Int J Clin Exp Med 2016;9(8):16070-16077
www.ijcem.com /ISSN:1940-5901/IJCEM0019684

Original Article

Ascending aorta replacement combined with open placement of triple-branched stent graft and total arch replacement combined with stented elephant trunk implantation for treating type A aortic dissection

Qingliang Chen[1*], Feng Cheng[2*], Tongyun Chen[1], Feng Zhao[1], Nan Jiang[1]

[1]*Division of Cardiac Surgery, Tianjin Chest Hospital, Tianjin 300070, China;* [2]*Graduate School, Tianjin Medical University, Tianjin 300070, China.* [*]*Equal contributors.*

Received November 13, 2015; Accepted April 5, 2016; Epub August 15, 2016; Published August 30, 2016

Abstract: There is no consensus on the treatment efficiency of type A aortic dissection (AD) using ascending aorta replacement combined with open replacement of triple-branched stent graft versus total arch replacement combined with stented elephant trunk implantation. The present study was designed to compare the short- and long-term outcomes of patients with type A AD after ascending aorta replacement combined with open replacement of triple-branched stent graft versus total arch replacement combined with stented elephant trunk implantation. Thirty-three patients with type A AD admitted in our department from 2009 to 2014 were included in this study. Twenty-two patients received operations using total arch replacement combined with stented elephant (group A), while 11 received operations using triple-branched aortic arch covered stent grafts (group B). Adverse events and other clinical events were also recorded to compare the efficiency of two different methods. Complications were similar between the two groups. The intraoperative blood loss was significantly larger in group B compared to that of group A. In group A, the left ventricular size and the aortic diameter was decreased, and the left ventricular ejection fraction (LVEF) was elevated after surgery. In group B, the aortic diameter was decreased. No statistical difference was noticed in the survival duration of patients in both groups. The intraoperative blood loss is significantly increased in the patients received triple-branched stent graft compared to those received Sun's procedure. The Sun's procedure is superior to triple-branch graft with improvements in left ventricular size and left ventricular ejection fraction. Both surgery types contribute to the improvement of aortic diameter.

Keywords: Type A aortic dissection, ascending aorta replacement, total arch replacement

Introduction

Aortic dissection (AD), the most frequent and catastrophic manifestations of the aorta, is considered as one of the leading causes for cardiovascular disease related death worldwide [1]. Nowadays, acute type A AD shows a mortality rate of about 1% per hour initially without treatment [2]. Despite treatment, the mortality rate is still higher and many patients showed life-long sequela causing remarkable effects on the life quality.

Currently, the treatment of type A AD is largely depend on the surgery. The conventional elephant trunk technique has been widely used for the stage aortic replacement [3]. Nowadays, some modifications based on that technique are also available such as the arch-first procedure introduced by Kouchoukos et al [4] and the so-called "skeletonized elephant trunk technique" designed by Sun et al [5]. However, the optimal approach for patients with type A AD involving the aortic arch remains controversial. Besides, there are ongoing debates about the benefits and shortcomings of ascending aorta replacement combined with open placement of triple-branched stent graft, and total arch replacement combined with stented elephant trunk implantation in type A aortic dissection [6]. This leads us to investigate the treatment efficiency of these methods in patients with type A AD in Chinese population.

In this study, we analyzed the clinical information on in-hospital clinical outcomes and follow-

