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Original Article

Surgical stent-graft implantation by open procedure for type B aortic dissection without optimal landing zone

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Abstract

Thoracic endovascular aortic repair (TEVAR) has been considered as a first-choice treatment for type B aortic dissection (TBAD). However, some patients that is lack of optimal landing zones (<15 mm in dissected Z_2, Z_3 or the presence of a lusorian artery) still pose significant challenges for TEVAR. We utilized a surgical stent-graft implantation in the descending aorta combined with supra-aortic vessels transposition through median sternotomy for these special TBAD patients. The short- and mid-term results showed that our procedure is a good and alternative therapy for such kind patients.

Keywords: Type B aortic dissection, open surgery

Introduction

Type B aortic dissection (TBAD) carries a high mortality and morbidity rate although great strides have been made within the past 20 years. Some studies argued that medical management could bring a satisfactory survival rate for uncomplicated TBAD patients[1–2]. Unfortunately, 20%–40% of TBAD patients eventually developed dissected aortic aneurysm conditions and required surgical intervention during long-term follow-up[3–4]. Since TEVAR has received approval by United States Food and Drug Administration, TEVAR was considered to be the first-choice treatment for TBAD because of its clear benefit with a lower mortality and morbidity rate compared to open surgery[3,5–9]. The total coverage of the proximal entry tear and redirection of the thoracic aortic flow entirely through the true lumen are the fundamental principles for its successful therapy, while the success of this strategy particularly depends on the optimal landing zone. However, not all TBAD patients come with optimal landing zones in clinical practice, that is to say, dissected Z_2, dissected Z_3 with a landing zone less than 15 mm, or presence of a lusorian artery (the lusorian artery is a rare variant of the right subclavian artery, which originates in the descending aorta and crosses behind the esophagus to the right) is accompanied. Therefore, such conditions remain a significant challenge for these TBAD patients.

In the very beginning of 2012, inspired by the surgical treatment for type A aortic dissection (TAAD), we implanted the surgical stent-graft into the descending aorta covering the proximal entry tear and

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reconstructed the supra-aortic vessels for these special TBAD patients by performing an open surgical procedure. Here, in this study, we evaluate the short- and mid-term results of this procedure that may lead to enhanced therapeutics and improve the clinical outcome in patients with TBAD in the future.

Patients and methods

The study population and demographics

Between January 2012 and June 2015, 31 TBAD patients without an optimal landing zone were underwent open surgery in our cardiovascular institution. Twenty-seven patients had uncontrolled chest pain and the other four patients were in their chronic stage with increased false lumen. All of the patients were diagnosed by computed tomography (CT) angiography and evaluated by echocardiography preoperatively. Information pertaining to medical history (co-morbidities including: hypertension, chronic obstructive pulmonary disease, diabetes mellitus, uremia need dialysis, and stroke) was collected. The demographics and clinical characgteristics of the patients are shown in ***Table 1***. All of the patients gave their consent for this clinical information and data analysis. The procedure was approved by the ethical committee of Nanjing First Hospital and Nanjing Medical University before January 2012. The exclusion criteria were as follows: 1) TBAD due to connective tissue disorders or genetic reasons; 2) TBAD combined valvular disease or ascending aortopathy; 3) TBAD patients in a coma or stage of organ ischemia preoperatively.

Table 1 **Demographics and clinical characteristics (*n*=31)**

Variable	Value
Gender (*n*)	
Male	24
Female	7
Age (year)	52.16±11.05
Stage (*n*)	
Acute	27
Chronic	4
Hypertension [*n* (%)]	31 (100)
COPD* [*n* (%)]	1 (3.23)
Diabetes mellitus [*n* (%)]	3 (9.68)
Uremia need dialysis [*n* (%)]	2 (6.45)
Stroke [*n*(%)]	1 (3.23)

*COPD: chronic obstructive pulmonary disease.

