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Article

Debranching Thoracic Endovascular Aortic Repair Combined with Ascending Aortic Banding: Analysis of a New Surgical Procedure

Hui-Qiang Gao[1,*], Shang-Dong Xu[1], Jun Zheng[1]

[1]Department of Cardiac Surgery, Beijing Anzhen Hospital, Beijing Institute of Heart, Lung & Vascular Diseases, Capital Medical University, 100029 Beijing, China
*Correspondence: ghqngys@sina.com (Hui-Qiang Gao)
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Abstract

Background: To analyze the clinical effect of debranching thoracic endovascular aortic repair combined with ascending aortic banding. **Methods**: The clinical data of patients who underwent a debranching thoracic endovascular aortic repair combined with ascending aortic banding at Anzhen Hospital (Beijing, China) between January 2019 and December 2021 were reviewed to evaluate the occurrence and outcomes of postoperative complications. **Results**: A total of 30 patients underwent a debranching thoracic endovascular aortic repair combined with ascending aortic banding. There were 28 male patients (93.3%) with an average age of 59.9 $\pm$ 11.8 years. Twenty-five patients underwent simultaneous surgery and five patients had staged surgery. Postoperatively, two patients developed complete paraplegia (6.7%), three patients developed incomplete paraplegia (10%), two patients developed cerebral infarction (6.7%), and one patient developed femoral artery thromboembolism (3.3%). No patient died during the perioperative period, and one patient (3.3%) died during the follow-up period. None of the patients underwent retrograde type A aortic dissection during the perioperative and postoperative follow-up periods. **Conclusions**: Banding the ascending aorta with a vascular graft to restrict its movement and to serve as the proximal anchoring area of the stent graft can reduce the risk of retrograde type A aortic dissection.

Keywords

banding; debranch; thoracic endovascular aortic repair; retrograde type A aortic dissection

Introduction

Surgical operations have become increasingly minimally invasive. Surgery to treat aortic arch lesions is complicated, difficult to perform, and traumatic, and the probability of complications is high. With the advancement of aortic endovascular technology, hybrid surgery, such as debranching thoracic endovascular aortic repair (d-TEVAR), has been increasingly performed for the treatment of aortic arch lesions. However, the increased incidence of retrograde type A aortic dissection (RTAAD) severely limits the application of this technology, which is only used in high risk patients [1,2]. The present study described an improvement in this technique, in which the ascending aorta was first banded with a vascular graft and then used as an anchoring site for d-TEVAR to avoid RTAAD [3].

Methods

Patient

This was an observational and retrospective study. The inclusion criteria for patients were as follows: (1) Non-A non-B dissection, regardless of the location of the rupture in the aortic arch or proximal descending aorta, the dissection or hematoma retrogradely involves the aortic arch (zone 1 or 2 involvement); (2) penetrating aortic ulcers (PAUs) located in the aortic arch; (3) aortic aneurysms involving the aortic arch (dilation involves zone 1 or 2); and (4) patients who underwent d-TEVAR combined with ascending aorta banding at Anzhen Hospital (Beijing, China) between January 2019 and December 2021. Patient information and disease-related data were extracted from hospitalized patient case records. Since this was a retrospective study, it did not require informed consent from patients. The study was approved by the Ethics Committee of Anzhen Hospital.

