Abstract

OBJECTIVES: A new surgical technique named triple-branched stent graft was developed and reported to have excellent clinical results for Stanford type A aortic dissection. However, we found some potential risks, in our experience, of this technique. We compared this technique with total arch replacement combined with stented elephant trunk implantation in patients with acute Stanford type A dissection.

METHODS: Thirty-eight patients with acute Stanford type A aortic dissection underwent surgical treatment from January to November 2010. These patients were divided into two groups: patients with total arch replacement combined with stented elephant trunk implantation (Group A, n = 22) and those with ascending aorta replacement combined with open placement of triple-branched stent graft (Group B, n = 16).

RESULTS: In-hospital mortality was not different in the two groups (9.1 and 6.25%, respectively). Cardiopulmonary bypass, aortic cross-clamp, circulation arrest, selective cerebral perfusion and low-body arrest times were shorter in Group B. Mechanical ventilation support, duration of intensive care unit (ICU) stay and hospitalization time were not different in the two groups. The incidence of postoperative stent graft-related complications was significantly higher in Group B. Actuarial survival rates and freedom from reoperation during the follow-up did not differ in the two groups.

CONCLUSIONS: The triple-branched stent graft technique truly has some advantages in simplifying the procedure and reducing the surgical time. However, this technique has some potential risks such as postoperative stent graft shifting or kinking, which may cause occlusion, aortic disruption and malperfusion syndrome. Long-term follow-up and further multicentre clinical trials are necessary to verify their use in this setting and the design of the grafts and surgical procedure should be further refined to reduce the incidence of stent graft complications.

Keywords: Triple-branched stent graft • Potential risks

INTRODUCTION

With significant advances in diagnosis and therapy, the outcome of surgical repair of acute type A aortic dissection has significantly improved over the last few decades [1–3]. Ascending aortic replacement with or without hemiarch replacement is widely accepted as a conventional treatment [4, 5]. However, this leaves behind a residual dissection distal to the anastomosis and aneurysm formation or further dissection limits the long-term clinical benefits of surgery [6, 7]. To avoid residual dissection and aneurysm formation or further dissection after conventional operation, original surgical managements were formulated by several cardiovascular centres. Recently, Chen et al. [8] developed a single-stage hybrid technique in which the true lumen of the descending aorta, aortic arch and three arch vessels were replaced with triple-branched stent graft to obtain a primary repair of the thoracic aorta, simplify extensive primary repair and reduce the risks of the late thoracoabdominal aneurysm formation and reoperation.

Despite the excellent clinical results which the authors reported [8], we found some potential risks, in our experience, of this technique. In order to illustrate the potential risks of the triple-branched stent graft, we compared the clinical results of total arch replacement combined with stented elephant trunk implantation over the same period.

PATIENTS AND METHODS

Patients

From January to November 2010, 38 patients (28 men and 10 women) with Stanford type A aortic dissection underwent surgery. The patients we selected satisfied the following inclusion criteria [8]: (1) the intimal tear located in transverse arch or proximal descending aorta that could not be resected by hemiarch replacement, (2) serious involvement of the arch vessels and (3)
Marfan syndrome. The 16 patients selected for triple-branched stent graft placement satisfied the additional criteria [8]: (1) the diameters of the native aortic arch and arch branches were 10–20% smaller than those of the corresponding stent grafts, (2) the distances between two neighbouring arch branches were equal to the distances between two corresponding sidearm stent grafts, (3) no history of carotid artery disease, (4) no aortic aneurysm in arch or proximal descending aorta and (5) all three arch branch ostia could be seen clearly from the arch true lumen through the transverse incision of the distal ascending aorta. The positions and the diameters of the native aortic arch and arch branches are different in different cases; we measured these data by preoperative three-dimensional computed tomography and then chose the optimal size for individuals.

The average age of these patients was 45 ± 11.3 years (range, 19–63 years). The diagnosis was based on computed tomography and echocardiography. Of these, 22 patients underwent total arch replacement combined with stented elephant trunk implantation (Group A) and 16 patients underwent ascending aorta replacement combined with open placement of triple-branched stent graft (Group B). The clinical data of the two groups are summarized in Table 1. The ethics committee of Xiangya Second Hospital approved the experimental procedure. We obtained written informed consent from each patient. Postoperative computed tomography scans and 3D reconstruction with contrast enhancement were done routinely to assess the residual false lumen and the placement of the stent graft during follow-up.