Table 1. Baseline characteristics of the patients

Variable	A (n=22)	B (n=11)	*t*	*P*
Age (± *SD*), y	46.0±11.3	53.8±11.3	1.636	0.112
Male, n (%)	18 (81.8)	9 (81.8)		1.000
Smoking, n (%)	11 (50)	2 (18.2)		0.132
Drinking, n (%)	2 (9)	2 (18.2)		0.586
Hypertension, n (%)	17 (77.3)	10 (91.9)		0.637
Marfan syndrome, n (%)	0	0		
Diabetes mellitus, n (%)	1 (4.5)	0		1.000
ALT (± SD), U/L	42.9±49.3	63.4±113.8	7.29	0.471
AST (± SD), U/L	32.8±31.4	89.2±142.6	1.295	0.223
Cr (± SD), umol/L	80.1±18.4	107.7±25.8	3.173	0.006
BUN (± SD), mmol/L	6.6±1.98	9.2±5.0	1.675	0.121
Hb (± SD), g/L	128.0±12.3	126.3±9.5	0.397	0.694
INR (± SD)	1.3±0.1	1.1±0.2	1.242	0.224
LVIDD (± SD), mm	55.0±7.5	53.8±2.4	0.624	0.538
Left ventricular ejection fraction (± SD), %	60.9±6.7	58.0±5.6	1.219	0.232
Ascending aorta diameter (± SD), mm	48.8±11.0	50.9±9.2	0.545	0.590
Aortic valve regurgitation, n (%)	16 (72.3)	8 (72.3)		1.000

ALT: Alanine aminotransferase; AST: Aspertate aminotransferase; Cr: Creatinine; BUN: Urea nitrogen; HGb: Hemoglobin; INR: International sensitivity index; LVIDD: Left ventricular internal diameter at end-diastole.

up data of 33 type A AD patients received total arch replacement combined with stented elephant trunk implantation or triple branches aortic arch stent-graft placement, respectively. We aim to evaluate long-term survival rates and the clinical differences in patients underwent different operations.

Material and methods

Patients

Thirty-three type A AD patients (male: 27, female: 6, mean age: 48.3±11.6 yrs) admitted o our department by surgery from January 2009 to December 2014 were included in this study. Among these patients, 22 received total arch replacement combined with stented elephant trunk implantation (group A), and 11 received triple branches aortic arch stent-graft placement (group B). Type A AD is defined as any dissection that involves the ascending aorta. The diagnosis was based on electron-beam computed tomography and echocardiography. Ten patients showed tear site at the ascending aorta, 11 at the transverse arch, and 4 at the proximal descending thoracic aorta. No entry tear was detected in 8 patients. Twenty-seven patients had hypertension without effective control, and 13 patients revealed a history of smoking (**Table 1**).

Surgical procedure

All procedures were performed under general anesthesia. The arterial blood pressure in the upper and lower limbs was monitored, and a probe for transesophageal echocardiographic monitoring was inserted. The procedures were carried out by a median sternotomy and total cardiopulmonary bypass (CPB) with selective cerebral perfusion (SCP).

The Sun's procedure was performed as previously described [7]. Briefly, the artrial line was bifurcated for the right axillary artery and for antegrade perfusion. Upon reaching a temperature of 18-22°C, circulatory arrest was performed. The left subclavian artery was cross-clamped at the distal part, and then the descending aortic graft was replaced. Subsequently, anastomosis was performed at the distal end of 4-branch prosthetic graft (Boston Scientific Inc, Boston, MA) and the proximal end of the descending aorta. On this basis, blood supply of the descending aorta was obtained through the prosthetic graft. Upon the perfusion of blood flow in the descending aorta was obtained, rewarming was initiated. The resting 3 branches of prosthetic graft were anastomosized with the brachiocephalic trunk, left common carotid artery, and the dis-

Table 2. Intraoperative comparison of parameters in group A and B

Variable	A (n=22)	B (n=11)	t	p
Cardiopulmonary by pass time (± SD), min	141.5±36.0	134.8±32.8	0.086	0.932
Aortic cross clamp time (± SD), min	103.0 ±27.8	102.5±28.9	0.048	0.962
Circulation arrest time (± SD), min	40.8±17.3	36.5±9.2	0.579	0.567
Lower body arrest time (± SD), min	74.8±34.0	65.1±28.8	0.739	0.466
Intraoperative blood loss (± SD), min	2630.5±1821.2	3586.4±2926.8	2.175	0.005
Perioperative death	6 (27.3)	3 (27.3)		1.000
ICU staying (± SD), day	9.9±10.9	11.9±11.9	0.478	0.633

