# Thoracic Endovascular Aortic Repair Combined with Assistant Techniques and Devices for the Treatment of Acute Complicated Stanford Type B Aortic Dissections Involving Aortic Arch

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**Background:** The present study retrospectively reviewed and evaluated the effectiveness of thoracic endovascular aortic repair (TEVAR) combined with assistant techniques and devices for the treatment of acute complicated Stanford type B aortic dissections involving aortic arch.
**Methods:** Fifty-six patients with acute complicated Stanford type B aortic dissection involving aortic arch were treated with TEVAR combined with hybrid procedure, chimney-graft technique, and branched stent grafts from January 2009 to March 2014.
**Results:** Seventeen patients undergone TEVAR combined with hybrid technique. Technical success was achieved in 94.1% with 5.8% of early mortality. Strokes occurred in a patient developing paraplegia, who completely recovered after lumbar drainage. Cardiocirculatory and pulmonary complications, bypass dysfunction or severe endoleak was not observed. Thirty patients undergone TEVAR combined with chimney technique with 100% technical success rate. Chimney-stent compression was observed in 1 patient, and another bare stent was deployed inside the first one. Three patients (10%) died during the study period. Immediate postoperative type I endoleak was detected in 4 cases (13.3%). TEVAR assisted by Castor branched aortic stent grafts in 9 patients was successful. Mortality during perioperative period and 30 days after TEVAR was null. No serious complications such as strokes, acute myocardial infarction, and ischemia of arms occurred.
**Conclusions:** The results indicate that TEVAR combined with hybrid technique, chimney technique, and branched stent grafts is proven to be a technically feasible and effective treatment for acute complicated Stanford type B aortic dissection involving aortic arch in small cohort.

## INTRODUCTION

Thoracic endovascular aortic repair (TEVAR) has been proven to be an excellent alternative to open surgery in anatomically suitable candidates since its advent.[1–5] Several reports have shown the beneficial effects of TEVAR in acute complicated type B dissection,[6–9] but there is still no consensus on when to use this method.

A proximal landing zone of healthy and nondissected aorta of at least 15 mm along the curvature of the aortic arch is a prerequisite for successful stent-graft placement. As the aortic arch is involved in >25% (by intimal tear in the arch or propagation from the descending aorta), the proximal landing zone may need to be extended for proper fixation of endografts.[10] The presence of an inadequate

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proximal zone is often a limiting factor for TEVAR and to extend the proximal landing zones and achieve an adequate seal, the innominate artery (IA), left common carotid artery (LCCA) and left subclavian artery (LSA) needs to be covered often. However, covering the origins of these arteries may induce certain complications, such as left upper limb ischemia, posterior circulation ischemia, or cerebral infarction.

These considerations make the reconstruction of supra-arch branch vessels necessary for favorable outcomes. On one hand, TEVAR combined with graft bypass (hybrid procedure) has gained a widespread implementation and extended-endovascular treatment options.[11–13] On the other hand, chimney-graft technique and new branched stent grafts are reported to revascularize aortic arch branches during TEVAR.[14–16] We retrospectively reviewed our experience and evaluated the effectiveness of TEVAR combined with assistant techniques and devices for the treatment of acute complicated Stanford type B aortic dissections involving aortic arch.

## METHODS

### Study Design and Patient Selection

The study was carried as per the principles of the Declaration of Helsinki with the approval of institutional review board, and a written informed consent was obtained from all the patients. Patients with acute complicated type B aortic dissections involving aortic arch were eligible for TEVAR combined with assistant techniques and devices with the fulfillment the conditions mentioned in the following:

(1) Presented <14 days after the onset of symptoms;
(2) Had one or more of the following conditions: imminent rupture, rupture, intractable chest pain, false lumen aneurysm formation, uncontrollable hypertension, or end-organ ischemia; and
(3) Had difficult proximal landing zones and not suitable for standard thoracic stent-graft insertion. A difficult proximal landing zone was defined as severe neck angulation, short landing-zone length (<15 mm), cone-shaped neck, extensive thrombus at landing zone (>50%), or too large vessel size at the desired landing zone.
(4) Primary entry tear next to the orifice of LSA.

Fifty-six patients (50 men; median age 52 years, range 38–73) with acute complicated Stanford type B aortic dissection involving aortic arch with the primary entry tear next to the orifice of LSA were treated with TEVAR combined with assistant techniques and devices during January 2009 to March 2014. Based on digital subtract angiography, the primary entry tear of 39 patients were only involved in the LSA, 16 were involved in the LCCA, and 1 with right-sided aortic arch. Significant comorbidities were hypertension (50, 89.2%), coronary artery disease with previous myocardial infarction (10, 17.8%), diabetes (8, 14.2%), and chronic renal insufficiency (7, 12.5%).