Surgical procedures

Patients were examined by CT angiography and echocardiography preoperatively to assess the true/false lumen, branch involvement, proximal entry tear, abdominal aorta diameter, and measurement of the heart function. Transesophageal echocardiography (TEE) was performed in all of the patients during the operation. After general anesthesia, the arterial blood pressures of both the upper and lower limbs were monitored. The the right axillary artery was exposed for perfusion cannula and a median sternotomy was performed. An arterial cannulation was inserted into the right axillary artery, and a dual-stage atriocaval cannula was placed at the right atrium. Right axillary artery cannulation was routinely used for cardiopulmonary bypass (CPB) was routinely established with selected cerebral perfusion (SCP). Patients were cooled to a nasopharyngeal temperature of approximately 24 °C to 26 °C by CPB. During the cooling process, the brachiocephalic arteries were dissociated and exposed for as long as possible. The ascending aorta was clamped and cardioplegia was given. CPB was discontinued when the nasopharyngeal temperature was less than 26 °C, while the time of circulatory arrest, the brain continued to be perfused at a rate of approximately 5 to 10 mL/(kg·minute) through the right axillary artery cannulation. A curved incision in the aortic arch was performed. A catheter sheath containing the surgical stent-graft (diameter 26–30 mm, length 100–150 mm, CRONUS, Shanghai MicroPort Lifesciences Co., Ltd.) was inserted into the descending aorta, then deployed. The proximal entry tear, including left subclavian artery (LSA), was covered by the stent-graft. The proximal end of stent-graft was sutured to the aortic wall carefully without creating a new tear. The aortic arch incision was closed as quickly as possible and systemic perfusion was restored. LSA was transplanted to the left carotid artery (LCA) following this procedure. If the left vertebral artery (LVA) was present to be dominant, both the LSA and dominant LVA were transplanted to the LCA. If the lusorian artery was present, the femoral artery was chosen for perfusion, and bilateral carotid arteries were used for cerebral perfusion during circulatory arrest. In this situation, apart from reconstruction of the LSA, the right subclavian artery (RSA) also needed to be transplanted. All of the operations were done by the authors of this paper in Nanjing First Hospital.

Follow-up methods

Follow-up CT angiography studies were performed

at three months and one year regularly postoperatively. Graft patency, true and false lumen, endoleak, and aortic morphology were assessed.

Statistical analysis

Values are expressed as mean±SD. For continuous variables where the one-way ANOVA analysis was used for the comparison in more than two groups. The survival analyses were performed using the Kaplan-Meier method. A P value of less than 0.05 (P<0.05) was considered statistically significant.

Results

Operative results

Total of 31 patients were enrolled in the present study. The baseline clinical characteristics of the study subjects are detailed in ***Table 1***, which summarizes the demographic data and clinical history of the TBAD patients [24 males and 7 females; mean age, (52.16±11.05) years]. In this cohort study, dissected Z_2 and Z_3 with a landing zone less than 15 mm was present in 13 patients (41.94%) and 8 patients (25.81%), respectively. Dominant LVA was present in 5 patients (16.13%), and the lusorian artery was present in 3 patients (9.68%, ***Fig. 1***).

Operation was successfully performed in all of the 31 patients. CPB time was (201.10±30.32) minutes and circulatory arrest time was (22.81±5.56) minutes. All of the patients regained consciousness within 24 hours after operation without stroke, paralysis, paraplegia, hemiplegia or other neurological complications. The postoperative intubation time less than 48 hours was achieved in 30 patients, with one exception that the patient was required for re-intubation and tracheotomy due to a severe lung infection. There was no new occurrence of acute kidney injury (AKI) in this group, and the two patients who had uremia prior to enrollment were not included. One patient had a re-open sternotomy (7 days postoperatively) due to pericardial effusion and sternal instability. Finally, all patients were successfully discharged.

Follow-up results

Follow-up was achieved for all patients postoperatively with mean follow-up time of (34.06±12.63) months. One of the two uremia patients died 23 months after operation due to end-stage renal failure. One patient died from myocardial infarction in the emergency room 21 months postoperatively. The three-year survival rate was 93.55% (***Fig. 2***).