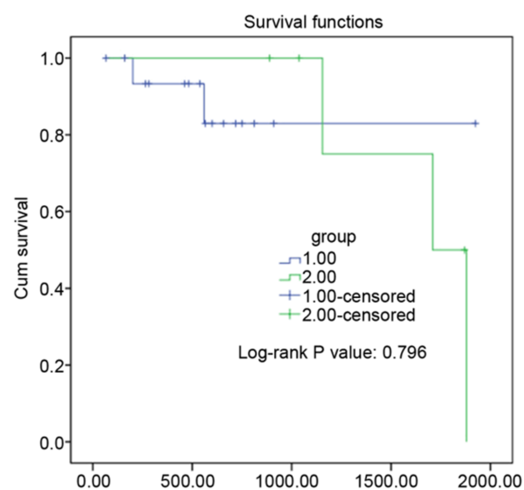

Figure 1. Survival rates of patients.

tal ends of the left subclavian artery, respectively. Finally, the brachiocephalic trunk, left common carotid artery, and the proximal ends of the left subclavian artery were clamped, and then extracorporeal circulation was carried out after the air was flushed out from the proximal ends of the anastomotic stoma.

Open triple-branched stent graft placement was performed as previously described [8]. Blood perfusion of the lower body was started via the perfusion limb of the 4-branch prosthetic graft. The flow of cardiopulmonary bypass was maintained in a range of 2.4~2.6 L min-1 m-2. After that, multiple cold blood cardioplegia (4°C) was given in order to obtain myocardial protection. The aorta was cross-clamped at the base of the innominate artery, and then the main graft of the triple-branched stent graft was inserted into the true lumen of the arch and proximal descending aorta. Each sidearm graft was positioned one by one into the aortic branch. Subsequently, the main graft and sidearm grafts were dilated with balloon catheters assisting by transesophageal echocardiography, which was used to confirm that they were fully opened and not kinked. The transected distal stump of the ascending aorta was reconstructed by the inner proximal stent-free dacron tube of the main graft and outer Teflon felt. After that, continuous anastomosis to the 1-branched dacron tube graft was made in an end-to-end manner. The air was flushed out from the triple-branched stent graft with femoral and right axillary blood return. Subsequently, antegrade systemic perfusion from the branch of the dacron tube graft was started, and the patient was rewarmed.

Data collection

The clinical variables evaluated in this study included patient demographics, case history, clinical manifestations, physical findings, radiological results, medical and surgical treatment, as well as the treatment outcomes including mortality. Adverse events and other clinical events were also recorded. Follow up was carried out by telephone or direct interviews in our department. Patients were followed up prospectively by contrast-enhanced computed tomographic scan and echocardiographic examination before discharge, 6 months after the surgery, and annually thereafter.

Statistical analyses

SPSS 20.0 software was used for the data analysis. Numerous data were presented as numbers and percentages. Continuous data were presented as means ± standard deviations or medians and interquartile ranges. Enumeration data were presented as percentage. Fisher exact test was used for the comparison between two groups. Student's t test was used for the comparison of multiple groups. Survival time of patients was analyzed using