### Preprocedural Assessment

To evaluate the extent of the dissection, to identify the primary entry tear and secondary entry sites, to measure the maximal transverse diameter of the aorta, explore the anatomy of the supra-aortic branches and to determine the intended proximal landing zone, all patients underwent preoperative computed tomography angiography (CTA) scan. Ishimaru's classification was used to categorize the proximal landing zone of the stent graft.[17] The extension of the landing zone may differ as per the supra-aortic branches involved. Hybrid techniques, chimney technique, and branched stent grafts were the therapeutic strategies that were used to extend the proximal landing zones.

### Hybrid Technique

Based on Ishimaru's classification, aortic arch is divided into 4 zones: Z0, Z1, Z2, and Z3; and various strategies of hybrid techniques were used to extend proximal landing zones as per the position of the entry tear of aortic dissection.

All the patients underwent TEVAR after 24 hours of hybrid procedure during the 2-stage procedure. The bypass grafts were carried out in a hybrid interventional suite for patients under general anesthesia with the administration of intravenous heparin. Supra-aortic vessels were accessed through vertical or transverse neck incisions of the carotid arteries, and a transverse left supraclavicular incision was performed for the LSA. The carotid-to-carotid 8-mm expanded polytetrafluorethylene grafts were tunneled in front of the trachea or behind the pharynx by digital tissue separation.

LSA revascularization was achieved by its transposition to the carotid artery or carotid-to-subclavian bypass which was considered necessary in the presence of a dominant left vertebral artery.

Surgical occlusion of the IA, LCCA, or LSA was performed to avoid type II endoleak after TEVAR.

### TEVAR Procedure

All TEVAR procedures were performed in a hybrid interventional suite with the patients under general anesthesia, by a team of vascular surgeons and interventional radiologists. After left radial artery puncture, a pigtail catheter was placed under fluoroscopic guidance with a guidewire getting advanced toward the LSA. After right femoral artery puncture, a guidewire and catheter were placed under fluoroscopic visualization to ensure that the catheter is in the true lumen. A Lunderquist superstiff guidewire was placed followed by removal of 6F right femoral sheath, and the puncture site was serially dilated up to 12F until an 18F delivery sheath could be inserted. A total of 5,000 units of heparin were administered intravenously before stent-graft insertion with routine antibiotic prophylaxis.

The optimal diameters of the proximal covered stent graft were selected with 10% oversizing. The stent and delivery system were inserted via the 18F sheath and positioned. The stent graft was delivered over the guidewire to the predetermined position and released. Once the stents were deployed, and the delivery system was removed. Procedural success was defined as complete sealing of the primary entry tear followed by obliteration of the false lumen in at least the thoracic region. Patients with left arm ischemia were treated with alprostadil (10-μg slow intravenous bolus injection once a day) for 7 days. Two types of endografts were included in the study: Valiant (Medtronic, USA; $n = 10$) and TAG (Gore, USA; $n = 7$).

### Chimney Technique

The chimney graft is defined the implantation of a bare or covered stent parallel to the main aortic stent graft that extends into an over stented vital side branch to preserve its perfusion. Inclusion criteria included: (1) an inadequate proximal landing zone (<15 mm); (2) high surgical-risk patients who are not suitable for open repair or hybrid procedures; and (3) emergent endovascular repair of acute dissections.

All chimney stents were deployed into the LSA through a 6F arterial sheath after puncturing the left radial artery for the bare stent delivery systems (Complete-SE stent [Medtronic, USA; $n = 6$], SMART Control stent [Cordis, USA; $n = 5$]), or through a 9F sheath by surgically exposing the left brachial artery for the covered stent delivery system (VIABAHN [Gore, USA; $n = 19$]).

After accessing the wire in LSA, a pigtail catheter was sent into the LSA, through which a superstiff guidewire was sent into the ascending aorta. Then, the pigtail catheter was removed, and the chimney stent was delivered into the LSA along with the guidewire. After the deployment of endoaortic device, immediately the chimney stent was deployed parallel to the main aortic stent graft, with 1 cm overlapping and 1 cm protruding proximally. Complete ascending aortic angiogram was performed to evaluate the immediate results. Technical success was defined as the immediate postoperative aortogram, demonstrating successful proximal fixation of the aortic stent graft and preserved LSA. The lesion was excluded successfully and LSA had a favorable antegrade blood flow. All patients received a hypodermic injection of 5,000 U low-molecular-weight heparin once a day for 2–3 days, and orally administered with 100 mg/day for life.

