Fate of the False Lumen After Combined Surgical and Endovascular Repair Treating Stanford Type A Aortic Dissections

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Background. **The purpose of this study was to evaluate the alterations of the aorta by using a new combined surgical and endovascular technique for the treatment of aortic type A dissections. The diameter of the descending aorta, the implanted stent graft, and the false lumen were evaluated.**

Methods. **Between August 2005 and February 2009, 14 patients (aged 49 ± 13 years; 11 men, 3 women) with type A dissection in the aorta were operated on the thoracic aorta by the frozen elephant trunk technique. The size dynamics of the false lumen were analyzed by deducting the diameter of the stent graft obtained on computed tomography from the maximum dimension of the aorta.**

Results. **The technical success rate was 100%. All patients survived during the follow-up period. The mean follow-up period was 21.4 months. No redisection or aortic rupture occurred during the follow-up period. Postoperative computed tomography scans showed complete thrombus formation of the false lumen in the perigraft space within the entire zone of the stented segment of the hybrid prosthesis during the first 2 weeks after surgery in 12 patients (86%), whereas all patients showed complete obliteration of the false lumen at the 3-month control. The follow-up computed tomography scan obtained after 12 months revealed shrinkage of the false lumen in 9 patients (64%).**

Conclusions. **The combined surgical and endovascular technique described in this report proved effective for the treatment of extended aortic lesions. The perigraft space thrombosed completely and had shrunken after successful placement of the stent graft.**

(Ann Thorac Surg 2010;89:794–9)

The management of type A dissections can be challenging, especially if the aortic arch and the descending aorta are involved. Recent improvements in surgical and neuroprotective techniques [1, 2] have resulted in low perioperative mortality rates and better long-term outcomes for patients with complex thoracic aortic pathologies. In the majority of cases, the false lumen in the downstream aorta remains perfused after conventional repair of Stanford type A dissection, which can adversely affect the long-term outcome. Enlargement of the aortic diameter and a reoperation rate of as high as 27.5% have been reported after repair of type A dissection [3–5]. Endovascular stent graft insertion through a median sternotomy has been described by Kato and associates [6]. This technique is known as the frozen elephant trunk procedure and has evolved further. Antegrade stent grafting into the descending aorta is commonly performed together with replacement of the ascending aorta and the aortic branch with reattachment of the supra-aortic vessels [7, 8]. It achieves complete repair of extensive lesions of the thoracic aortic without increasing the risk of surgery [9].

We evaluated changes in the false lumen and the outcome of this combined surgical and endovascular treatment procedure.

Material and Methods

Patients

Between August 2005 and February 2009, 14 of 51 patients (11 men and 3 women) with a Stanford type A (DeBakey type I) dissection underwent surgery in the thoracic aorta by the frozen elephant technique. The majority of patients (n = 11) presented with acute dissections; 3 patients had a chronic condition. The patients' mean age was 49 ± 13 years.

All patients were operated by the frozen elephant trunk technique using the E-vita open endoluminal stent graft prosthesis (Jotec, Hechingen, Germany). Standardized informed consent for aortic arch repair was obtained from all subjects, and the study was approved by the local Ethics Committee. Numerous comorbidities and advanced age were relative contraindications for this procedure.

The primary tear was due to dissected aortic patholo-

Accepted for publication Nov 19, 2009.