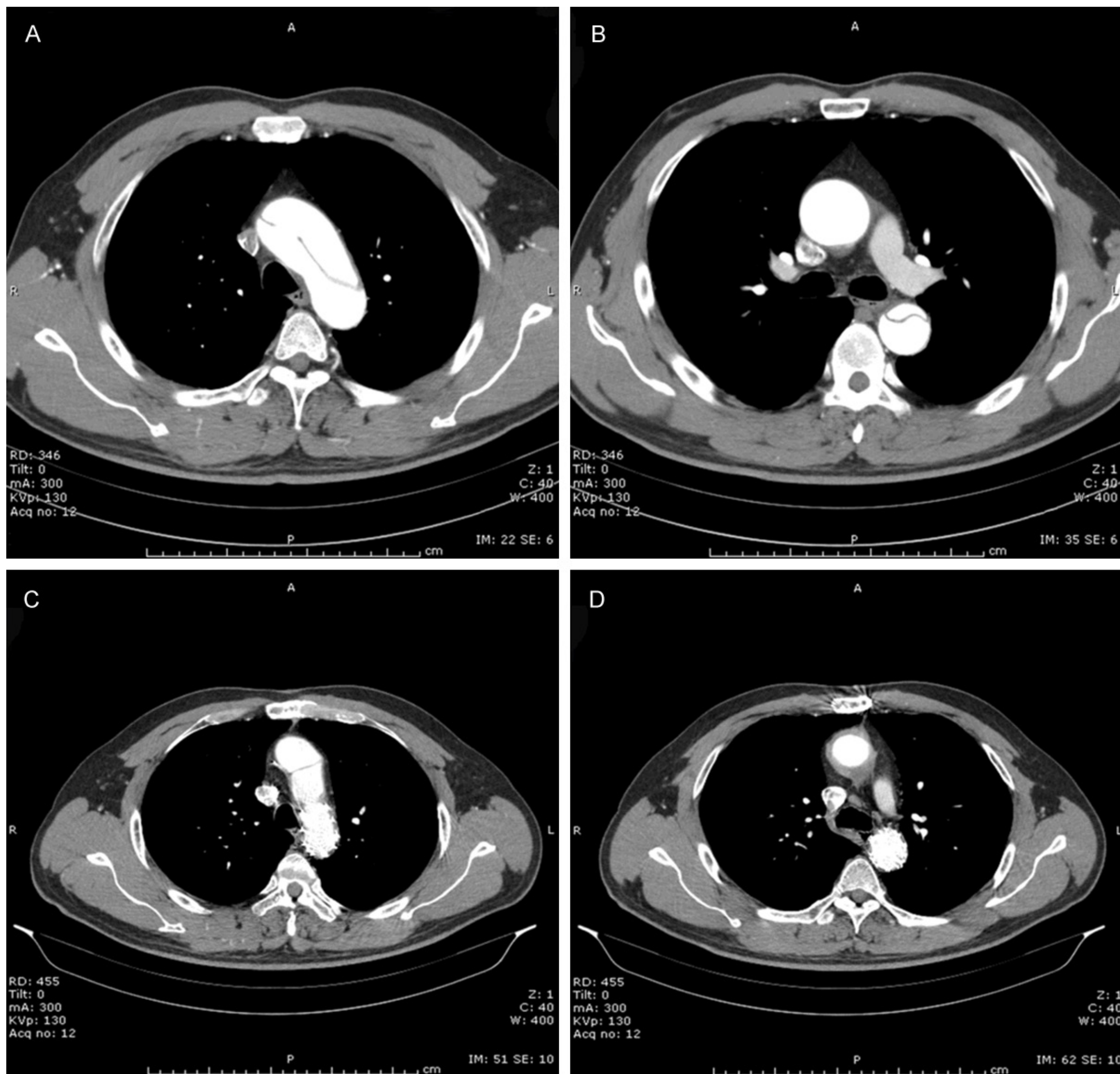

Figure 2. CT images of patients before or after Sun's procedure. A, B. Contrast enhanced CT scan for the patients before Sun's procedure. The opening of the dissection was localized at the aortic arch, and involved the descending aorta. C, D. CT images after Sun's procedure. The aortic diameters were remarkably decreased. No false aneurysm or stent occlusion was noticed in the anastomotic stoma.

the Kaplan-Meier method. $P<0.05$ was considered statistically significant.

Results

Patient's characteristics

Table 1 summarized the baseline characteristics of the patients. The characteristics were well balanced between the two treatment groups (**Table 1**). To be exact, no statistical differences were observed in the baseline characteristics in group A compared to those of group B, except the creatinine ($P<0.05$). Male patients were more apt to develop AD compared to the female counterparts. Besides, more patients showed hypertension, elevation of left ventricular ejection fraction, and decrease of ascending aorta diameter in patients of group A than in those of group B (**Table 1**).