### Castor Branched Aortic Stent Graft

The Castor branched aortic stent graft was a branched 1-piece graft consisting of a self-expandable nitinol stent and polyester vascular graft fabric (MicroPort Medical [Shanghai] Co., Ltd., China). It was composed of a main graft and 1 sidearm graft. The main graft was tapered and flexible enough to conform to the curved aortic arch. At proximal end of main graft, there was a 10-mm long stent-free sewing Dacron tube. The first sidearm graft was 35-mm long with a diameter 14–16 mm. The distance between neighboring sidearm graft and edge of main graft was 5 or 10 mm. When the length between LSA and LCCA is less than 6 mm, the former (5 mm) is chosen, on the contrary, the latter (10 mm) is selected.

TEVAR was performed using Castor branched aortic stent grafts and delivery system devices (MicroPort Medical [Shanghai] Co., Ltd., China). The total arch endovascular repair using Castor branched aortic stent graft, a custom arch branched graft incorporating with 1 arch vessel (LSA) since January 2013. Technical success was defined as a successful branched-graft deployment with all target vessels incorporated and 24-hr survival in the angiographic absence of type I endoleak.

### Follow-Up

The follow-up protocol included postoperative CTA before discharge, a clinical examination, and a CTA 1 month and 6 months postoperatively, and annually thereafter.

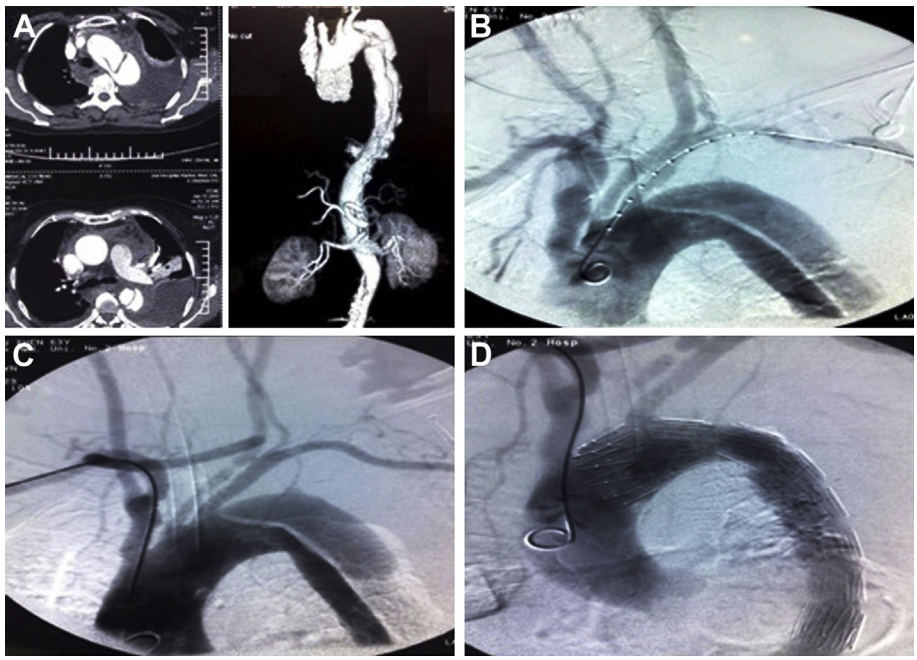


**Fig. 1.** TEVAR combined with hybrid techniques for type B acute complicated aortic dissection (the entry tear is in Z2 zone). **(A)** Preoperative CTA demonstrated a type B acute complicated aortic dissection. There were multiple entry tears in the descending aorta. **(B)** Preoperative digital subtract angiography (DSA) demonstrated the entry tear is near the LCCA. **(C)** DSA showed LCCA—LSA transposition was applied before TEVAR. The right—left carotid artery bypass and LCCA—LSA side-side anastomosis was made. **(D)** Postoperative DSA after TEVAR demonstrated no evidence of endoleak, the false lumen of aortic dissection disappeared.

## RESULTS

### TEVAR Combined with Hybrid Technique

A total of 17 patients (15 males; median age 53, range 42—67) underwent TEVAR combined with hybrid technique; of which 14 had concomitant hypertension, 2 had coronary heart disease, 2 with diabetes mellitus, and 2 with renal insufficiency. Nine entry tear was localized in zone 2 (Fig. 1), 5 in zone 1 (Fig. 2), and 2 in zone 3 (dominant left vertebral artery). One case was accompanied by a right-sided aortic arch and variation of the supra-aortic branches, where the bilateral carotid arteries aroused from ascending aorta and bilateral subclavian arteries aroused from descending aorta (Fig. 3). Technical data of TEVAR with hybrid techniques used for 17 acute complicated Stanford type B aortic dissections involving aortic arch are summarized in Table I.