Surgical Procedure

A median sternotomy was performed after administering anesthesia. The pericardium was then opened, the heart and the ascending aorta were exposed, and the branches of the brachiocephalic artery were mobilized. After heparinization, the side wall of the ascending aorta was clamped with a side bite clamp, and the main trunk of a double-Y-shaped vascular graft was anastomosed end-to-side with the side wall of the ascending aorta. The innominate artery was divided, the proximal stump was sutured, and the distal end was anastomosed end-to-end with one branch of the double-Y-shaped vascular graft to restore blood flow. The left common carotid artery was then transected and the stump was closed. The distal end of the left common carotid artery was anastomosed to one of the double-Y-shaped vascular grafts in an end-to-end fashion, to restore the blood supply to the left common carotid artery. The left subclavian artery was then transected, the proximal end was closed, the distal end was anastomosed with another end of the double-Y-shaped vascular graft branch, to restore blood flow to the left subclavian artery. The ascending aorta was banded with a straight vascular graft of an appropriate diameter and firmly sutured (Fig. 1). The distal end of the vascular graft and the position of the double-Y-shaped vascular graft's proximal anastomotic location were marked with a barium line (Fig. 2). A pigtail catheter was used to puncture the femoral artery to the ascending aorta for total aortic angiography to identify the lesion and the position of the vascular graft in the banded segment marked with a titanium clip. The stent graft was delivered to the ascending aorta via the femoral artery, and the banded vascular graft was used as the proximal anchoring site (Fig. 3) [3]. If needed, the second stent graft was delivered into the descending aorta, and the second stent graft was released using the distal end of the first stent graft as the anchoring site. Angiography was performed again to confirm that the lesion was sufficiently isolated and that there were no complications, such as endoleaks. The operation was then finished, the barium line was dismantled, and the chest was closed. Perioperatively, cerebrospinal fluid drainage was performed if spinal cord ischemia was suspected, such as sensorimotor abnormalities in the lower limbs. A gap between systolic blood pressure and cerebrospinal fluid drainage pressure (usually 10 mmHg) was maintained at >130 mmHg.

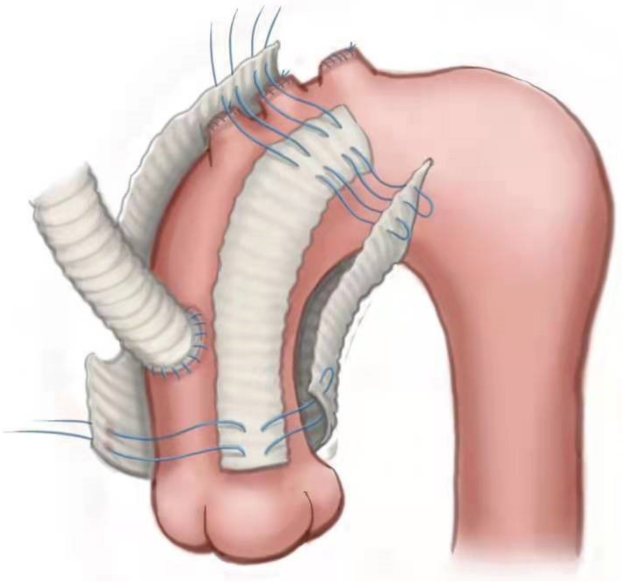

Fig. 1. After banding the ascending aorta with a vascular graft, it was used as the proximal anchoring area for the stent graft.

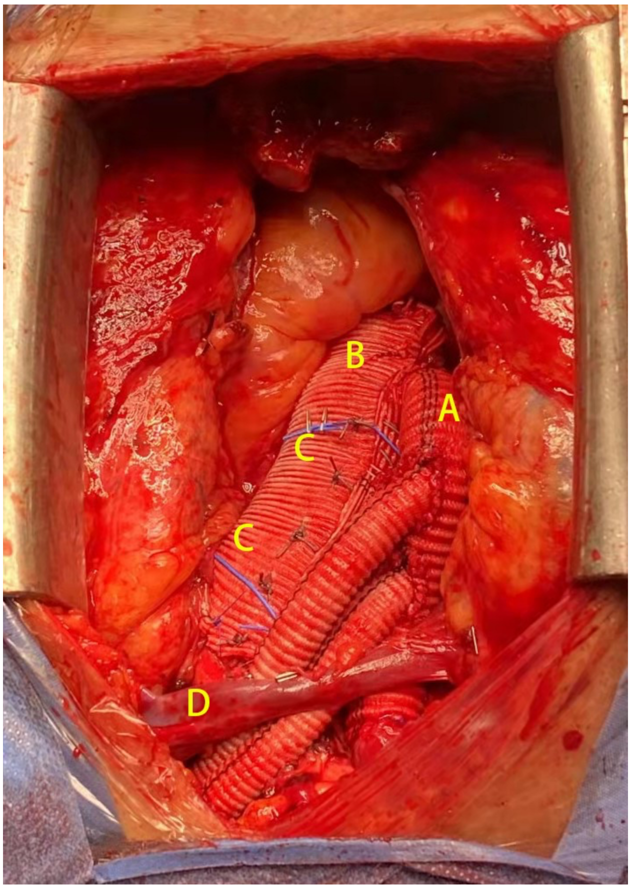

Fig. 2. Intraoperative images. (A) Double-Y-type vascular graft. (B) Ascending aorta banded with vascular graft. (C) Barium line. (D) Innominate vein.