Surgical variables and complications

As revealed in **Table 2**, patients of both groups showed no difference in the cardiopulmonary bypass time, aortic cross clamp time, circulation arrest time, lower body arrest time.

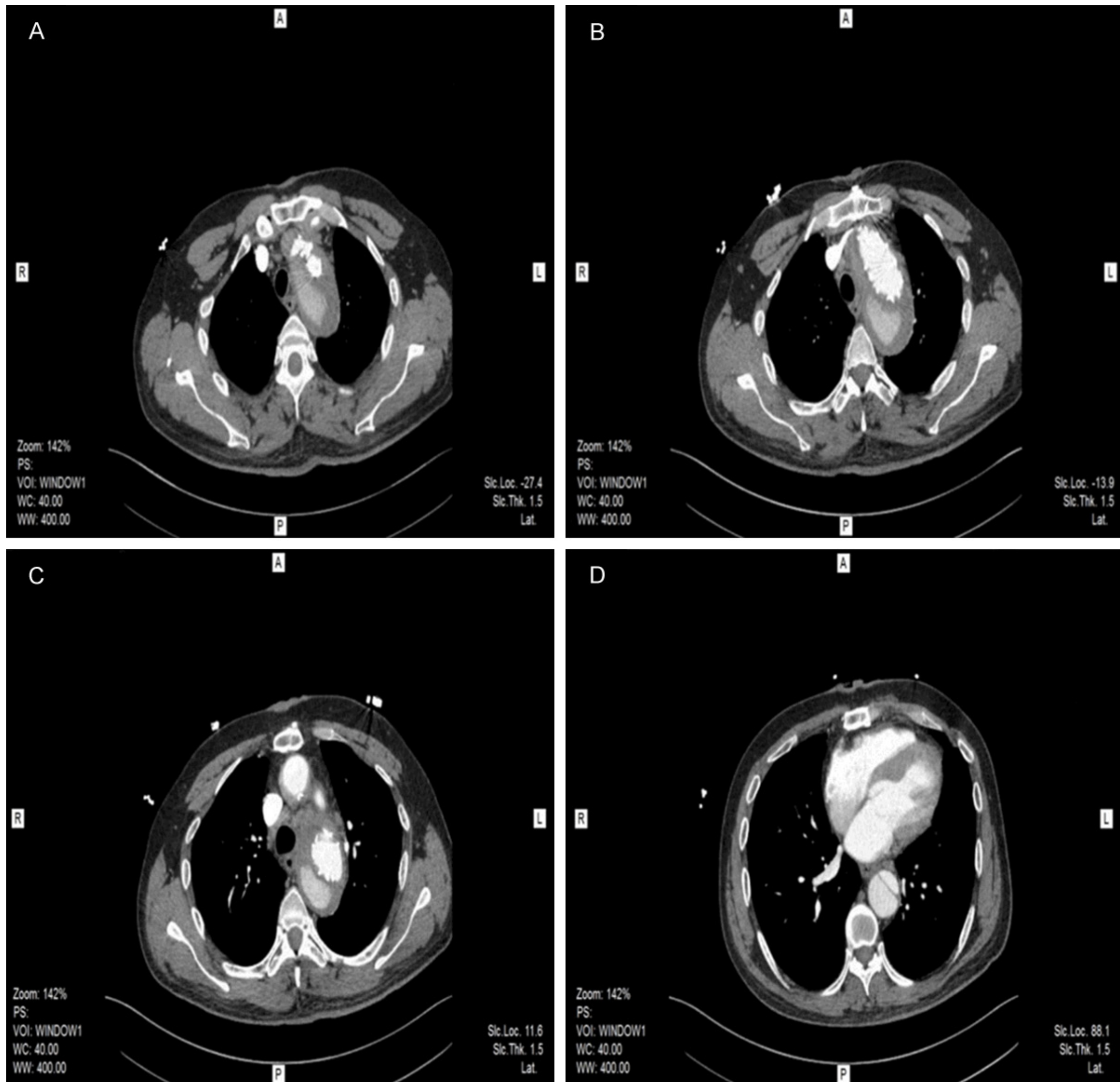

Figure 3. CT images of patients before or after triple-branch stent graft. A, B. Contrast enhanced CT scan for the patients before triple-branch procedure. C, D. CT images after the triple-branch procedure. The aortic diameters were remarkably decreased. No false aneurysm or stent occlusion was noticed in the anastomotic stoma.

