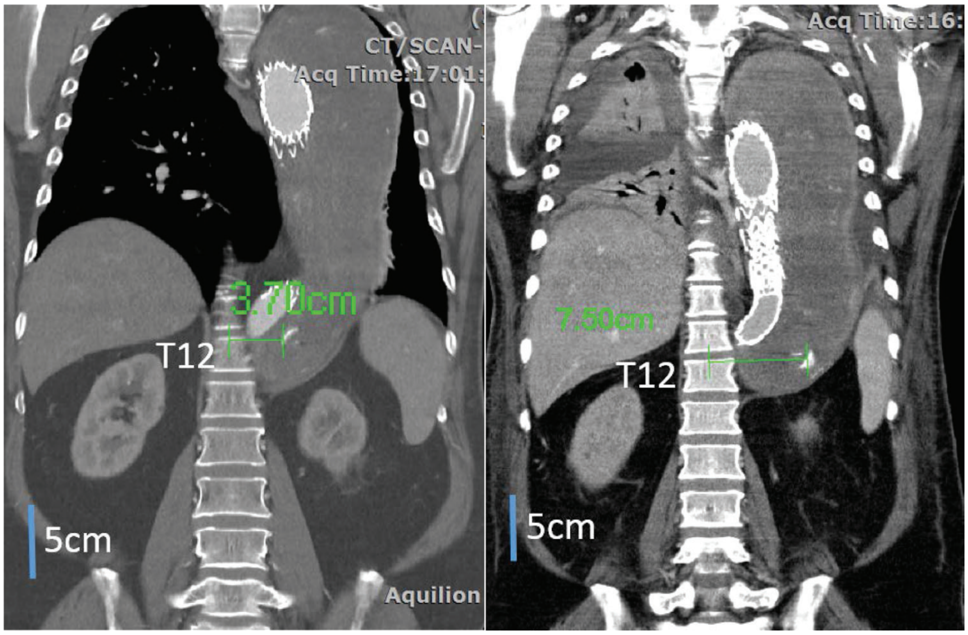

Fig. 2 Patient 2 underwent abdominal false lumen embolization using a vascular plug AVP2-22 (complete thoracic thrombosis before the procedure), but a fenestration hole remained in the celiac trunk (left). After 18 mo, the vascular plug had migrated and the maximal thoracic aortic diameter (distal to the T12 vertebra) had increased, as observed through CT imaging (coronal view; right).

However, these nonspecific devices can be limited by the larger FL diameter, resulting in the need for more than one device or a number of adjunctive embolization materials, and the outcome is more unpredictable.

The key to achieving FL complete thrombosis using the endovascular method is to ensure that all the larger reentry tears or fenestrations related to the branch vessels are covered. The TL approach is more practical. Thus, achieving FL complete thrombosis through FLE alone is not easy. Furthermore, the diameter of the thoracic aorta may continue to become enlarged if the abdominal FL is persistently patent, which caused thoracic FL still under huge pressure. The effect is like the movement of glacier, too slow to be found. Finally, the PDAA may rupture. Consequently, a regular CT follow-up is necessary even after total thoracic thrombosis using the candy-plug technique.

None of these techniques is suitable for all lesions or situations, and the technique selected should be the one that is optimal for the patient. An isolated FLE may not be an effective approach to achieving total FL thrombosis without using a specific FLE device.

In conclusion, FLE appears to be a relatively safe, simple, low morbidity technique allowing initiation of total thoracic FL thrombosis. However, the midterm outcomes of abdominal FL thrombosis are not positive, and unfavorable aortic remodeling cannot be halted.

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