There was no detected endoleak in all of follow-up images. Thrombosis of the thoracic false lumen was obtained in all patients. After the procedure, expansion of the true lumen and regression of the false lumen was noted. At the fourth thoracic vertebrae (T4) level, the diameter of thoracic true lumen was increased by 149.59%, 169.73%, 170.93%, 166.79% and 166.79% following up at 3, 12, 24, 36 and 48 months, respectively. The diameter of thoracic false lumen was decreased by 68.12%, 82.07%, 86.48%, 89.73% and 94.48% following up at 3, 12, 24, 36 and 48 months, respectively. The same tendency can be seen at T10 level (***Fig. 3***–***5***).

Discussion

Contributing to an unhealthy lifestyle and uncontrolled blood pressure, more and more patients suffer from acute aortic dissection (AD) in China, including

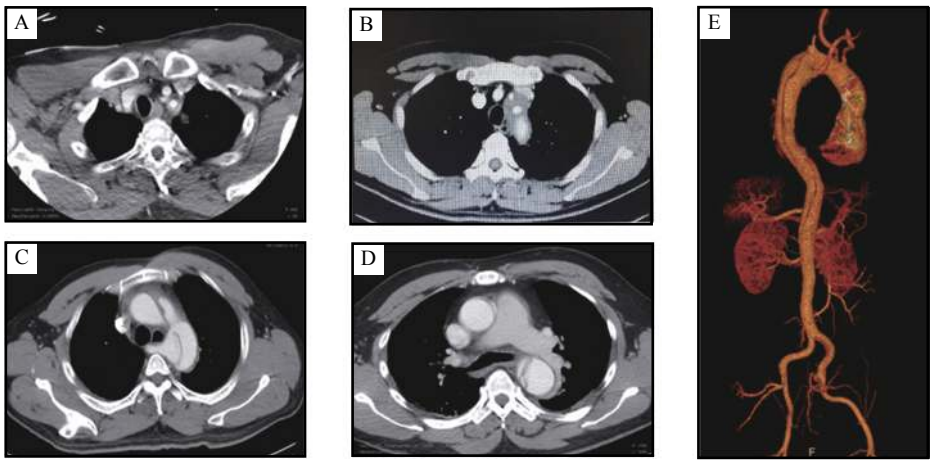

Fig. 1 **Preoperative computed tomography of TBAD patients.** A: LSA was dissected; B: Both LSA and LCA were dissected; C and E: Lusorian artery originated from the descending aorta nearby aortic arch; D: Severe oppression of true lumen was observed in the descending aorta. LSA: left subclavian artery; LCA: left carotid artery.

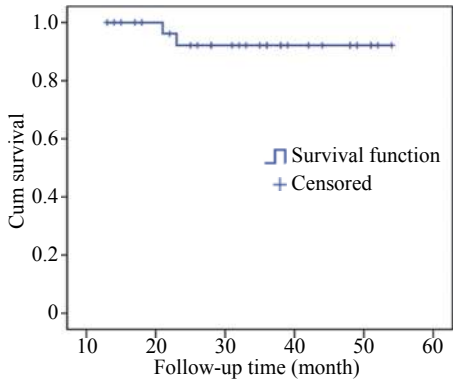

Fig. 2 **Kaplan-Meier estimate of the cumulative overall patient survival for all-cause mortality during follow-up.**

type A and B. Although majority of TBAD patients survived from acute phase during the therapy with optimal medical management in most of the circumstances, a subset of patients developed severe complications resulting from dissection progression that manifested as aneurismal degeneration, rupture, or end-organ malperfusion[6–8]. This is one of the reasons why aggressive treatment should be done for TBAD patients, even for uncomplicated cases[9]. The innovative treatment TEVAR has gained more acceptance across the world with excellent short-term results and offers the possibility of treating patients who are not a candidate for conventional open-surgery. However, TBAD patients without an optimal landing zone presents specific challenges for TEVAR. Since we have performed many operations on TAAD patients in our institution, we gained a lot of experience in aortic arch surgery which was performed under CPB and HCA and SCP. Therefore, inspired by the theory of TEVAR, we performed the aortic arch angiotomy, implanted the surgical stent-graft in the descending aorta and transplanted the supra-aortic vessels by performing an open surgical procedure under CPB. There were no postoperative neurological complications such as stroke, paralysis, paraplegia after this procedure, more than that, no surgical death revealing the satisfied safety of this surgical procedure. As described in previous studies, open surgical replacement of pathology aortic arch carries a high mortality and morbidity[10–11]. Although our procedure was also an open surgical repair under CPB and HCA, the incidence of death and complications was significantly lower compared with the conventional open surgery.