However, in group B, the intraoperative blood loss was significantly increased than that in group A. In group A, 6 perioperative deaths were recorded, while those for group B was 3. The ICU stay in both groups was similar with no statistical difference. In this study, we also compared the survival time of patients in each group. Log-rank test revealed no statistical difference was noticed in the both groups (**Figure 1**).

Postoperative echocardiographic examinations revealed the left ventricular size and the aortic diameter were decreased while the left ventricular ejection fraction (LVEF) was elevated after surgery in group A (**Figures 2** and **3**). Whereas, only the aortic diameter was decreased in group B (**Table 3**). For the postoperative complications, no patient with stroke or false lumen was observed in group A, while in group B, one with stroke or false lumen was noticed. One postoperative death was identified in group A due to heart failure, but no aberrant changes were noticed in the artificial graft and the descending aorta stent (**Table 4**) (Supplementary Table 1).

Discussion

Aortic dissection, an acute process of large blood vessels featured by dangerous pathogen-

Table 3. Ultrasonic examination of both groups

Value	A				B			
	Pre-operation	Post-operation	*t*	*P*	Pre-operation	Post-operation	*t*	*P*
LV (± SD), mm	55.0±7.5	50.9±6.9	3.709	0.020	53.5±2.5	48.4±9.2	1.611	0.150
EF (± SD), %	46.9±10.4	62.0±3.1	5.395	0.000	57.5±6.4	62.0±2. 6	1.821	0.110
Ascending aort (± SD), mm	50.9±6.6	28.2±1.6	14.501	0.000	50.9±9.8	28.6±3.9	6.173	0.000

Table 4. Postoperative complications

Value	A (n=16)	B (n=8)	*P*
False lumen, n (%)	0 (0.0)	1 (12.5)	0.333
Stroke, n (%)	0 (0.0)	1 (12.5)	0.333
Death, n (%)	1 (6.3)	0 (0.0)	1.000
Complication, n (%)	1 (6.3)	2 (25.0)	0.249

ic conditions and high fatality, has attracted extensive attention as it causes great threats to public health.

In 1983, ascending aorta and aortic arch replacement were proposed initially for the treatment of AD [9]. In addition, the descending aorta is built into a free artificial blood vessel. These procedures are supposed to avoid the two stage operation involving the aortic arch. Moreover, there is no need to use the deep hypothermic circulatory arrest. This is the classic procedure named stented elephant trunk. However, such procedure was reported to induce severe side effects in clinical practice [10, 11]. For example, organ embolism or even serious complications (e.g. paraplegia) were caused by vascular thrombosis and trunk shifting with blood swing [12]. Besides, it is still difficult to place the prosthetic graft into the true lumen of a type A dissection. Considering these limitations abovementioned, extensive studies have been carried out for the modifications of the elephant trunk procedure. The famous one is called the Sun's procedure, which is a surgical technique integrating total arch replacement by using a tetra furcated graft with implantation of a special stented graft in the descending aorta. To date, the procedure is considered as a treatment option for extensive dissections or aneurysms involving the ascending aorta, aortic arch and descending aorta [13]. The triple-branched stent graft was a branched 1-piece graft consisting of a self-expandable nitinol stent and polyester vascular graft fabric. During hypothermic circulatory arrest, the main graft of the triple-branched stent graft was inserted into the true lumen of the arch and proximal descending aorta through the transverse incision of the ascending aorta. Subsequently, each sidearm graft was positioned one by one into the aortic branch [14]. In clinical practices, upon the proper position of the main graft and sidearm grafts, the restraining strings were withdrawn, followed by deployment of the main graft and sidearm grafts. Such procedure has been approved to achieve a stronger distal anastomosis and to improve long term results, as well as reducing bleeding and simplifying the operations [6, 15].