Technical success was achieved in 94.1% (16 of 17). One stent-graft insertion was achieved through an antegrade approach, to overcome inappropriate transfemoral stent graft placement. The early mortality (within 30 days) was 5.8% (1 of 17), as the participant died from retrograde aortic dissection after 5 days of hybrid aortic arch repair (HAR). Stroke occurred in 1 patient leading to the development of paraplegia, who completely recovered after lumbar drainage. No cardiocirculatory and pulmonary complications occurred. No bypass dysfunction was seen during follow-up, and no severe endoleak was needed to be reintervened.

### TEVAR Combined with Chimney Technique

A total of 30 patients (27 males; median age 55, range 40—69) underwent TEVAR combined with chimney technique; of which 28 had concomitant hypertension, 6 had coronary heart disease, 5 had diabetes mellitus, and 3 had renal insufficiency.

The technical success rate was 100% (Fig. 4). All chimney grafts were successfully implanted. The diameter of aortic stent grafts was 31.7 ± 2.8 mm (range 24—41 mm), and the length was 170.5 ± 27.6 mm (range 80—220 mm). Chimney-stent compression was observed in 1 patient, and another bare stent was deployed inside the first one. A total of 30 chimney stents, including 11

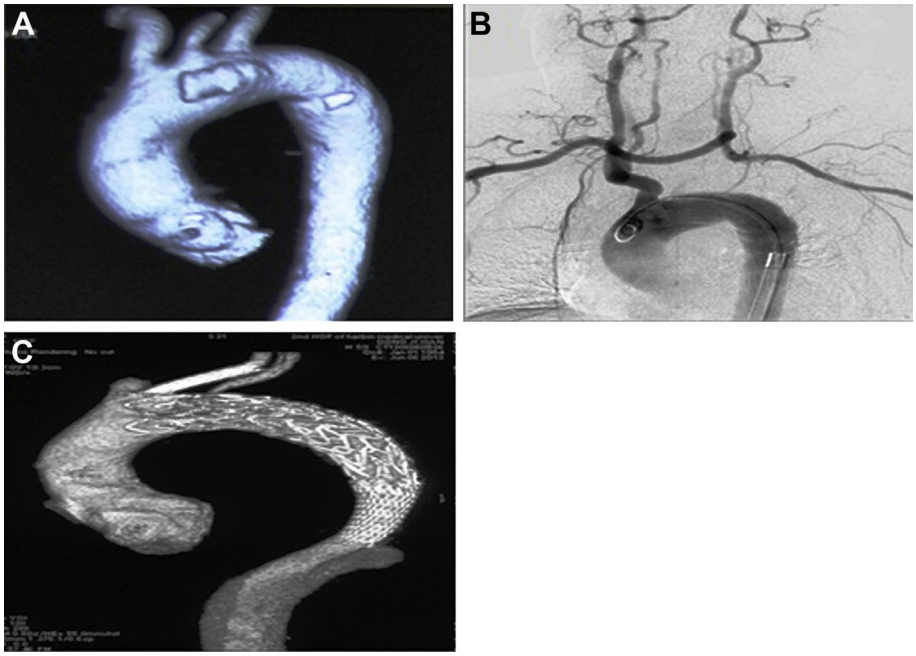


**Fig. 2.** TEVAR combined with hybrid techniques for a type B acute complicated aortic dissection (the entry tear is in Z1 zone). **(A)** Preoperative CTA demonstrated a type B acute complicated aortic dissection, where the entry tear was involved in the LCCA. **(B)** Digital subtract angiography showed the right–left carotid and the left carotid–subclavian bypass was used before TEVAR. **(C)** CTA demonstrated disappearance of false lumen of aortic dissection, a month after TEVAR combined with hybrid techniques.

bare and 19 covered stents, were deployed in 30 LSAs. The diameter of all chimney stents was 9.8 ± 1.1 mm (range 8–12 mm), and the length was 41.3 ± 5.9 mm (range 24–60 mm).

Three patients died during the study period. Two patients died because of ruptured aortic dissections immediately after 24 hours of TEVAR combined with chimney technique. One died of abrupt hemoptosis of unclear reason 7 days after TEVAR. Immediate postoperative type I endoleak was detected in 4 cases (4 of 30, 13.3%) on postoperative aortogram, in which the lesion was located at the outer curve of the aortic arch. No stroke and ST-elevated myocardial infarction were detected during the perioperative period. No stent fracture or recurrent type I endoleak was observed during the follow-up period. Treatment-related information of the 30 patients of aortic dissection treated by TEVAR combined with chimney technique is depicted in Table II.

### TEVAR Combined with Castor Branched Stent Graft

Nine patients (8 men, median age 51, range 38–73) undergone TEVAR combined with Castor branched stent-graft. Clinical data of these patients were depicted in Table III. TEVAR assisted by Castor branched aortic stent graft for 9 patients was successful (Fig. 5). All main grafts deployed successfully, and the entry tear was sealed satisfactorily with no type I endoleak. One case was changed to right approach because of difficulty of sending the main stent caused by left iliac artery stenosis. Two sidearm grafts were deployed with great difficulty, as the increased diameter of LSA caused the increase in release force. Successful release of the sidearm stents was achieved after repeated appropriate force traction. Three cases suffered from restenosis after expanding the sidearm grafts. Of which, 1 patient was treated with balloon dilatation, 2 cases were corrected by implanting balloon-expandable stent.

