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ORIGINAL ARTICLE

Combined surgical and endovascular treatment with arch preservation of acute DeBakey type I aortic dissection

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Abstract

Background: DeBakey type I aortic dissection is a catastrophic event that presents a formidable challenge to cardiovascular surgeon. Here, we evaluate a new combined surgical and endovascular technique for acute condition.

Methods: Between December 2011 and December 2015, 12 patients with type I aortic dissection concomitant involving supra-aortic vessels underwent ascending aortic replacement and simultaneous stent grafts inserted into the descending aorta, left subclavian, and left carotid arteries, and into the innominate artery when possible, without arch replacement. The stent grafts, Gore TAG thoracic endoprosthesis and Viabahn, were deployed under visual guidance through opened aortic arch into the true lumen, with the techniques of circulatory arrest, moderate hypothermia, and bilateral antegrade cerebral perfusion.

Results: Operation was performed smoothly in all patients. There was one death, and the other 11 recovered without any neurological deficits. Follow-up computed tomography scans showed that the true lumen expanded and false lumen regressed in both arch and descending aortic segments in 1 year. The diameter did not increase in either arch or descending aortic segments.

Conclusion: Ascending aortic replacement and stent graft for supra-aortic arteries and the descending aorta without arch replacement are feasible options for type I aortic dissection with satisfactory short-term aortic remodeling.

Keywords: Aortic dissection; Hypothermia; Descending aorta

1. INTRODUCTION

DeBakey type I aortic dissection treated by replacement of the proximal aorta usually leaves patients with late sequelae, including persistent patent false lumen (PFL), aneurysmal enlargement, and the need for reoperation.[1] The incidence of these sequelae was noted to be reduced with concomitant total aortic arch replacement (TAR).[2–4] Hence, some advocate aggressive replacement of the ascending aorta and concomitant TAR for type I aortic dissection, irrespective of the location of intimal tear;[3] however, concomitant TAR has been associated with a higher operative mortality,[5] and only proximal aortic replacement has been performed for type I aortic dissection in most patients unless the primary tear in the arch.

The development of the stent graft has changed the management of aortic disease and has reduced potential mortality and morbidity of aortic surgery with conventional surgical repair during the past two decades.[6] The frozen elephant trunk (FET) technique, with a stent graft attached to a vascular graft distal to the arch,[7] has been applied for aortic dissection and demonstrated to promote false-lumen thrombosis and reduce distal PFL rates[8] and late aneurysm formation[9] in the proximal descending aorta, when used in combination with TAR. Some groups have advocated a more aggressive approach in which routine TAR and/or placement of a descending aortic stent graft as the primary operative strategy for type I aortic dissection,[8,10–12] as supported in recent meta-analyses.[13-14] However, these meta-analyses reviewed data from high-volume centers and nonrandomized data sets, and the excellent outcomes of TAR and stent graft might not be applicable to most places around the world. It requires a longer duration of cerebral protection, circulatory arrest, and cardiopulmonary bypass (CPB), which might increase the risk of stroke and paraplegia.[15] Other hybrid techniques of combined surgical and endovascular approaches have been developed for aortic dissection to simplify the operation.[12]

The rationale for treatment of dissection is that successful exclusion of the primary intimal tear followed by thrombosis of false lumen distal to the vascular prosthesis prevents the development of descending aortic aneurysm after repair.[16] At the same time, it is expected that flow to the true lumen could increase and ameliorate a distal aortic malperfusion syndrome while aortic remodeling occurs. Hence, it is important that a primary intimal tear must be resected whenever possible. A computational fluid dynamics simulation model clearly reveals that when aortic dissection occurs, blood surges through a tear in the aortic intima and quickly forces apart the layers of intima and media. There is a great difference in pressure

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between the true and false lumens, resulting in compression of the true lumen by the false lumen and a false luminal aneurysm in the descending aorta.[17] If the true lumen is expanded by a stent graft, the pressure difference may be diminished and the blood flow may increase in the true lumen and decrease in the false lumen.

Hence, if the surgical goal is to restore the flow of blood in the true lumen as much as possible and does not focus on obliteration of the false lumen, the surgical treatment of aortic dissection could be simplified.