Despite the significant process in the Sun's procedure, there were actually significant differences in the blood loss of patients [16]. The reasons are as follows: Firstly, the stent graft and vascular prosthesis are in a bad fit, which may increase the chance of bleeding during the op Sun's procedure. Secondly, the bad fit of triple-branched stent graft and vascular prosthesis may increase the chance of bleeding during the operation. Thirdly, the coagulation could be completely recovered after the surgery due to the application of hemostatic drugs. Finally, the application of right atrial shunt contributes to the reduction of the risk of bleeding. In this study, 22 received total arch replacement combined with stented elephant trunk implantation, while 11 received triple branches aortic arch stent-graft placement. The intraoperative blood loss in group B was significantly increased than that in group A.

Periodical measures are usually needed to monitor signs of progression of aortic dilatation. In our study, the aortic diameters were significantly decreased in both groups compared with the baseline levels. Above all, false lumen can be effectively closed by the descending aortic stent [17]. Moreover, the risk of bleeding is reduced by reducing the local tension [18]. On this basis, the volume of distal anastomotic bleeding is reduced, and the distal false lumen closure rate is improved, together with the decrease of the reoperation rate. Furthermore,

a 4.0-fold increase was noticed in the incidence of postoperative complications in group B compared with that of group A (25% vs. 6.3%). This may relate to the stent shift induced by relatively fixed position of blood vessels and high variability. To sum up, we should strictly grasp the operation indication and prevent the injury of vascular wall of the false lumen induced by stent.

Several postoperative complications were reported after surgery for AD, including false lumen, stroke and death. In this study, the false lumen was a major complication of the operation. Therefore, positive measures should be taken to prevent false lumen. According to our clinical experiences, extensive efforts should be made to monitor the presence of distal laceration after surgery. Besides, for the cases with increase in the retrograde flow, and even enlarge of false lumen or new laceration at the distal ends, appropriate management should be given. If the new lesion was at the distal ends of the stent or not close to the major branches of the artery, a new segment of stent should be added at the distal ends. For the patients with large lesion and with aortic branches needing management, multi-layer stents are needed to adhere to the false lumen wall.

Indeed, there are still limitations in our study. This study is a retrospective study rather than a randomized controlled one. Besides, the sample size is comparatively small. In the future studies, we will focus on the randomized controlled studies with large sample size to investigate the treatment efficiency and complications of these methods.

In summary, the left ventricular size and the aortic diameter was decreased while the left ventricular ejection fraction (LVEF) was elevated after surgery in patients received Sun's procedure. Whereas, only the aortic diameter was decreased in patients undergoing triple-branch stent. The intraoperative blood loss was significantly increased in the patients received triple-branched stent graft compared to those received Sun's procedure.

Acknowledgements

This study was supported by the Scientific Foundation of Tianjin Health Bureau (No. 11KG122).

Disclosure of conflict of interest

None.

Address correspondence to: Nan Jiang, Division of Cardiac Surgery, Tianjin Chest Hospital, Tianjin 300070, China. Tel: +86-22-88185338; Fax: +86-22-88185338; E-mail: nanjiangtmu@yeah.net

References

[1] Mehta RH, Suzuki T, Hagan PG, Bossone E, Gilon D, Llovet A, Maroto LC, Cooper JV, Smith DE and Armstrong WF. Predicting death in patients with acute type A aortic dissection. Circulation 2002; 105: 200-206.

[2] Nienaber CA and Eagle KA. Aortic dissection: new frontiers in diagnosis and management part I: from etiology to diagnostic strategies. Circulation 2003; 108: 628-635.

[3] Liu ZG, Sun LZ, Chang Q, Zhu JM, Dong C, Yu CT, Liu YM and Zhang HT. Should the "elephant trunk" be skeletonized? Total arch replacement combined with stented elephant trunk implantation for Stanford type A aortic dissection. J Thorac Cardiovasc Surg 2006; 131: 107-113.