Mortality during perioperative period and 30 days after TEVAR was null. No serious complications such as strokes, acute myocardial infarction, and ischemia of arms were observed. CTA obtained at the 6 months after TEVAR showed elimination of the entry tear and false lumen. There was no stent twisting and migration.

## DISCUSSION

The management of acute complicated type B aortic dissection remains a clinical challenge, especially,

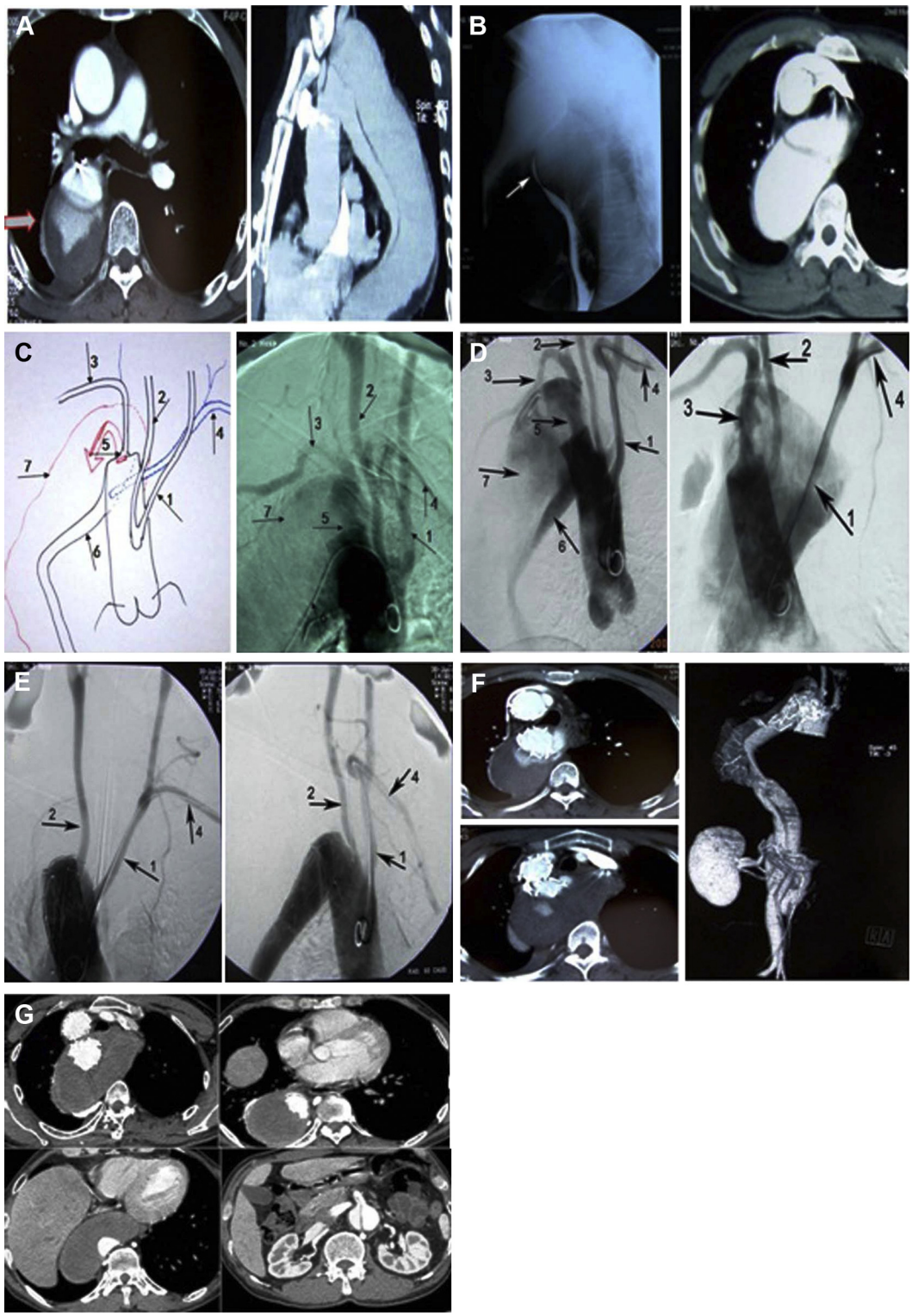


**Fig. 3.** **(A)** type B acute complicated aortic dissection with a right-sided aortic arch was treated by ipsilateral transposition and TEVAR. **(A)** Preoperative CTA demonstrated a type B acute complicated aortic dissection with a right-sided aortic arch. The *arrow* in **A** indicates esophagus compression. **(B)** The entry tear is at the top of the arch, and the esophagus was compressed. The *arrow* in **B** indicates the variation of the supra-aortic branches. **(C)** Preoperative digital subtract angiography (DSA) demonstrated, type B acute complicated aortic dissection with a right-sided aortic arch. 1: LCCA; 2: RCCA; 3: right subclavian artery; 4: LSA; 5: entry tear; 6: true lumen; 7: false lumen. **(D)** DSA showed LCCA—LSA transposition was applied before TEVAR. **(E)** Postoperative DSA after ipsilateral transposition plus TEVAR demonstrated no evidence of endoleak, the false lumen of aortic dissection disappeared. **(F)** After 1-month follow-up, CTA documented that the false lumen was largely thrombosed only with a minor endoleak. **(G)** After 5 years follow-up, CTA documented that the endoleak disappeared remarkably.

**Table I.** Technical data of TEVAR combined with hybrid techniques applied for 17 acute complicated Stanford type B aortic dissections involving aortic arch

| Variable | Zone 1 | Zone 2 | Zone 3 | Right-sided aortic arch |
|---|---|---|---|---|
| Patients | 5 | 9 | 2 | 1 |
| X-ray time, min | 14–16 | 13–15 | 6–8 | 25 |
| Contrast load, mL | 120–160 | 130–180 | 120–150 | 270 |
| Stent coverage length, cm | 150–200 | 157–200 | 150–200 | 200 |

with the aortic arch involvement, causes a dramatic and life-threatening condition. Endovascular repair of acute complicated type B dissection with a stent graft is proven to be technically feasible and effective.[13]

The potential advantage of TEVAR is less chance of surgical trauma with reduced postoperative morbidity and mortality. The need of an adequate proximal landing zone serves as a limiting factor of TEVAR. Many lesions extend proximally to the vicinity of the supra-aortic branch vessels or beyond and to extend the landing zone proximally and improve fixation and seal, LSA, LCCA, and IA need to be covered by the stent graft. Hybrid technique, chimney-graft technique, and Castor branched stent grafts were used to extend the proximal landing zones.