### Description of the device

The stent graft was a branched 1-piece graft consisting of a self-expansible nitinol stent and polyester vascular graft fabric (Yuhengjia Sci-Tech Co. Ltd, Beijing, China). It comprised a main graft and three sidearm grafts; the main graft was 145 mm in length, 30 mm in proximal diameter and 26 mm in distal diameter. At its proximal end, there was a 10-mm-long stent-free sewing Dacron tube. The first sidearm graft was 35 mm in length and 14 or 16 mm in diameter. Both the second and third sidearm grafts were 25 mm in length and 12 or 14 mm in diameter. The distance between two neighbouring sidearm grafts was 3 mm. The main graft and three sidearm grafts were individually mounted on four catheters and restrained by four silk strings. The single-branched graft was a product of Interguard, Intervascular, Datascope Co. (Montvale, NJ, USA).

### Operative technique

All surgical procedures were performed with patients under general anaesthesia, median sternotomy and total cardiopulmonary bypass (CPB). Myocardial protection was achieved by multiple administrations of cold blood cardioplegia (4°C). After CPB was established, cooling was initiated.

For Group A, the procedure was performed according to the method which had been described by Sun et al. [9-11]. In brief, cannulation of the right axillary artery was used for CPB and unilateral selective cerebral perfusion (SCP). The distal aorta was transected circumferentially between the origin of the left common carotid artery and the origin of the left subclavian artery. The stent was implanted into the distal aorta. The distal aorta incorporating the stented elephant trunk was firmly attached to the distal end of the 4-branched graft using the ‘open’ aortic method. Antegrade systemic perfusion was reestablished through the perfusion limb of the 4-branched prosthetic graft. The anastomosis to the left common carotid artery was carried out first. After the anastomosis was completed, CPB was gradually returned to normal flow, SCP was discontinued and rewarming was started. The anastomosis to the left subclavian artery, the innominate artery and the proximal anastomosis was completed.

For Group B, the procedure was performed according to the method described by Chen et al. [8]. In brief, CPB was established by two venous cannulas through the right atrium and two arterial return cannulas placed in the femoral and right axillary arteries. During core cooling, the innominate and left common carotid arteries were dissected out and exposed. The ascending aorta was clamped at the base of the innominate artery and transected above the sinotubular junction. When core cooling to a 22°C rectal temperature was achieved, SCP was established and perfusion to the lower body was discontinued. After the left common carotid artery and innominate artery were cross-clamped, the ascending aorta was transected. Through the transverse incision of the ascending aorta, the main graft of the triple-branched stent graft was inserted into the true lumen of the arch and proximal descending aorta, and each sidearm graft was positioned one by one into each of the aortic branches. Finally, the main graft and sidearm grafts were dilated with balloon catheters. The transected distal stump of the ascending aorta was reconstructed and subsequently continuous anastomosis was made. The air was carefully flushed out, antegrade systemic perfusion was started and the patient rewarmed.

### Follow-up

All patients were contacted by telephone or direct interviews in our department after discharge. All patients followed up prospectively by means of contrast-enhanced computed tomography scan and general examination on the following schedule: before discharge, 3 months after the operation and annually thereafter.
Statistical analysis

Categorical variables are presented as frequencies and percentages, and continuous variables are expressed as mean ± SD. Differences in baseline characteristics between patients were compared using the \( t \)-test for continuous variables and the \( \chi^2 \)-test for categorical variables. The mean CPB time, aortic cross-clamp time, circulation arrest time, SCP and low-body arrest times were shorter in Group B. Mechanical ventilation support, duration of ICU stay and hospitalization time were not different in the two groups.

RESULTS

Surgical and postoperative data

All surgical procedures were successful intraoperatively in all 38 patients. The surgical and postoperative data of the two groups are summarized in Table 2. CPB, aortic cross-clamp, circulation arrest, SCP and low-body arrest times were shorter in Group B. Mechanical ventilation support, duration of ICU stay and hospitalization time were not different in the two groups.

Complication and morbidity

We did not encounter any difficult bleeding from aortic anastomoses. No patient required additional surgery to correct excessive postoperative bleeding. The postoperative complication and morbidity data are summarized in Table 3. In-hospital mortality was not different in the two groups (9.1% and 6.25%, respectively). The incidence of postoperative stent graft-related complications was significantly higher in Group B. Actuarial survival rates and freedom from reoperation during the follow-up did not differ in the two groups.

Computed tomography scans and 3D reconstructions

The preoperative and postoperative computed tomography scans and 3D reconstructions were collected for patients with Stanford type A aortic dissection who underwent ascending aorta replacement combined with open placement of triple-branched stent graft (Fig. 1). We also compared the postoperative computed tomographic scans and 3D reconstructions with patients who underwent total arch replacement combined with stented elephant trunk implantation (Fig. 2).