Follow-Up

Regular patient follow-up was conducted using the address, telephone number, and other relevant contact information recorded at the time of admission. Patients were instructed to return to the hospital annually for a computed tomographic angiography (Fig. 4). Patients who did not return were contacted via telephone. Patients' postoperative recovery and complications outcomes, including delayed complications, were recorded in detail.

Statistical Analysis

Continuous variables were expressed as the mean ± standard deviation. Categorical variables were expressed as frequencies and percentages. The analyses were performed with R (http://www.R-project.org) and Empower Stats software (https://www.empowerstats.net/en/, X&Y Solutions, Inc., Boston, MA, USA).

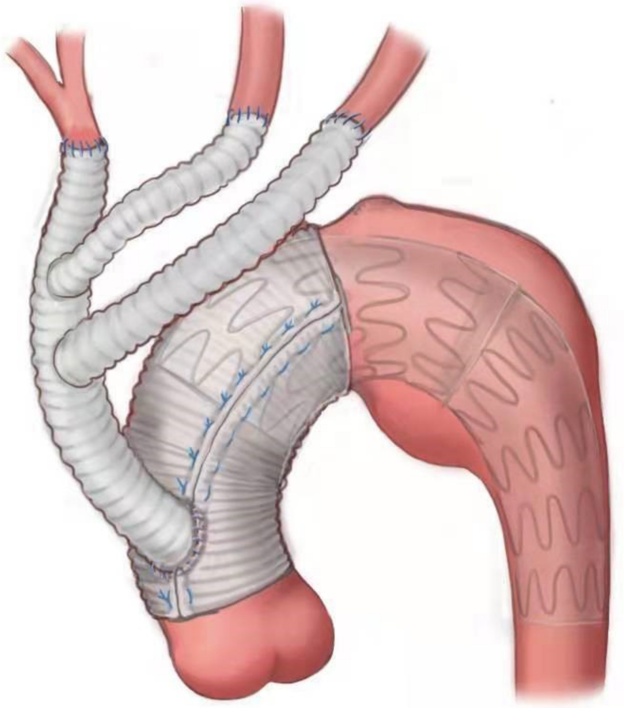

Fig. 3. Debranching thoracic endovascular aortic repair combined with ascending aortic banding.

Fig. 4. Postoperative reconstruction image. Proximal stent end was anchored by ascending aorta banded with vascular grafts.

Results

A total of 30 patients underwent d-TEVAR combined with ascending aortic banding at the cardiac surgery ward five of the Anzhen Hospital between January 2019 and December 2021. The patients included 28 males (93.3%) with an average age of 59.9 ± 11.8 years. Patient diagnoses included 10 cases of non-A-non-B aortic dissection (including eight cases of acute dissection and two cases of chronic dissection), 10 cases of aortic arch aneurysm, and 10 cases of penetrating aortic ulcer (PAU). The preoperative baseline information for these patients is shown in Table 1. One of the patients had paraplegia due to dissection involving the intercostal artery before surgery.

Table 1. Patient data.

Item	Value
Number	30
Gender (male), n (%)	28 (93.3%)
Age (years), mean ± SD	59.9 ± 11.8
BMI	25.6 ± 3.1
Main diagnosis	
Non-A-non-B dissection	10 (33.3%)
Acute dissection	8 (80%)
Chronic dissection	2 (20%)
Aortic arch aneurysm	10 (33.3%)
Penetrating aortic ulcers	10 (33.3%)
Coexisting diseases	
Hypertension	24 (80.0%)
CAD	6 (20.0%)
Dyslipidemia	4 (13.3%)
Diabetes	3 (10.0%)
Cerebral infarction/cerebral hemorrhage	6 (20.0%)
Kidney disease	3 (10.0%)
Paraplegia	1 (3.3%)
History of previous surgery	
PCI	2 (6.7%)

CAD, coronary artery disease; SD, standard deviation; BMI, body mass index; PCI, percutaneous coronary intervention.