## Hybrid Techniques

HAR has been demonstrated as an effective alternative to open surgery, with decreased morbidity and mortality in selected patients.[18] HAR may give equivalent or better long-term outcomes for patients at high risk of surgical repair.[19,20] At present, few reports are available on clinical outcomes of HAR in patients with acute complicated aortic dissection,[11] which usually combine patients with aortic aneurysms, dissection, and other pathologies without routine analysis of these different cohorts in a separate manner.[21,22]

The present study will help readers to understand the value of HAR for acute complicated type B aortic dissection. The research has summarized the methods of hybrid for complicated aortic arch dissection. LCCA–LSA bypass serves as a most common hybrid method, when the entry tear is in Z3 zone with dominant left vertebral artery or incomplete circle of Willis. RCCA–LCCA and RCCA-LCCA-LSA bypasses serves better if the entry tear is in Z2 zone. Cervical and complete debranching techniques can help to extend proximal landing zones for Z1 zone. HAR repair in zones 1 and 2 appears as a viable alternative to conventional aortic arch surgery in patients with acute complicated type B aortic dissection.

Retrograde aortic dissection, strokes, and endoleaks constitute the Achilles' heel of hybrid arch repairs and occur in 1–2% of cases.[22,23] Owing to the lack of conformability of stent grafts in the aortic arch, the excessive radial forces applied at the convexity of the arch and the need for aortic cross-clamping during total arch debranching and endovascular maneuvers makes retrograde aortic dissections to be more frequent after hybrid arch procedures than after single TEVAR. Type I endoleaks remains a serious issue after stent grafting in the aortic arch. Persistent perfusion of the false lumen of the stent-graft exclusion segment poses complex diagnostic and therapeutic problem.

## Chimney Technique

The chimney technique consists of endovascular stent or stent-graft placement parallel to the main aortic stent graft to preserve or rescue flow to aortic branch vessels and to allow proximal extension of endograft fixation zones. In 2007, Criado systemically introduced this technique for aortic endovascular repair.[14] In the past few years, this technique has been increasingly reported to expand endograft repair in the aortic arch.[24,25]

This technique is less challenging compared with fenestrated and branched endografting, and it can be used as a planned procedure or bailout option with a variety of stents or stent grafts in stock, making it applicable in urgent situations. In addition, this technique might be helpful in reducing the number of extra-anatomic bypasses as in case hybrid TEVAR cases.[25]

The chimney technique was used for acute complicated Stanford type B aortic dissection involving aortic arch during elective and emergent TEVAR procedure that required LSA revascularizing to obtain sufficient landing zones for the thoracic stent-grafts. The chimney technique being minimally invasive provides a way of preserving flow to the arch branches combined with a favorable midterm outcome in case of type B acute dissections. The technique has been demonstrated as both feasible and safe.