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Published by Elsevier Inc

0003-4975/10/$36.00
doi:10.1016/j.athoracsur.2009.11.054

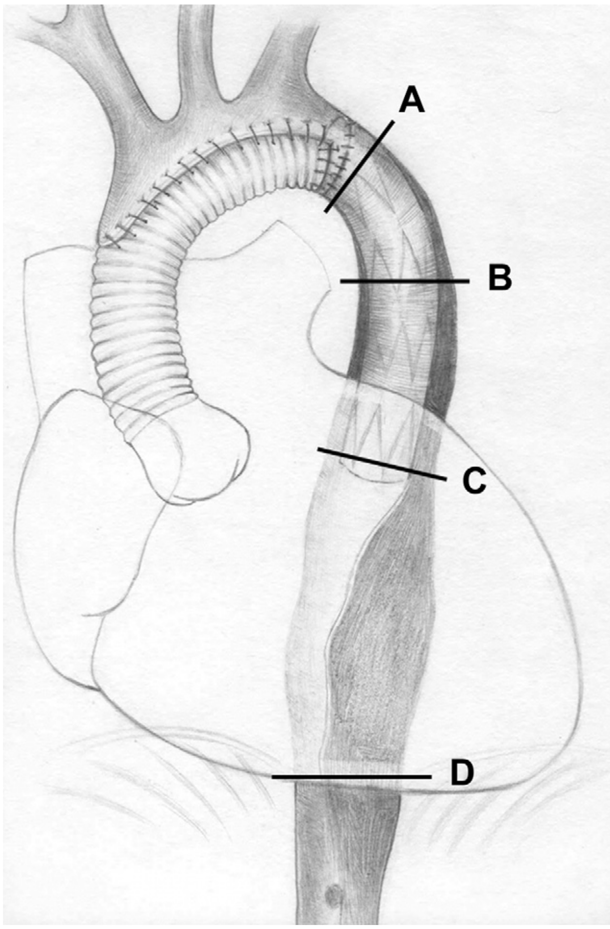

Fig 1. Measuring lines at the descending aorta: (A) distal to the offspring of the left subclavian artery; (B) level of the pulmonary artery; (C) end of the stent graft; and (D) level of the diaphragm.

gies in the ascending aorta in 13 patients, whereas 1 patient had a retrograde dissection after stent graft implantation because of a Stanford type B aortic dissection.

The following comorbidities were present: all patients had hypertension, 3 had chronic renal failure, 2 had coronary artery disease, 2 had chronic obstructive pulmonary diseases, and 3 had diabetes mellitus. One patient had a Marfan syndrome. Additional aortic valve reconstruction was performed in 3 patients, the Tirone-David procedure in 2 patients, and the modified Bentall-De Bono operation in 1.

A spiral computed tomography (CT) angiography of the thoracic aorta was performed preoperatively in all patients to assess the extent of the dissection and determine the size of the stent graft.

The commercially available endovascular prosthesis (E-vita open endoluminal stent graft; Jotec) is a stent graft with a 70-mm Dacron (C. R. Bard, Haverhill, PA) cuff loaded in a delivery system. The system permits a one-step intervention by combining reconstruction of the ascending aorta and the aortic arch with the integrated Dacron prosthesis and antegrade stenting of the descending aorta. This device significantly simplifies procedures for combined reconstruction from the ascending aorta to the proximal portion of the descending aorta. Self-expandable stents measuring 15 cm in length were used in 2 patients, and stents measuring 13 cm in length were used in 12 patients. The diameter of the implanted antegrade stent graft was 28 mm in 1 patient, 30 mm in 5 patients, 33 mm in 5 patients, and 36 mm in 3 patients. Stent grafts of 13-cm length are custom made and available only on request. For use in smaller patients, this length was specially designed to avoid an overextended coverage of intercostal arteries.

Procedure

Arterial cannulation was created through right subclavian artery in all patients. After introduction of a cardiopulmonary bypass, the patient's body temperature was reduced to a core temperature of 25°C. Once this target temperature had been achieved, the cardiopulmonary bypass was disconnected. The ascending aorta and the concavity of the aortic arch were resected to the level of the left subclavian artery. All patients received retrograde cold blood cardioplegia. Bilateral antegrade cerebral protection was performed through the arterial cannula by clamping the brachiocephalic trunk and an additional selective perfusion line into the left carotid artery.