During the past few years, 12 cases of acute DeBakey type I aortic dissection involving supra-aortic branches were managed by replacement of the ascending aorta and insertion of stent grafts into the descending aorta, left carotid, and subclavian arteries, and into the innominate artery when possible, without total arch replacement. Consideration of the results of the simplified hybrid operation is the purpose of this study. By the way, the remodeling effects of both the true and false lumens are also addressed in this study.

2. METHODS

2.1. Patient selection

This retrospective study was approved by the institutional review board of our institution (approval number: IRB 2015-11-009BC), and all subjects gave informed consent.

Between December 2011 and December 2015, a total of 71 patients presented to Taipei Veterans General Hospital with acute DeBakey type I dissection, confirmed by computed tomography (CT) scans in all patients before urgent operation. Twelve patients without neurologic symptom were treated with this method. Exclusion criteria were Marfan syndrome diagnosed preoperatively and aortic arch diameter >4.5 cm as shown by CT. Patients whose descending aorta had a diameter >4 cm were also excluded because a suitable stent graft for this condition was not available in our hospital.

2.2. Surgical technique

During preparation for anesthesia, multidetector CT contrast angiography was reviewed to determine the size and length of the stent graft for the descending aorta and supra-aortic branches. The diameter of the stent graft was determined by adding around 10% to the outmost diameter of the descending aorta and adding 2 mm to the outer diameter of supra-aortic branches at the intended level of placement.

Before sternotomy, right axillary artery (right carotid artery in patient 5) and one side of common femoral artery and vein were exposed; then two 8-mm expanded polytetrafluoroethylene grafts were anastomosed to axillary and common femoral arteries (Fig. 1). The contralateral common femoral artery was also exposed; a 14 Fr sheath was inserted for passage of a 40-ml Coda balloon catheter (Cook Inc, Bloomington, Ind, USA) to the level of descending aorta confirmed by transesophageal echocardiography. After sternotomy, CPB was set up by double arterial cannulations and femoral venous cannulation. During the process of body cooling to 28°C, the ascending aorta was cross-clamped, incised proximally, checked for tears, and transected to the level of sinotubular junction. The diseased outer aortic wall was reinforced with Teflon felt strips. A Dacron tube graft was anastomosed to sinotubular junction with polypropylene. Aortic root reconstruction was performed if aneurysm formation of Valsalva sinus. After completion of the proximal anastomosis and body temperature had reached 28°C, the supra-aortic arteries and the arterial cannula to the femoral artery were clamped. The flow rate of CPB was decreased to 1.5 L/min temporarily, and the aortic cross-clamp was released. The ascending aorta was resected to the level of the innominate artery, the dissected aortic arch was inspected, and the soft guide wire was pulled out. A 10-cm covered stent (Viabahn; Gore Inc, Flagstaff, AZ, USA) was cannulated and deployed in the left carotid artery under direct visualization after the clamp was released. Then, a 12 Fr distal perfusion catheter (LeMaitre Inc, Burlington, MA, USA; extension from the arterial cannula to axillary artery) was inserted into the Viabahn, and the flow rate of the CPB was increased to 2.5 L/min after the catheter balloon inflated.

If covered stent would be inserted into the innominate or right aberrant subclavian artery (Aortic Extender Endoprosthesis or Viabahn, respectively; Gore Inc), it was done at this time with the same maneuver, and the flow to right axillary artery was stopped temporarily during insertion into the innominate artery. Then, the J-curved guide wire with 5 cm Viabahn was cannulated into the left subclavian artery (LSA) but kept in situ without deployment (usually 1.5 cm of covered stent was protruded into the arch lumen).

The stent graft (TAG; Gore Inc) was pushed into the aorta and deployed antegrade through the soft guide wire without introducer under direct visualization, and the proximal end of the stent graft was kept on the level of the LSA. During the procedure, the soft guide wire was held tightly to facilitate the deployment. Finally, remaining Viabahn was deployed in the LSA. This sequence of deployment can make sure that LSA is patent, if the TAG was expected to be deployed more proximally.

After all stent grafts were deployed, the Coda balloon was inflated in the TAG and the flow rate of the CPB could be resumed fully and begin to warm up. The distal anastomosis could be performed between the Dacron graft and the native aorta reinforced in the outer wall with a Teflon felt strip. Cerebral perfusion was monitored by Brain oximeter (Somanetics, Covidien Inc, Boulder, CO, USA) during the whole procedure.