Combinations of several types of stents or covered stent served as chimney grafts. Both self-

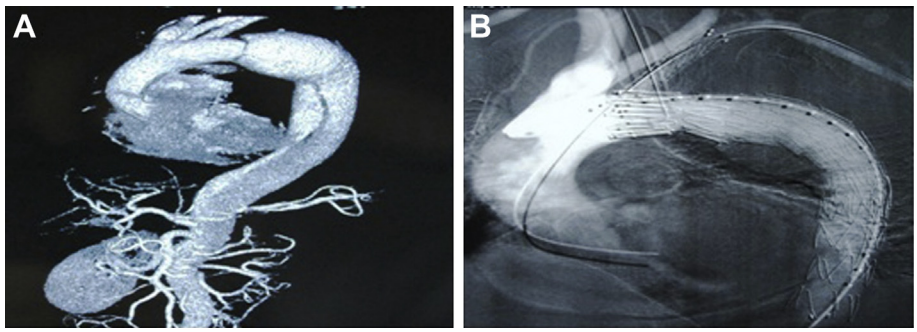


**Fig. 4.** TEVAR combined with chimney technique for recanalization of LSA for an arch having type B acute complicated aortic dissection. **(A)** Preoperative CTA; **(B)** postoperative digital subtract angiography.

**Table II.** Treatment-related information of the 30 patients of aortic dissection treated by TEVAR combined with chimney technique

| | LSA | Numbers |
|---|---|---|
| Stent types | Covered | 19 |
| | Bare | 11 |
| | Balloon expandable | 23 |
| | Self-expanding | 7 |
| Complications | Immediate type I endoleak | 4 |
| | Compression of stent | 1 |
| | ST-elevation myocardial infarction | 0 |
| | Stroke | 0 |
| | Stent fracture | 0 |
| Surgical bypasses | | 0 |

expanding and balloon-expandable devices were used. Generally, bare stents are applied to restore blood flow in over stented branch vessels, whereas covered stents are used to improve proximal seal. The choice of self-expanding versus balloon-expandable devices is a tradeoff between the need for flexibility and radial force. The mechanical properties of an ideal chimney graft are unknown and need to be established.

One of the main concerns of the chimney technique is the risk of proximal type I endoleak. The bare stents are highly prone to type I endoleaks. Chimney-stent patency is another controversial topic. A balloon-expandable stent should be regarded as the first choice because of its greater radial strength. Therefore, balloon-expandable covered stents for the chimneys were preferred to be used to avoid graft erosion and fracture due to aortic pulsatility and respiratory movement. Extensive research needs to be conducted to draw robust conclusions regarding this promising alternative endovascular technique.

## Branched Stent Grafts

The incidence of atherosclerosis due to arterial dilation has been increased in recent. The presence of limb and visceral ischemia, paraplegia, and other serious complications will lead directly to disability and fatality. The endovascular stent-graft repair has significantly reduced surgical trauma and has gradually become the main treatment for aortic dilatation disease. However, because of lack of suitable graft, the surgery involving LSA is relatively a contraindication for endovascular treatment.

The advent of Castor is an invaluable alternative and a crucial step toward the treatment of aortic arch atherosclerosis. The clinical trials with Castor stent-graft system is one of the world's first prospective, randomized, multicenter clinical study that has been approved by State Food and Drug Administration for Branched thoracic stent graft. It has also become an important part of National 863 Projects and the 12th Five-Year Plan of the country. The successful first implantation again demonstrates company's commitment in bringing meaningful innovations to market that provide more treatment options to a broader spectrum of patients.

Tapered Castor stent-grafts of 180—200 mm length are more suitable for TEVAR of aortic dissections involving aortic arch. No uncontrollable endoleaks was detected with 10% oversizing. The results of early follow-up after operation were satisfactory.

Depending on its reasonable and accurate release approach, integrated-aortic arch branched reconstruction stent graft brings a new reconstruction method to LSA. The advantages include avoiding the injury brought by compound operation and the reduced incidence of the endoleak caused by chimney techniques.