After identification of the true and false lumen in acute aortic dissections, a pigtail catheter was inserted before the stiff guidewire to avoid a miscarriage of the stent graft into the false lumen. The special-shaped soft tip of this catheter prevented perforation into the false lumen. However, this is a weak point of the procedure. Guiding

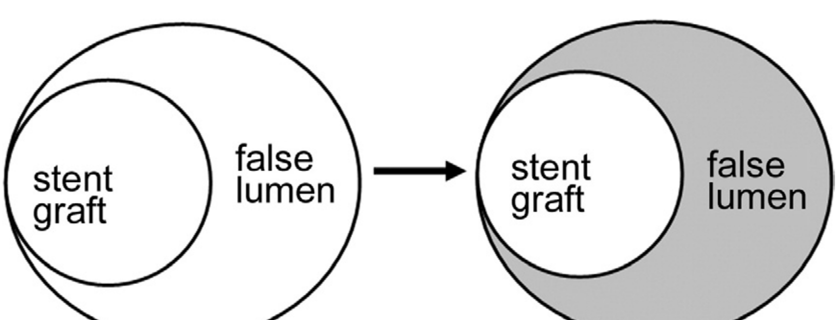

Fig 2. Calculation of the diameter of the stent graft, the false lumen, and the total diameter of the aorta.

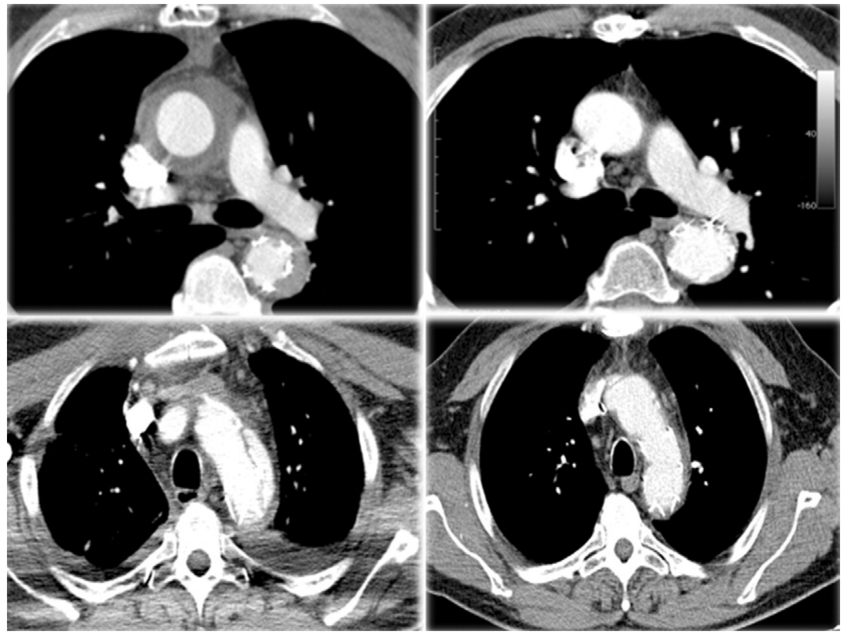

Fig 3. States of false lumen postoperatively (left panels) and after 3 months (right panels) at the level of the pulmonary artery. Complete thrombosis of the false lumen and shrinkage during the follow up period.

of the stent graft under angioscopic control will improve the insertion maneuver in the future. A stiff guidewire through the femoral artery was inserted intraoperatively to identify the true lumen in chronic dissections.

The landmark for stent graft placement was the origin of left subclavian artery. The stent graft was deployed 1 cm distal to this landmark. The Dacron graft was pulled slightly out of the stent. Approximately 1 cm of the attached Dacron graft was circumferentially sutured to the descending aorta, and secured with a Teflon (Impra, subsidiary of L. R. Bard, Tempe, AZ) strip. The woven crimped vascular Dacron prosthesis was then retracted completely from the implanted stent graft and resected. The replacement of the ascending aorta and the aortic arch repair was performed with a separate Dacron graft. For reimplantation of the supra-aortic branches, an appropriately sized window was transected from the Dacron prosthesis, and the arch vessels were anastomosed en bloc ("complete" arch replacement). In cases of unfavorable anatomical conditions, "light" aortic arch repair [10] was performed by resection of the concavity of the aortic arch but no isolation of the supra-aortic branches. After implantation of the stent graft and fixation of the Dacron prosthesis distal to the origin of the subclavian artery, the remaining aortic arch was replaced with a separate Dacron prosthesis according to the hemiarch technique. After deairing, circulatory arrest was discontinued and rewarming initiated. Finally, the anastomosis of the proximal ascending aorta was performed.