The air was removed from a venting cannula placed on the anterior aspect of the Dacron graft. The operation was completed in the usual way. The final configuration is shown in Fig. 1.

2.3. Follow-up

All patients were followed up regularly in the outpatient department. Medications included antihypertensives, and aspirin or clopidogrel for stent graft as soon as possible after the surgery for long-term use. Postoperative CT surveillance was performed first within 1 month postoperatively and yearly thereafter.

2.4. Evaluation of aortic remodeling

The entire aorta, including the supra-aortic vessels, was included in the CT scan. The digital imaging and communications in medicine data were transferred to OsiriX MD (OsiriX, Version 1.1 Pixmeo SARL, Bernex, Switzerland) for measurement. Volumes were automatically calculated using region of interest (ROI)-computed volumes. According to volumetric investigation, arch aorta was defined from the level of the innominate artery to the LSA and the descending aorta was defined from the level of the LSA to the celiac trunk.[18] The volumes of the true lumen and false lumen of both the aortic arch and the descending aortic segments were measured individually and compared to those on the preoperative CT scan at the same level. The diameter of the aortic arch was measured at the level of the orifice of LSA and the diameter of the descending aorta at the level of pulmonary artery.

The status of the false lumen in the segment of the arch or descending aorta covered by TAG stent graft on imaging was classified as having no thrombosis if flow was present in the absence of thrombus, as partially thrombosed if both flow and thrombus were present, or as totally thrombosed if no flow was detectable on CT imaging.[19]

2.5. Statistical analysis

Continuous variables were expressed as mean ± SD if necessary. Comparison between preoperative and postoperative CT imaging was performed using the Wilcoxon signed-rank test. A p value <0.05 was considered as statistically significant. Data were analyzed using SPSS statistical software (Version 22.0; IBM Corp. Armonk, NY, USA)