Postoperative computed tomography scans and 3D reconstructions showed outcomes of 20 discharged patients who underwent total arch replacement combined with stented elephant trunk implantation are satisfactory, and there were no space or blood flow surrounding the stent grafts. For the 15 discharged patients who underwent ascending aorta replacement combined with open placement of triple-branched stent graft, postoperative computed tomography scans and 3D reconstructions showed that the stent grafts of 11 patients were fully patent and not kinked, but other 4 patients had stent graft-related complications: 1 patient had residual endoleak and 3 patients had sidearm grafts kinked (1 in the first branch and 2 in the third branch) (Fig. 3).

Follow-up

Thirty-five patients were discharged from the hospital and followed up to the end date of this study (August 2011). The follow-up was 100% complete. There were no late deaths and no need for reoperation during the mean follow-up of 12 ± 3 months (range, 8–18 months). The two patients with paraplegia could not walk. One patient with postoperative hoarseness (Group A) still had hoarseness. For the four patients who had stent graft-related complications, the residual leak vanished 14 months after discharge, but the kinked stent grafts were not improved. Although no neurological complications were observed during follow-up for the four patients, long-term follow-up is necessary. Other patients resumed normal life.

Table 2: Surgical and postoperative data of the two groups

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
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<tbody>
<tr>
<td>Concomitant procedure</td>
<td></td>
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<tr>
<td>Sinus of Valsalva</td>
<td>8 (36.4)</td>
<td>7 (43.8)</td>
</tr>
<tr>
<td>Aortic valve replacement</td>
<td>5 (22.7)</td>
<td>3 (18.8)</td>
</tr>
<tr>
<td>Aorta valve repair</td>
<td>2 (9.1)</td>
<td>1 (6.25)</td>
</tr>
<tr>
<td>CABG, n (%)</td>
<td>1 (4.5)</td>
<td>1 (6.25)</td>
</tr>
<tr>
<td>Surgical data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPB (min)</td>
<td>179 ± 67.6</td>
<td>138 ± 56.4*</td>
</tr>
<tr>
<td>Aortic cross-clamp (min)</td>
<td>134 ± 46.5</td>
<td>98.6 ± 28.1*</td>
</tr>
<tr>
<td>Circulation arrest (min)</td>
<td>48.7 ± 18.2</td>
<td>27.3 ± 14.8*</td>
</tr>
<tr>
<td>SCP and low-body arrest time (min)</td>
<td>50.9 ± 26.1</td>
<td>29.3 ± 11.3*</td>
</tr>
<tr>
<td>Postoperative data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mechanical ventilation support (h)</td>
<td>64.9 ± 50.9</td>
<td>43.9 ± 36.8</td>
</tr>
<tr>
<td>Duration of ICU stay (h)</td>
<td>113 ± 80</td>
<td>105 ± 75.8</td>
</tr>
<tr>
<td>Duration of hospitalization (days)</td>
<td>21.2 ± 12.7</td>
<td>16.2 ± 6.68</td>
</tr>
</tbody>
</table>

CABG: coronary artery bypass graft; CPB: cardiopulmonary bypass; SCP: selective cerebral perfusion; ICU: intensive care unit.

*P < 0.05.

Table 3: Complication and morbidity of the two groups

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
</tr>
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<tbody>
<tr>
<td>Paraplegia, n (%)</td>
<td>1 (4.5)</td>
<td>1 (6.25)</td>
</tr>
<tr>
<td>Pulmonary complication, n (%)</td>
<td>2 (9.1)</td>
<td>1 (6.25)</td>
</tr>
<tr>
<td>Postoperative hoarseness, n (%)</td>
<td>4 (18.2)</td>
<td>4 (25%)</td>
</tr>
<tr>
<td>Stent graft related complication, n (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Death, n (%)</td>
<td>2 (9.1)</td>
<td>1 (6.25)</td>
</tr>
<tr>
<td>Actuarial survival rates during follow-up, n (%)</td>
<td>20 (90.9)</td>
<td>15 (93.8)</td>
</tr>
<tr>
<td>Reoperation during the follow-up, n (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
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</table>
DISCUSSION

Acute Stanford type A dissection is the most lethal cardiovascular disease and has a high morbidity and mortality even with optimal treatment [12]. Ascending aortic replacement with or without hemiarch replacement as a conventional treatment is widely accepted to achieve the objectives of complete resection of the intimal tear and obliterate the entry of blood into the false lumen [4, 5, 13]. The diseased dissected aortic wall is often left residual in proximal and distal aorta to the replaced aortic segment which has been proven to be a critical factor in the determination of prognosis [6, 7]. However, there have been some retrospective studies that show that the incidence of significant dilatation of the descending aorta after conventional surgical procedure appears to be relatively low [14, 15]. So the appropriate surgical procedure for patients in Stanford type A aortic dissection has remained controversial. Different extent of propagation and involvement of aortic dissection, the site of the intimal tear and the attending surgeon’s discretion are the critical factors that impact the choice of surgical procedure.