Follow-Up

Computed tomographic angiography was routinely performed within 10 days after surgery, at 3, 6, and 12 months, and at yearly intervals thereafter. To assess the extent of the diameter of the true and false lumen, the entire descending thoracic aorta was evaluated at three different levels of the thoracic aorta. Widths of the stent graft and the aorta were measured directly distal to the

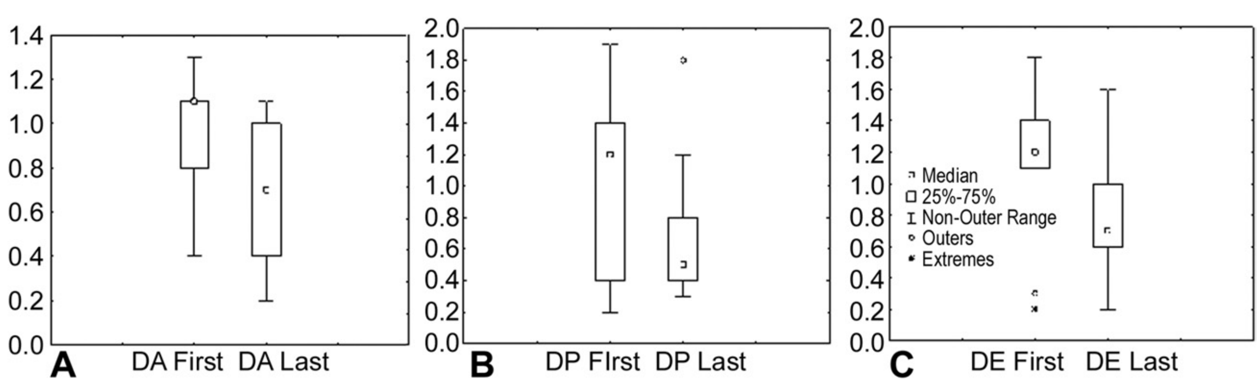

Fig 4. Shrinkage of the false lumen (A) at the level distally of origin of subclavian artery, (B) at the pulmonary artery, and at (C) the end of the stent graft. (DA = difference A [origin of subclavian artery]; DE = difference E [end of stent graft]; DP = difference P [pulmonary artery]; first = postoperative control; last = latest follow-up control).

offspring of the left subclavian artery (Fig 1A), at level of the pulmonary artery (Fig 1B), and the end of the stent graft (C). The diameter of the aorta was measured at the level of the diaphragm (Fig 1D). Shrinkage of the excluded false lumen was calculated by comparing the diameter of the stent graft diameter and the total diameter of the aorta (Fig 2).

Statistical Analysis

Data were analyzed using the software programs StatXact, version 8 (Cytel, Cambridge, MA) and Statistica, version 8 (StatSoft, Tulsa, OK) for the scatterplot. We applied the accepted descriptive statistical tools (median value, upper and lower quartiles). Statistically significant differences between the diameter of the stent graft, the false lumen, and the entire aorta were calculated using the permutation test for paired replicates [11]. Changes in diameter were evaluated for significance between the first and the subsequent postprocedural images. Differences during observation time were analyzed using scatterplots. Two-dimensional scatterplots are used to visualize relations between the diameter of the stent graft, the false lumen, the entire aorta, and time. A linear function and the distance-weighted least squares smoothing procedure are fitted to the points to express the trend. The Spearman rank-order correlation coefficient R is a measure of association between two variables that requires that both variables are measured in at least an ordinal scale so that the objects or individuals under study may be ranked in two ordered series. The coefficient and testing the significance was calculated to detect associations between the diameter and time. Continuous variables are expressed as means and ± SD. We used *p* values of less than 0.05 for the determination of statistical significance.