Neurological events must be considered as serious complications after treatment of TBAD. Previous studies showed the incidence of neurological morbidity of TEVAR in TBAD patients, including stroke (1.4% to 20%) and paraplegia (0 to 13.3%)[1,7,12]. We argue that the management of the supra-aortic vessels

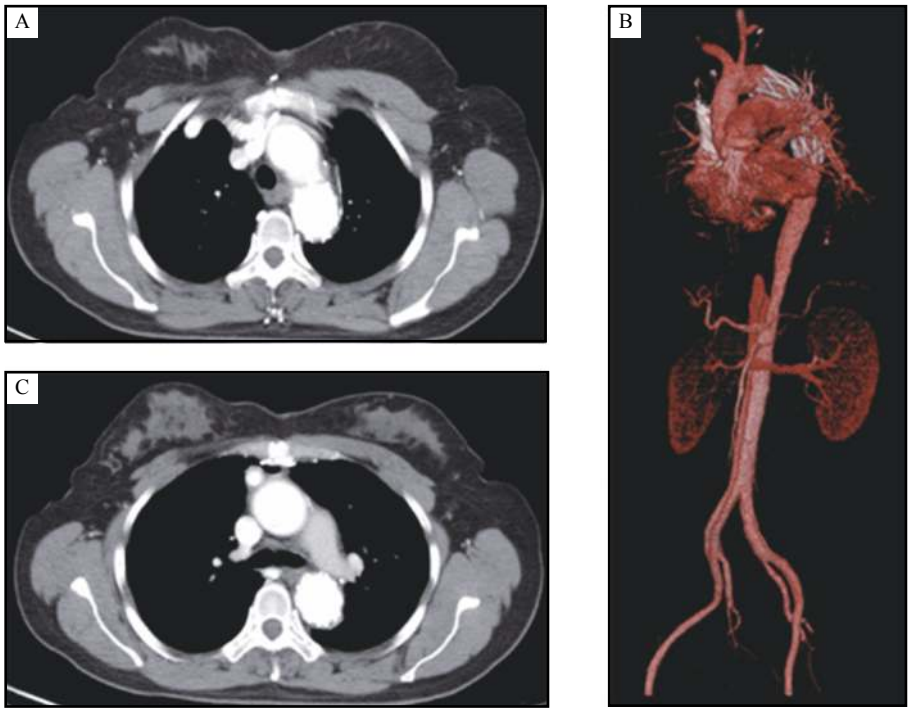

Fig. 3 **Postoperative computed tomography of TBAD patients.** A: The right subclavian artery was rebuilt in the ascending aorta using an artificial vessel; B: Expansion of true lumen and regression of false lumen were observed in the descending aorta compared to the preoperative time; C: LSA was transplanted to LCA, while the opening site of LSA was covered by the stent-graft. LSA: left subclavian artery; LCA: left carotid artery.

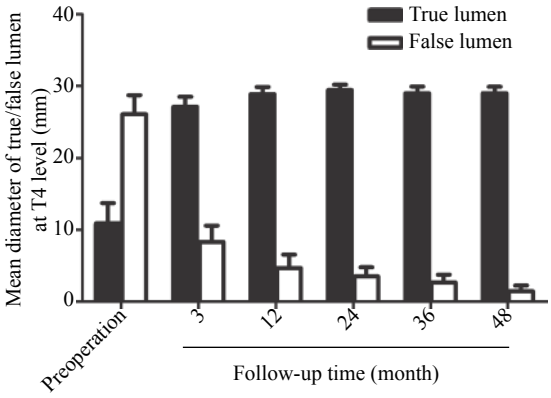

Fig. 4 **Expansion of the true lumen and regression of the false lumen were noted in the follow-up time at the T4 level.** After the implantation of the surgical stent, the true lumen of the thoracic aorta was obviously enlarged compared to the preoperative measurements (P<0.05); meanwhile, the false lumen was greatly regressed (P<0.05).