Original surgical procedures were formulated by several cardiovascular centres in recent years and had been proved to have encouraging outcomes. Kato et al. [16] developed a hybrid technique in which the ascending aorta and aortic arch were replaced with a 4-branched graft and a conventional straight stent graft was implanted into the descending aorta; Sun et al. [9–11, 17] developed total arch replacement combined with stented elephant trunk implantation. However, in the procedure of these techniques, careful manipulation and elaborate anastomoses are complicated and time-consuming and could induce phrenic and recurrent laryngeal nerve injury [18, 19]. There are still risks of anastomotic bleeding and repeat surgery for haemostasis due to the additional number of anastomoses and longer bypass time. All of these factors related to surgical outcomes. In our series, CPB
time, aortic cross-clamp time, circulation arrest time, SCP and low-body arrest time were relatively longer in the total arch replacement combined with stented elephant trunk implantation group.

To simplify the extensive primary repair of the thoracic aorta, Chen et al. [8] developed a single-stage hybrid procedure named triple-branched stent graft placement technique for Stanford type A acute aortic dissection repair and reported excellent clinical results. During our surgical treatment, triple-branched stent graft technique truly made the surgical procedure easier, time-saving and fewer invasions. However, we also observed four patients who had stent graft-related complications. Although the 16 patients satisfied the inclusion and exclusion criteria instituted by Chen et al., we carefully performed the interpolation and dilation procedure to make sure the stent grafts under suitable positions. Postoperative computed tomography scans and 3D reconstructions showed that one patient had residual endoleak and three patients had sidearm stent grafts kinked: one in the first branch and two in the third branch. Our surgical team discussed these complications and below are the potential reasons: the triple-branched stent graft was a branched 1-piece graft, the main graft and three sidearm grafts were integration, the main graft was flexible but still had its rigidity, the three sidearm grafts–main graft connected parts were not flexible enough to conform to the curved aortic arch for the patients who had smaller or larger curved aortic arch angle, which means the main graft and the three sidearm grafts would not conform to the curved aortic arch and the three arch vessels simultaneously. Moreover, the tripled-branched stent graft was positioned when core cooling to 22°C rectal temperature and in order to make the main graft and the three sidearm grafts fully opened; 37°C warm stroke-physiological saline solution was recommended to sprinkle the grafts. After the grafts were properly positioned and end-to-end anastomosis was completed, antegrade systemic perfusion from the branch of the Dacron tube graft and rewarming were started. During these procedures, the three sidearm grafts underwent cooling–crumpling–warming–recooling–rewarming process. All these factors may cause shifting of stent grafts to some degree and lead to kink finally because of stress–strain response and thermal expansion and contraction on the nitinol stent [20].

We have some suggestions to avoid stent graft-related complications as far as possible. After the triple-branched stent graft was properly positioned, suture fixation of the first sidearm stent graft with the innominate aorta wall was of great benefit to keep sidearm stent grafts from shifting or kinking, which would make the main graft and the three sidearm grafts conform to the curved aortic arch and the three arch vessels simultaneously and minimize the effect of thermal expansion and contraction. Moreover, the first sidearm graft is 35 mm in length and 14 or 16 mm in diameter, whereas the other two sidearm grafts are 25 mm in length and 12 or 14 mm in diameter. This pattern would not match to the patients who have anomalous branching pattern of the aortic arch; the design of the grafts should be further refined to satisfy the requests of individual treatments.

**LIMITATIONS**

This study is subject to the limitations inherent in clinical trials. Non-randomized designs and relatively small sample sizes may affect the results because of individual patient’s consent and condition. The age of patients was relatively young due to low awareness of disease and poor control of hypertension in China.

**CONCLUSIONS**

The triple-branched stent graft technique truly has some advantages in simplifying the surgical procedure and reducing the surgical time. However, as an original surgical procedure, this technique has some potential risks such as postoperative stent graft shifting or kinking, which may cause occlusion, aortic disruption and malperfusion syndrome. Long-term follow-up
and further multicentre clinical trials are necessary to verify their use in this setting, and the design of the grafts and surgical procedure should be further refined to reduce the incidence of stent graft complications.

Conflict of interest: none declared.

REFERENCES