Results

The prosthesis was successfully implanted by the use of an antegrade guidewire in all patients. The total duration of the cardiopulmonary bypass, the duration of hypothermic circulatory arrest, and the aortic cross-clamp time were 213 ± 33.7 minutes (range, 154 to 263), 57 ± 12.4 minutes (range, 37 to 76), and 98 ± 33.4 minutes (range, 52 to 137), respectively. Deployment of the stented end of the hybrid prosthesis required an average of 10 minutes (range, 8 to 12). The duration of stay at the intensive care unit was 6.3 ± 6.5 days (range, 1 to 22) and that for the hospital stay, 20 ± 9.8 days (range, 9 to 38). Patients were discharged after control CT scan was performed. One patient had a postcardiotomy syndrome, causing prolonged hospital stay.

All patients survived during the follow-up period. Two patients (14%) experienced neurologic deficits (weakness of the upper extremities), which had resolved completely at the time of discharge.

The duration of follow-up ranged from 1 to 43 months (mean 21.4). No redissection or aortic rupture occurred during the follow-up period. The postoperative CT scans revealed complete thrombus formation of the false lumen in the perigraft space in the stented segment of the hybrid prosthesis within the first 2 weeks after surgery in 12 patients (86%). All patients after acute and chronic dissection showed complete thrombosis of the false lumen at the 3-month control (Fig 3).

Changes in the maximum diameter of the descending thoracic aortic and the stent graft distal to the offspring of the left subclavian artery, at the level of the pulmonary artery, and the end of the stent graft were assessed immediately after surgery. Changes that occurred during

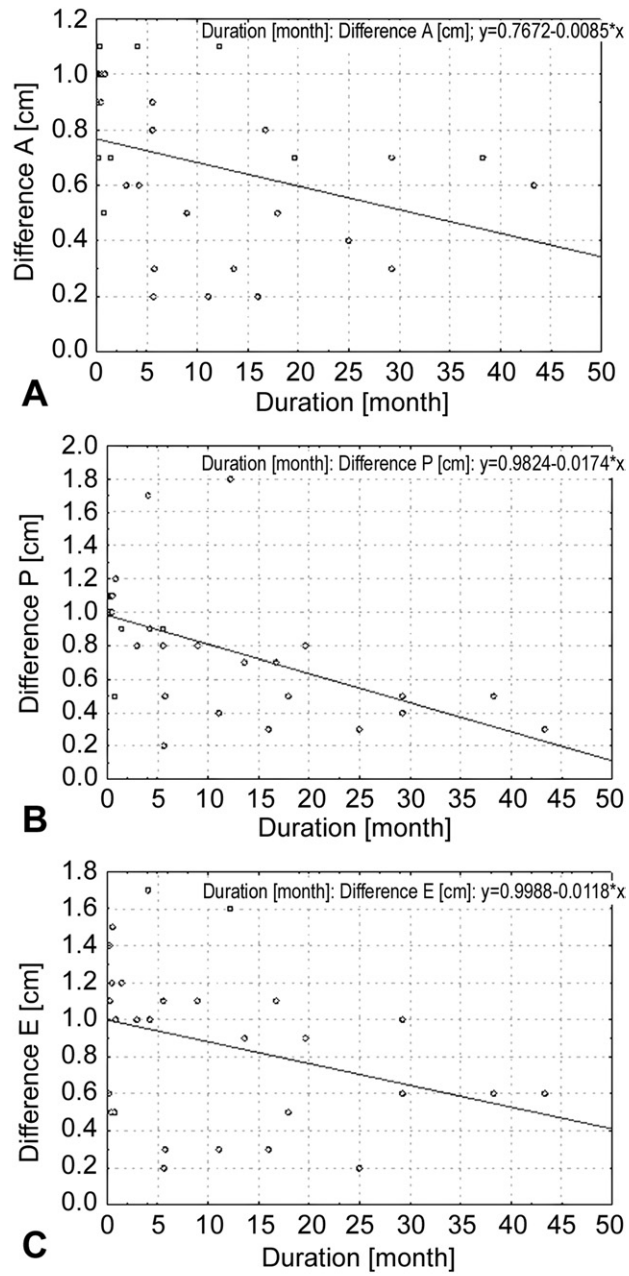

Fig 5. Linear correlation of the shrinkage tendency of the false lumen at (A) the origin of subclavian artery (difference A), (B) the pulmonary artery (difference P), and (C) the end of the stent graft (difference E). (y = difference, in cm; x = time, in months.)