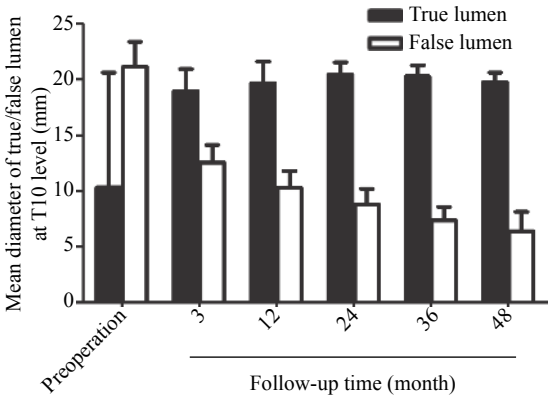

Fig. 5 **Expansion of the true lumen and regression of the false lumen were observed in the follow-up time at the T10 level.** Compared to pre-operation, the true lumen of the thoracic aorta was obviously expanded (P<0.05); meanwhile, the reversed tendency can be seen in the false lumen (P<0.05).

is of much importance. Some articles reported that the LSA could be covered safely by prosthesis after a strong preoperative evaluation[13–14]; however, there is an increasing number of studies suggesting that revascularization of LSA (including dominant LVA in some cases) offers protection against a composite endpoint of stroke, paraplegia and death[15–17]. We performed the arteries transposition to rebuild the supra-aortic vessels, which was at least a contributor to a non-neurological event in this study. More importantly, for the presence of lusorian artery, the RSA was reconstructed in the ascending aorta safely and completely and it is one of the advantages of the open procedure.

The surgical supra-aortic transpositions extend the proximal landing zone, which supplies a healthy and safe coverage site for surgical stent-graft. Retrograde ascending dissection (RAD) is a catastrophic complication after TEVAR and occurs in 1%–3% of patients[18–19]. Although multiple risk factors have been suggested to explain RAD, the unhealthy landing site is considered as one of the potential risk factors leading to RAD[20]. In this study, the safe landing site was ensured and the stent-graft was sutured to the healthy aortic wall under direct vision and this is why no RAD and neurological problems present themselves as an early or late complication after the operation.

Thrombosis of the thoracic false lumen, expansion of the true lumen, and regression of the false lumen are signs of fine aortic remodeling after the surgery, which are related to long-term survival and re-intervention rates. In the INSTEAD trial, mean percentage expansion of the thoracic true lumen was 114% and regression of the thoracic false lumen was 84% at 12-month follow-up after TEVAR[21]. Similar findings were achieved in this study. Follow-up CT images showed a notable expansion of true lumen and a distinct regression of false lumen after surgery in this group of patients, which suggests that aortic remodeling following stent-graft implantation occurs with satisfactory results.

Since TEVAR is recommended as the first line of therapy for TBAD, fenestrated and branched stent technologies are supplementary means for those patients who have no optimal landing zones, but they still have some technology related difficulties and complications. Besides that, hybrid procedures, which combine supra-aortic vessel transposition with TEVAR, have emerged as an effective treatment and gained satisfactory results for these TBAD patients[22]; however, the hybrid procedure not only costly, but also demands a special hybrid operating room bringing economic burden and difficulties for patients and hospitals alike.

In this study, we did not set TEVAR as the control to try to demonstrate the superiority of our therapy on TBAD patients, because we argue that TEVAR and our procedure have different indications and treat different aortic pathologies. Additionally, we are aware that the size of the cohort is small.

In conclusion, surgical stent-graft implantation by an open surgical procedure emerges as an alternative therapy for TBAD patients without an optimal landing zone. It showed satisfactory results.

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