In conclusion, combining with techniques that extends proximal landing zone, such as hybrid

**Table III.** Clinical data of 9 patients treated with TEVAR combined with Castor branched stent graft

| Number | Gender | Age (years/old) | Diameter of main graft (mm) | Coated length (mm) | Diameter of sidearm graft (mm) | Operation time (min) |
|---|---|---|---|---|---|---|
| 1 | Male | 57 | 34−30 | 180 | 10 | 140 |
| 2 | Male | 61 | 32−26 | 200 | 10 | 95 |
| 3 | Male | 41 | 34−28 | 200 | 10 | 170 |
| 4 | Male | 38 | 30−24 | 180 | 10 | 115 |
| 5 | Male | 51 | 32−26 | 200 | 10 | 110 |
| 6 | Female | 61 | 32−28 | 200 | 10 | 110 |
| 7 | Male | 49 | 34−30 | 180 | 10 | 225 |
| 8 | Male | 53 | 32−26 | 200 | 10 | 110 |
| 9 | Male | 50 | 34−30 | 180 | 10 | 175 |

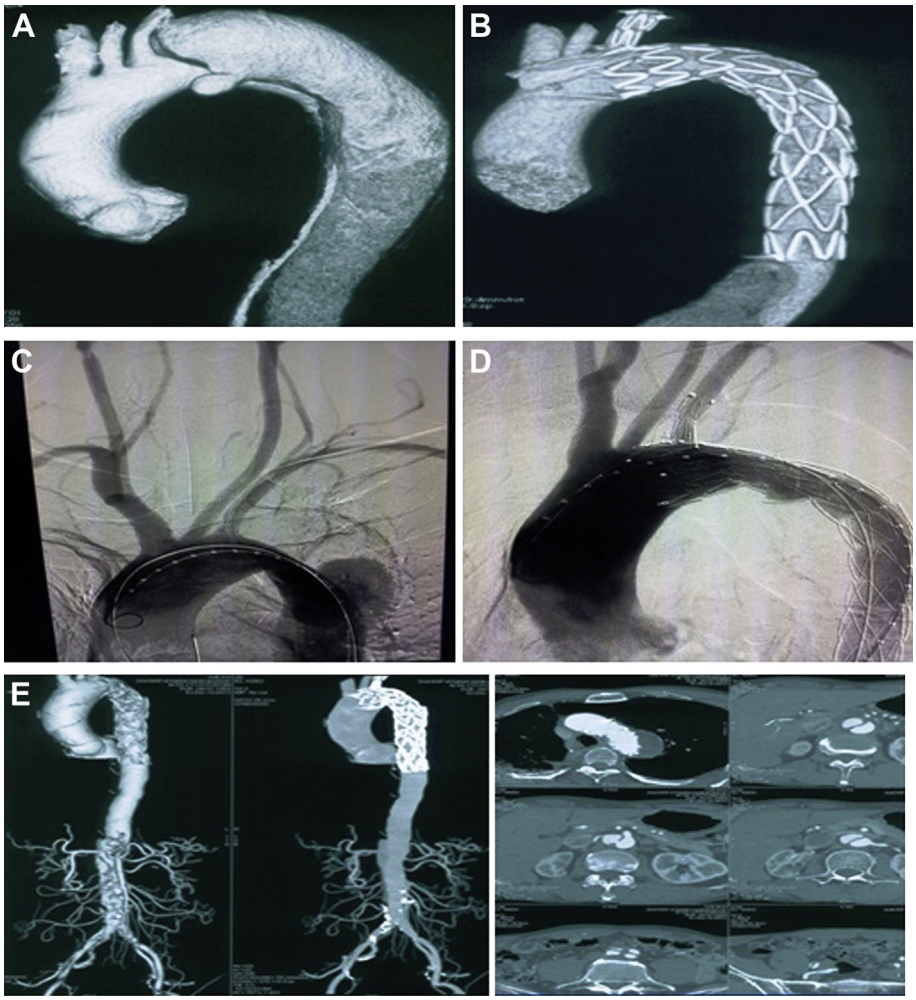


**Fig. 5.** TEVAR combined with Castor branched stent graft was used for a patient with acute complicated type B aortic dissection extending from arch to descending aorta. **(A)** Preoperative CTA; **(B)** postoperative CTA; **(C)** preoperative digital subtract angiography (DSA); **(D)** postoperative DSA; **(E)** CTA at 6 months after TEVAR.

technique, chimney technique, and endodebranching stents, TEVAR could effectively fix arch-involved aortic dissections. Each of previously mentioned techniques has specific advantages and disadvantages, so they should be carefully chosen.

The limitations of the present study to be considered are as follows: small numbers and the heterogeneity of patients and the lack of a randomized control group precluded direct comparison with conventional TEVAR. In addition, to make any significant conclusions regarding the durability of the repair and morphologic changes, long-term follow-up is required.

## CONCLUSIONS

The results of the study indicate that TEVAR combined with hybrid techniques, chimney technique, and branched stent-grafts is proven to be a technically feasible and effective treatment for acute complicated Stanford type B aortic dissection involving aortic arch in small cohort. Long-term follow-up is necessary to document sustained efficacy.

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