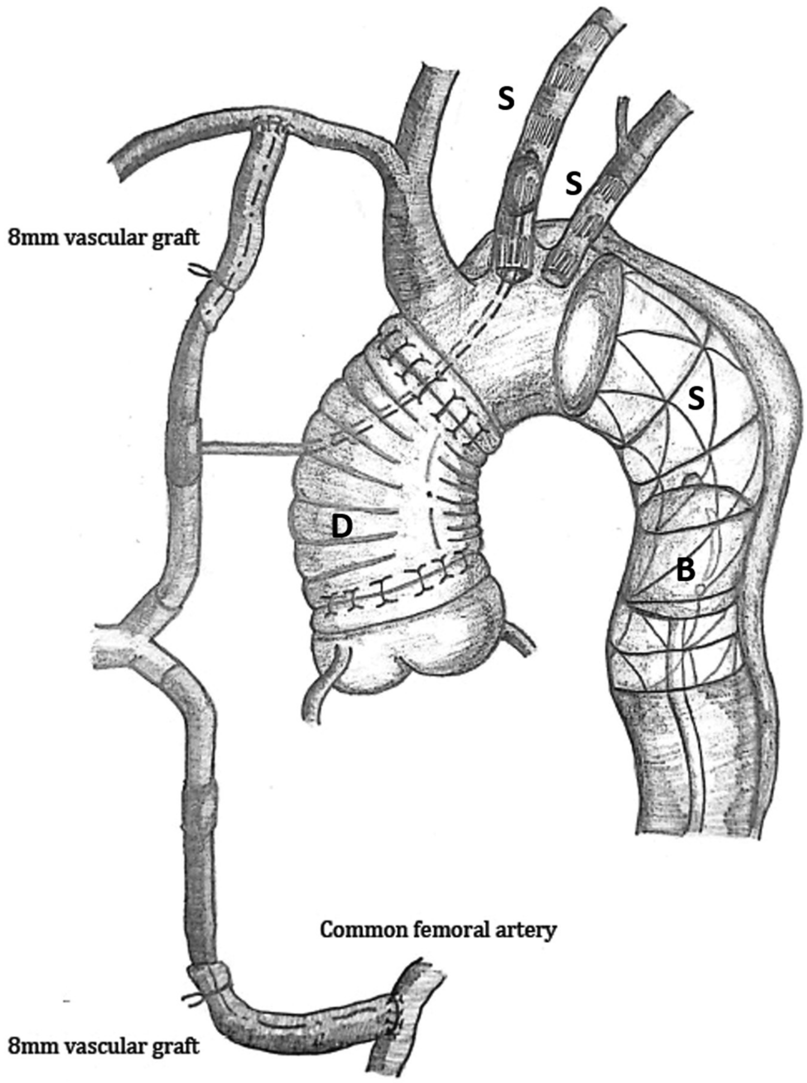

Fig. 1 Diagram of the operative method with Dacron graft (D) and stent grafts (S), including arterial cannulation and Coda balloon (B) in the thoracic stent graft.

3. RESULTS

Twelve patients (six men and six women), aged 61.6 ± 12.5 years, were performed with this method. The important characteristics, including preoperative symptoms, hospital mortality, and long-term complications are shown in Table 1.

There was one death (patient 9). This patient regained consciousness postoperatively without any neurologic deficits; however, subsequently, she was sedated for an endoscopic procedure due to persistent oropharyngeal oozing, and anisocoria was noted 3 hours after the procedure. Emergent brain CT demonstrated that the left vertebral artery was covered by Viabahn; that the carotid arteries bilaterally, the right vertebral arteries, and the arteries of the circle of Willis were patent; and that there was generalized ischemic change in the brain. This death might have been coverage of the ostium of the left vertebral artery by the stent graft, thereby causing cerebellar ischemia, followed by increased intracranial pressure and uncal herniation. The remaining patients recovered well without any neurological deficits. It is expected that neurological outcome could be improved by this method.

The other 11 patients had some symptoms of cerebral, cardiac, and visceral malperfusion in addition to severe chest pain preoperatively. All of them recovered well without any neurologic deficits, but one developed chronic renal failure. Patients 1 and 10 were elderly women, both of whom tolerated the operation uneventfully. Patient 7 was diagnosed with Marfan syndrome via genetics diagnosis postoperatively.

The operative information and status of false-lumen thrombosis during 1-year follow-up are shown in Table 2. Aortic root reconstruction was performed in three patients, and longer aortic clamp time was expected. Both 34- and 37-mm diameter thoracic stent grafts were used for most patients. Although arrest time may be >40 minutes in some patients, most of the arrest time spent was in the status of bilateral antegrade brain perfusion and low flow to the lower body. There were three patients whose primary tear was not resected during the surgical procedure and five patients with PFL 1 year postoperatively.

3.1. Remodeling of true and false lumens

During 1-year postoperative follow-up, total thrombosis of the false lumen from the aortic arch to the descending aorta was noted in four patients, two patients had partial thrombosis of the descending aorta, and one patient had partial thrombosis of the aortic arch. The left four patients were noted without thrombosis and persistent PFL from arch to descending aorta. In patient 9, who died in the hospital, CT imaging showed total thrombosis to the level of the descending aorta in 1 month postoperatively.

The volume of both the true and false lumens showed significant changes in the first postoperative year. In the aortic

Table 1

Patient demographics, preoperative conditions, hospital mortality, and long-term complications

Patient	Age, y	Sex	Cerebral event	Cardiac event	Visceral malperfusion	Hospital mortality	Long-term complications	Notes
1	82	F	...	...	...	...	No	
2	60	F	...	...	...	...	No	
3	52	M	...	Tamponade	Liver and renal malperfusion	...	Renal failure	
4	68	M	Syncope	Aortic regurgitation	...	...	No	
5	71	F	...	...	...	...	No	Aberrant right subclavian artery
6	57	M	...	...	...	...	No	
7	59	M	...	Aortic regurgitation Right coronary artery malperfusion	Renal malperfusion	...	No	Marfan syndrome
8	49	M	...	Aortic regurgitation	...	...	No	
9	39	F	Syncope	...	...	Yes		
10	81	F	...	...	...	...	No	
11	62	M	...	...	...	...	No	
12	59	F	...	...	...	...	No	

F = female; M = male.