All of the patients underwent d-TEVAR combined with ascending aortic banding. A total of 25 patients had simultaneous surgery and five patients underwent staged surgery (d-TEVAR first, then TEVAR). Two of the patients underwent off-pump coronary aortic bypass grafting (OP-CABG), and one patient underwent renal artery stent implantation during surgery (Table 2). No patient died or developed RTAAD during the perioperative period.

Postoperatively, two patients developed complete paraplegia (6.7%), three patients developed incomplete paraplegia (10%), two patients developed cerebral infarction (6.7%), and one patient developed femoral artery thromboembolism (3.3%; Table 3). Among the paraplegic patients, two patients with complete paraplegia did not recover after surgery. The symptoms of the three patients with incomplete paraplegia were improved to a certain extent: one patient partially recovered the ability to walk, while two other patients recovered completely.

Table 2. Perioperative data.

Perioperative data	Value
Surgical approach	
Debranch	30 (100%)
Ascending aortic banding	30 (100%)
TEVAR	30 (100%)
OPCABG	2 (6.7%)
Renal artery stent implantation	1 (3.3%)
Staged operation	5 (16.7%)
Operation time (h)*	6.1 ± 1.2
Anesthesia wake time (h)*	5.4 ± 3.7
Ventilator assistance time (h)*	16.6 ± 9.8
ICU stay time (h) (median (interquartile range))*	22.3 (17.7, 55.0)
Postoperative hospital stay (day)*	9.2 ± 3.1
Position of the distal end of the stent (thoracic level)	9.1 ± 1.5
Average number of stents used	1.9 ± 0.7
Stent brand**	
GORE	3 (10.0%)
Valiant	11 (36.7%)
GRIMED	16 (53.3%)

*Data for simultaneous surgery; **Proximal stent; OPCABG, off-pump coronary artery bypass grafting; TEVAR, thoracic endovascular aortic repair.

Table 3. Perioperative and follow-up complications.

Complication	Value
Perioperative period	
Death	0 (0%)
RTAAD	0 (0%)
Complete paraplegia	2 (6.7%)
Incomplete paraplegia	3 (10.0%)
Cebral infarction	2 (6.7%)
Femoral artery thromboembolism	1 (3.3%)
Follow-up period	
Death	1 (3.3%)
RTAAD	0 (0%)

RTAAD, retrograde type A aortic dissection.

The patients were followed up for an average of 10.5 ± 9.2 months with a follow-up rate of 100%. One patient died of complications related to a cerebral infarction during the follow-up period. None of the patients experienced RTAAD during the postoperative follow-up periods. One patient died during the follow-up period, and the mortality rate was 3.3%.

Discussion

In recent years, minimally invasive surgery has become the preferred treatment for many surgical procedures. In the cardiovascular field, congenital heart disease closure with fluoroscopy intervention, aortic interventional surgery, and valvular interventional surgery have increasingly been used as the mainstream surgical procedures. Aortic arch surgery has always been a challenge in cardiac surgery due to technical difficulty and increased incidence of complications, such as hemorrhage, cerebral infarction, hypoxemia, and acute kidney injury. The current interventional methods to treat arch lesions, such as parallel grafts, also have technical issues, such as a high risk of endoleaks and the need for reintervention [4]. The emergence of d-TEVAR greatly reduces the operation difficulty and avoids deep hypothermic circulatory arrest, while decreasing the risk of endoleaks. However, d-TEVAR has its own complications which include RTAAD with an incidence of 2.8–18.7% [1,2,5–11].

The incidence of RTAAD is about 1.33% in conventional TEVAR surgery when the anchoring area of the initial segment is in the descending aorta [12]. When the anchoring area of the stent moves forward to the ascending aorta and aortic arch in d-TEVAR, the incidence of RTAAD greatly increases, suggesting that the use of the ascending aorta as the anchor area is responsible for this change.