[4] Kouchoukos NT, Masetti P, Mauney MC, Murphy MC and Castner CF. One-stage repair of extensive chronic aortic dissection using the arch-first technique and bilateral anterior thoracotomy. The Ann Thorac Surg 2008; 86: 1502-1509.

[5] Sun LZ, Qi RD, Chang Q, Zhu JM, Liu YM, Yu CT, Lv B, Zheng J, Tian LX and Lu JG. Surgery for acute type A dissection using total arch replacement combined with stented elephant trunk implantation: experience with 107 patients. J Thorac Cardiovasc Surg 2009; 138: 1358-1362.

[6] Chen LW, Dai XF, Lu L, Zhang GC and Cao H. Extensive primary repair of the thoracic aorta in acute type A aortic dissection by means of ascending aorta replacement combined with open placement of triple-branched stent graft early results. Circulation 2010; 122: 1373-1378.

[7] Sun L, Qi R, Zhu J, Liu Y and Zheng J. Total arch replacement combined with stented elephant trunk implantation a new "standard" therapy for type a dissection involving repair of the aortic arch? Circulation 2011; 123: 971-978.

[8] Sun X, Lu S, Yang S, Lai H, Chen H, Hong T and Wang C. Open triple-branched stent graft placement for the surgical treatment of acute aortic arch dissection. J Cardiothorac Surg 2012; 7: 130.

[9] Strauch JT, Spielvogel D, Lauten A, Lansman SL, McMurtry K, Bodian CA and Griepp RB.

Axillary artery cannulation: routine use in ascending aorta and aortic arch replacement. Ann Thorac Surg 2004; 78: 103-108; discussion 103-108.

[10] Tian L, Qi R, Chang Q, Yu C, Zhu J, Liu Y, Zheng J and Sun L. Surgery for type B dissection using a short-stented elephant trunk procedure. Heart Surg Forum 2012; 15: E79-83.

[11] Isabella MA and Roselli EE. Reverse frozen elephant trunk procedure for rescue of a thoracic stent-graft in the false lumen. Ann Thorac Surg 2015; 99: 1445-1447.

[12] Geroulakos G. The risk of venous thromboembolism from air travel: the evidence is only circumstantial. BMJ 2001; 322: 188.

[13] Sun LZ, Ma WG, Zhu JM, Zheng J, Liu YM, Ziganshin BA and Elefteriades JA. Sun's procedure for chronic type A aortic dissection: total arch replacement using a tetrafurcate graft with stented elephant trunk implantation. Ann Cardiothorac Surg 2013; 2: 665-666.

[14] Shen K, Tang H, Jing R, Liu F and Zhou X. Application of triple-branched stent graft for Stanford type A aortic dissection: potential risks. Eur J Cardiothorac Surg 2012; 41: e12-e17.

[15] Böckler D, Nassar J, Kotelis D, Geisbüsch P, Hyhlik-Dürr A, Von Tengg-Kobligk H, Weber TF and Schumacher H. Hybrid approach for arch and thoracoabdominal pathologies. J Cardiovasc Surg (Torino) 2009; 50: 461.

[16] Di Eusanio M and Di Bartolomeo R. The Sun procedure-a new paradigm of treatment in DeBakey type 1 acute aortic dissection? Ann Cardiothorac Surg 2013; 2: 629-630.

[17] Ma WG, Zhu JM, Zheng J, Liu YM, Ziganshin BA, Elefteriades JA and Sun LZ. Sun's procedure for complex aortic arch repair: total arch replacement using a tetrafurcate graft with stented elephant trunk implantation. Ann Cardiothorac Surg 2013; 2: 642-648.

[18] Mizuno T, Toyama M, Tabuchi N, Wu H and Sunamori M. Stented elephant trunk procedure combined with ascending aorta and arch replacement for acute type A aortic dissection. Eur J Cardiothorac Surg 2002; 22: 504-509.