Table 2

Operative information and false-lumen thrombosis during 1-year follow-up

Patient	Additional procedure	Diameter of DsAo ST	CPB, min	Clamp time, min	Arrest time, min	Primary tear resection	Arch FL thrombosis	DsAo FL thrombosis
1		34	296	177	74	Yes	Total	Total
2		31	231	66	20	No	Total	Total
3		31	424	137	91	Yes	Total	Partial
4	Aortic root reconstruction	34	349	249	70	Yes	Total	Total
5	ST of right carotid and aberrant SA	34	285	153	80	Yes	Total	Partial
6	Hemiarch replacement	37	324	151	78	Yes	No	No
7	Aortic root reconstruction and ST of IA	37	320	188	42	Yes	Partial	No
8	Aortic root reconstruction and ST of IA	34	247	225	95	Yes	No	No
9	Hemiarch replacement	34	270	121	63	Yes	...	...
10		37	247	158	53	Yes	Total	Total
11		37	203	113	24	No[a]	No	No
12		37	200	116	20	No	No	No

[a]Primary tear was not found in the ascending and arch aorta.

CPB = cardiopulmonary bypass; DsAo = descending aorta; FL = false lumen; IA = innominate artery; min = minutes; SA = subclavian artery; ST = stent graft.

arch segment, the true lumen expanded and the false lumen regressed in all patients (Fig. 2A, B). In the descending aortic segment, the remodeling was as it was in the aortic arch segment, but one patient (patient 6) showed expansion of the false lumen (Fig. 2D, E). Arch diameter increased in four patients (patient 3, 5, 7, and 11), and the diameter of the descending aorta increased in five patients (patient 6, 7, 8, 10, and 11; Fig. 2C, F). No statistically significant change in diameter was found in either the aortic arch (from 34.8 ± 2.6 to 35.3 ± 3.6 mm) or the descending aorta (from 29.5 ± 2.6 to 30.5 ± 4.2 mm) 1 year postoperatively. Only one of 26 covered stents placed in supra-aortic branches showed thrombosis and occlusion. This stent was in the LSA, which did not cause obvious symptoms.

4. DISCUSSION

DeBakey type I aortic dissection being a potentially lethal condition, the primary aim of surgery must be to save the patient's life.[20] Furthermore, many of these patients have not reached the age of retirement; the second aim should be allowing the patients to return to work earlier without complications, especially neurologic ones. Hence, we developed a method that was expected to maintain the advantages of TAR, which also minimized the risk of neurologic deficit. In our method, several stent grafts to keep the true lumen open were used to simplify the operation.

4.1. Neurological outcome

There are several factors to improve neurological outcome. The first is *bilateral antegrade cerebral perfusion*. To set up bilateral antegrade perfusion with our method is easy, time saving, and safer because information about intracranial blood supply is incomplete.

The second is *stent graft implanted into* left common carotid artery (*LCCA*) *and LSA* to reduce the risk of brain malperfusion and ischemia. Brain malperfusion, which could cause neurological deficits or coma, is usually due to compromised flow in the true lumen of a supra-aortic artery by compression from a false lumen. Actually, bare stent also fits our purpose to keep true lumen opened; however, we are familiar with the product of stent graft.

A 10-cm Viabahn was used for the left carotid artery because the dissection might extend to the level of carotid bifurcation sometimes, and a 5-cm Viabahn was used for the LSA. Because the distance from the ostium of LSA to the branch of vertebral artery was usually <5 cm (average 4.36 cm) in our 12 cases, preoperative measurement was very important and 3.5 cm length for landing zone was adequate. Hence, the stent graft should protrude into the lumen a little. After the death of patient 9, we made a greater effort to maintain patency of the left vertebral artery.

The third is to *keep the native configuration of the arch*. Traditional TAR with trifurcated vascular prosthesis may induce anastomosis stenosis, distal PFL, and even kinked prosthesis after weaning CPB because of limited space of the upper anterior