Jin *et al*. [13] found that the movement of the ascending aorta in each cardiac cycle is more complicated than that of the descending aorta. The ascending aorta does not only periodically contract and relax in diameter with changes in blood pressure, but also moves forward and rotates axially with the contraction of the heart. The descending aorta often only needs to periodically contract and dilate in diameter with changes in blood pressure. Therefore, the ascending aorta wall has a greater compliance than the descending aorta. The implanted stent graft in the present study was rigid and lacked compliance and elasticity. When the ascending aorta expands, the stent cannot expand along with it. The extremely high energy blood flow can impact the gap between the stent and the proximal end of the ascending aorta, causing the stent to shift. When the aorta contracts, the crown-shaped bare stent extending outwards at the proximal end of the stent squeezes the wall of the aorta, which is likely to cause a new rupture of the stent, thereby forming an RTAAD. When the ascending aorta moves horizontally combined with a certain degree of rotation, the rigid stent graft cannot move well with the ascending aorta. They shift and rub against each other to damage the aortic wall and cause RTAAD. Czerny *et al*. [11] has referred to this phenomenon as a compliance mismatch between the ascending aorta and the stent graft.

The improvement described in the present study was designed to address this compliance mismatch. The banded blood vessel cannot perform a diastolic motion with the heartbeat. When the ascending aorta was banded with a vascular graft, it limited the contraction and diastolic motion of the autogenous artery of the banded segment and fixed it at the same diameter, thereby reducing compliance mismatch between the ascending aorta and the stents. At the same time, the high strength of the vascular graft was beneficial to the strength of the autologous artery wall, so that the proximal end of the stent graft could not easily damage the intima of the ascending aorta when it moved out of synchronization with the ascending aorta, thus avoiding RTAAD [3].

In addition, compliance mismatch is not the only cause of RTAAD of the ascending aorta after d-TEVAR. Damage to the ascending aorta by the side biting clamp, the impact of blood flow on the anastomosis, and catheter damage to the intima of the aorta during interventional surgery can also be involved [7]. The damage of the crown-shaped bare stent at its proximal end to the aortic wall is also one of the reasons for the occurrence of RTAAD. Therefore, manufacturers such as Cook have designed new stents without proximal bare stents. We believe that RTAAD caused by d-TEVAR can be avoided as the technology matures. Avoiding RTAAD caused by compliance mismatch should be studied further. Therefore, we propose to use a vascular graft to wrap and strengthen the ascending aorta as the proximal anchoring site for d-TEVAR.

The incidence of neurological complications in this study was high. The incidence of paraplegia reached 16.7%. The researchers believe that paraplegia is not a rare complication. However, its specific cause remains to be determined. At present, the possible causes of paraplegia may involve the following aspects: (1) Patients with severe atherosclerosis also have atherosclerosis in the blood vessels supplying the spinal cord, and collateral flow cannot be established after some blood vessels are blocked by stents, resulting in spinal cord ischemia; (2) In some patients, the stent is situated too distally, blocking the Adamkiewicz artery and resulting in spinal cord ischemia; (3) In patients with dissection, the intercostal artery originates from the false lumen, and the blood supply to the spinal cord is insufficient after false lumen thrombosis. The causes and preventive measures for the occurrence of paraplegia are still being explored, but early detection and early cerebrospinal fluid drainage are currently considered to be beneficial measures for the recovery of paraplegic patients.

The present single-center retrospective study had a small sample size with the inherent biases of retrospective research. However, there was no RTAAD during the average follow-up period of 10.5 $\pm$ 9.2 months, which shows that the method is somewhat effective. With accumulating number of operations and emergence of related reports, more precise conclusions about the method's reliability will be made. It is possible that this improved technique can become the key to popularizing this procedure for low-risk patients.

Conclusions

In this study, no patient developed RTAAD during the perioperative and postoperative follow-up. The ascending aorta banded with a vascular graft can be used as the anchoring area for d-TEVAR, and this can reduce the compliance mismatch between the anchoring area and the stent, thereby reducing the incidence of postoperative RTAAD. We believe that ascending aorta banding may be an effective method to reduce the incidence of RTAAD in d-TEVAR.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

HQG, SDX and JZ designed the research study and performed the research. GHQ analyzed the data. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was approved by the Ethics Committee of Anzhen Hospital (Approval number: 2023091X).

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Conflict of Interest

The authors declare no conflict of interest.

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