the follow-up period were compared. Additionally, the diameter of the aorta was measured at the level of the diaphragm. The diameter of the descending aorta decreased significantly at the level of the subclavian artery (3.9 ± 0.45 cm versus 3.6 ± 0.39 cm; $p = 0.011$), whereas no significant changes were observed at the level of the pulmonary artery and the end of the stent graft. As the stent graft was fixed at the origin of the subclavian artery, its diameter was not subject to change. However, the stent graft was extended at the level of the pulmonary artery (2.5 ± 0.44 cm versus 3.1 ± 0.36 cm, $p = 0.054$) and its end (2.3 ± 0.49 cm versus 2.7 ± 0.34 cm; $p = 0.031$). At the level of the diaphragm, the diameter of the aorta had increased from 2.9 ± 0.77 cm to 3.6 ± 0.88 cm ($p = 0.99$).

Most interestingly, the false lumen showed significant shrinkage at all levels in the stented region: approximately 3 cm distal to the subclavian artery, it shrank on average from 1.1 ± 0.33 cm to 0.7 ± 0.32 cm ($p = 0.004$), at the level of pulmonary artery from 1.2 ± 0.58 cm to 0.5 ± 0.5 cm ($p = 0.031$), and at the end of the stent graft from 1.2 ± 0.54 cm to 0.7 ± 0.42 cm ($p = 0.0059$; Fig 4).

The difference of diameter (y, in cm) of the false lumen within the observation period (x, in months) and the strength of the linear relationship (R) analyzed with the Spearman rank-order correlations test showed significant shrinkage of the false lumen in all levels within the area of the stent graft. The correlation equation distally of the subclavian artery revealed $y = 0.77 - 0.0085^* \times$ (R= −0.5; $p = 0.003$); at the level of pulmonary arteries, $y = 0.99 - 0.0174^* \times$ (R = −0.7; $p = 0.00002$); and at the end of the stent graft, $y = 0.998 - 0.0118^* \times$ (R = −0.4; $p = 0.029$; Fig. 5) This analysis enables a prediction of shrinkage per month, for example, at the subclavian artery 0.0085 cm/month.

Furthermore, thrombosis of the false lumen was achieved in all levels of the stent graft. The follow-up CT scan obtained after 12 months revealed shrinkage of the false lumen in 9 patients (64%).

Comment

Repair of Stanford type A dissections results in chronic dissection of the aortic arch and the descending aorta in as many as 77% of patients, whereas the false lumen remains patent in 70% to 100% [4, 5, 12, 13]. An enlargement of the descending aorta is associated with an increased risk of reoperation and mortality. The patent false lumen in the downstream aorta has an impact in morbidity and mortality in the entire literature [5, 12, 13]. Reentries at the proximal descending aorta are discussed as one of the main reason for false lumen perfusion and consecutive enlargement and rupture [14, 15]. Prospective, randomized studies are difficult to perform because of the acute pathology in aortic dissections. The results of international registries will determine the mortality and morbidity rate in a large cohort of this selected patient group in the future.

The unfavorable long-term prognosis for patients who have undergone conventional repair of Stanford type A dissections has been reported in several series. Fattori and associates [5] registered a reoperation rate of 27.5% in 84 months, resulting from the increasing diameter of the descending aorta. In a recent report, Park and associates [12] found that the false lumen remains patent in 63.1% of patients who have undergone surgery for Stanford type A dissection. Dilation of the descending aorta was increased by more than 1 cm in 47.5%, and 15.6% of patients underwent distal reoperation during the mean follow-up period of 33.6 months. In his commentary, Miyamoto [12] noted that the elephant trunk technique is the only feasible method to treat complex pathologies of the aorta.