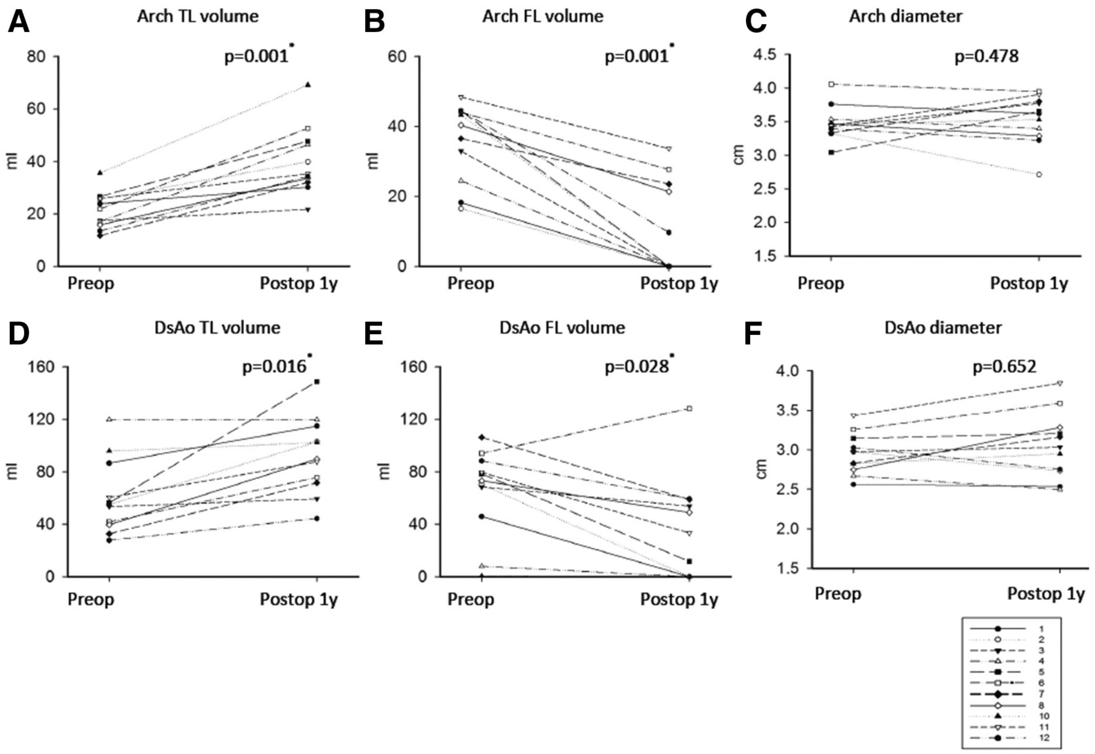

Fig. 2 Remodeling of the aortic arch and DsAo segments 1 year after operation. Symbol 1-12: patient 1 to patient 12. DsAo, descending aortic; FL, false lumen; TL, true lumen. **p* value < 0.05 compared between preoperative status and postoperative 1 year status by Wilcoxon signed-rank test.

mediastinum. In our method, the configuration of the arch was not changed and cerebral flow (at least to the left side) was maintained without any compromise.

4.2. Primary tear location

It was generally believed that the primary tear must be resected whenever possible to depressurize the distal false lumen and decrease the risk of future development of descending aortic aneurysm;[16] however, there are also conflicting reports that PFL does not appear to correlate with successful exclusion of the primary intimal tear, depending on the presence of distal fenestrations between the true and false lumens.[21] This observation suggests that the pressure in the false lumen of the proximal descending aorta is important. Hence, we focused on depressurizing the false lumen through stent grafts to keep true lumen open and resection of the primary tear when feasible.

4.3. Aortic remodeling

Remodeling of the true and false lumens in our patients was similar to the results after concomitant TAR and FET, which resulted in a significant expansion of the true lumen and shrinkage of the false lumen over time. No significant change in diameter was found in either the aortic arch or the descending aorta 1 year postoperatively. These results are not worse than those reported previously.[22,23] Results were plotted only for 1 year, because most of operations were done in past 2 years. The first several cases were stable after 1 year. Although short-term remodeling may be satisfactory even when the false lumen remains patent, long-term monitoring is necessary because of concern for aneurysm formation in the proximal descending aorta.

The selection of stent graft, which might induce a new tear in both the proximal and distal ends, is most difficult for the descending aorta. We used 15 cm TAG because of its conformability and not to compromise the spinal supply as possible. The diameter of TAG was 10% of the outmost diameter of the descending aorta. We may need more time to evaluate the results of this intervention.

In conclusion, combined surgical and endovascular stent graft treatment of the supra-aortic arteries and descending aorta without arch replacement is a simple option with an acceptable outcome, and short-term aortic remodeling is also satisfactory.

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