We performed extensive treatment to stabilize the descending aorta without increasing the risk of operation. This report describes our experience with a single-stage procedure using a hybrid prosthesis combining the features of a conventional vascular prosthesis and a stent graft. The ascending aorta and the aortic arch are replaced with Dacron prosthesis whereas the descending aorta is treated with the stented segment of the hybrid prosthesis. This successful approach has been reported by several authors [9, 13, 16–20]. Although the procedure is associated with low rates of perioperative mortality and morbidity and yields a favorable outcome, the fate of the false lumen remains unclear. Therefore, follow-up data are needed before antegrade implantation of the stent graft can be advocated as a successful procedure.

Uchida and colleagues [21] registered thrombus formation at the midportion and the distal margin of the stent graft 1 month after surgery. Absorption or obliteration was seen in nearly all patients after 3 months. These findings are comparable to the thrombosed false lumen at the level of the pulmonary artery and the end of the stent graft in our series. Owing to the tight anastomosis distal to the subclavian artery, no endovascular leak occurred. In addition, intercostal arteries were obliterated by the stent, and any additional tears that may occur are covered.

At the level of the superior mesenteric artery, the authors registered a 48% rate of thrombosed false lumen after 1 month. False lumens that were patent at 1 month remained patent throughout the follow-up period. In our series, the false lumen distal to the stent graft remained open. However, the overall diameter of the aorta did not increase statistically significant during the observation period. Patent distal intercostal and lumbar arteries remain patent and prevent spinal cord ischemia. Furthermore, repetitive tears in the aorta distal to the stent permit antegrade perfusion of the mesenteric and the left renal arteries, which originate at the false lumen and may become occluded in case of thrombus formation or obliteration.

In patients who undergo consecutive repair of the distal descending or the abdominal aorta, which could potentially involve obliteration of the existing spinal and lumbar arteries, the clinician must consider the risk of paraplegia.

The descending aorta can be remodeled by extending the stent graft into the true lumen, followed by obliteration of the false lumen, without increasing the risk and duration of the operation [22]. Treatment of the distal arch and the proximal descending aorta has been extensively reported. This area was shown to be at high risk for dissection-related death, rupture, or reoperation [14, 15].

Study Limitations

Given the need for acute intervention in Stanford type A dissections, the present investigation was conducted as a retrospective intention-to-treat analysis. The results support the prevalence of early thrombosis of the false lumen in the descending aorta, which can be obtained by combined surgical and endovascular repair of the thoracic aorta, although the number of patients is small. Antegrade stent grafting of the proximal descending aorta eliminates all possible additional entries and reentries and avoids late problems of a residual false lumen. One patient in our series had Marfan syndrome. The long-term prognosis of stent grafts in this setting is unknown and needs careful consideration. None of our patients required repeat surgery for a patent false lumen distal to the stent graft. We registered no significant enlargement of the distal descending aorta or in the abdominal region. Repetitive tears in the aorta distal to the stent permit antegrade perfusion of the mesenteric and, commonly, the left renal arteries, which originate at the false lumen and may become occluded in case of thrombus formation or obliteration. An extended follow-up period will clarify the advantages of consistent perfusion of the lumbar, mesenterial, and renal arteries as opposed to the need for repeat interventions in this area.

In conclusion, by performing frozen elephant repair in patients with Stanford type A dissections, the false lumen can be thrombosed until the end of the antegrade implanted stent graft. This method may reduce the need for further reoperation and can be performed without increasing the risk of surgery. The risk of rupture or death due to enlargement or secondary dissection of the thoracic descending aorta can be avoided by this procedure.

References

1. Estrera AL, Miller CC, Huynh TT, Porat E, Safi HJ. Neurologic outcome after thoracic and thoracoabdominal aortic aneurysm repair. Ann Thorac Surg 2001;72:1225–30.
2. Gega A, Rizzo JA, Johnson MH, Tranquilli M, Farkas EA, Elefteriades JA. Straight deep hypothermic arrest: experience in 394 patients supports its effectiveness as a sole means of brain preservation. Ann Thorac Surg 2007;84:759–66.
3. Zierer A, Voeller RK, Hill KE, Kouchoukos NT, Damiano RJ, Moon MR. Aortic enlargement and late reoperation after repair of acute type A aortic dissection. Ann Thorac Surg 2007;84:479–87.
4. Halstead JC, Meier M, Etz C, et al. The fate of the distal aorta after repair of acute type A aortic dissection. J Thorac Cardiovasc Surg 2007;133:127–35.
5. Fattori R, Bacchi-Reggiani L, Bertaccini P, et al. Evolution of aortic dissection after surgical repair. Am J Cardiol 2000;86: 868–72.
6. Kato M, Ohnishi K, Kaneko M, et al. New graft-implanting method for thoracic aortic aneurysm or dissection with a stented graft. Circulation 1996;94:II188–93.
7. Schoenhoff FS, Schmidli J, Eckstein FS, Berdat PA, Immer FF, Carrel TP. The frozen elephant trunk: an interesting hybrid endovascular-surgical technique to treat complex pathologies of the thoracic aorta. J Vasc Surg 2007;45:597–9.
8. Karck M, Chavan A, Khaladj N, Friedrich H, Hagl C, Haverich A. The frozen elephant trunk technique for the treatment of extensive thoracic aortic aneurysms: operative results and follow-up. Eur J Cardiothorac Surg 2005;28:286–90.
9. Uchida N, Shibamura H, Katayama A, Shimada N, Sutoh M, Ishihara H. Operative strategy for acute type a aortic dissection: ascending aortic or hemiarch versus total arch replacement with frozen elephant trunk. Ann Thorac Surg 2009;87: 773–7.
10. Gorlitzer M, Weiss G, Thalmann M, et al. Combined surgical and endovascular repair of complex aortic pathologies with a new hybrid prosthesis. Ann Thorac Surg 2007;84:1971–6.
11. Sigel S, Castellan NJ. Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill, 1998:174–84.
12. Park KH, Lim C, Choi JH, et al. Midterm change of descending aortic false lumen after repair of acute type I dissection. Ann Thorac Surg 2009;87:103–8.
13. Kouchoukos NT, Masetti P, Rokkas CK, Murphy SF. Single-stage reoperative repair of chronic type A aortic dissection by means of the arch-first technique. J Thorac Cardiovasc Surg 2001;122:578–82.
14. Akutsu K, Nejima J, Kiuchi K, et al. Effects of the patent false lumen on the long-term outcome of type B acute aortic dissection. Eur J Cardiothorac Surg 2004;26:359–66.
15. Sakaguchi G, Komiya T, Tamura N, et al. Patency of distal false lumen in acute dissection: extent of resection and prognosis. Interact Cardiovasc Thorac Surg 2007;6:204–7.
16. Di Bartolomeo R, Di Marco L, Armaro A, et al. Treatment of complex disease of the thoracic aorta: the frozen elephant trunk technique with the E-vita open prosthesis. Eur J Cardiothorac Surg 2009;35:671–6.
17. Karck M, Kamiya H. Progress of the treatment for extended aortic aneurysms: is the frozen elephant trunk technique the next standard in the treatment of complex aortic disease including the arch? Eur J Cardiothorac Surg 2008;33:1007–13.
18. Mestres CA, Fernández C, Josa M, Mulet J. Hybrid antegrade repair of the arch and descending thoracic aorta with a new integrated stent-Dacron graft in acute type A aortic dissection: a look into the future with new devices. Interact Cardiovasc Thorac Surg 2007;6:257–9.
19. Mizuno T, Toyama M, Tabuchi N, Wu H, Sunamori M. Stented elephant trunk procedure combined with ascending aorta and arch replacement for acute type A aortic dissection. Eur J Cardiothorac Surg 2002;22:504–9.
20. Jakob H, Tsagakis K, Tossios P, et al. Combining classic surgery with descending stent grafting for acute DeBakey type I dissection. Ann Thorac Surg 2008;86:95–101.
21. Uchida N, Shibamura H, Katayama A, Shimada N, Sutoh M. Total arch replacement with an open stent graft for acute type A aortic dissection: fate of the false lumen. Eur J Cardiothorac Surg 2009;35:83–8.
22. Huptas S, Mehta RH, Kühl H, et al. Aortic remodeling in type B aortic dissection: effects of endovascular stent-graft repair and medical treatment on true and false lumen volumes. J Endovasc Ther 2009;16:28–38.