Successful repair of mega aorta using reversed elephant trunk procedure

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The case reported is of a patient with mega aorta and a symptomatic thoracoabdominal aortic segment. Successful treatment involved resection and graft replacement of the thoracoabdominal segment as an initial procedure using a "reversed elephant trunk" technique, followed by resection and replacement of the ascending aorta and transverse aortic arch as the second stage. (J Vasc Surg 1998;27:183-8.)

Long-term studies have shown that the life expectancy of untreated patients with aortic aneurysms is limited, with death from rupture or associated disease occurring within 5 years in more than 75% of these patients.[1] Patients with aortic aneurysms have a high incidence of multiple aortic segmental involvement or multiple aneurysms, as demonstrated by Crawford and colleagues.[2] Graft replacement, the standard form of treatment, prevents rupture and prolongs life in patients who have multiple or extensive aneurysms.[2]

The "elephant trunk" procedure, introduced by Borst and colleagues,[3,4] is the preferred technique for the treatment of patients with multifocal aneurysmal disease of the entire thoracic aorta. Although the technique described by Borst and colleagues has undergone modifications,[5-7] because it is based on sound clinical rationale the procedure remains the gold standard for the staged repair of aneurysms involving the entire thoracic aorta, both proximally and distally, that is, mega aorta. The elephant trunk technique is used in patients with fusiform aneurysmal disease as well as aortic dissection. The concept allows for replacement of the ascending aorta and transverse aortic arch, leaving a free-floating portion of the graft within the proximal descending thoracic aorta beyond the distal anastomosis to be used at the second operation for distal aortic replacement. The technique facilitates the second-stage procedure after the aortic arch has been repaired and reduces the risks of multiple-stage aortic replacement.[8]

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We present the case of a patient with mega aorta as a result of chronic fusiform medial degenerative disease and chronic type III aortic dissection. The thoracoabdominal portion of the aneurysm was symptomatic, necessitating that the distal aorta be replaced at the initial operation. Successful replacement of the entire thoracic aorta down to the suprarenal abdominal aorta was achieved in two stages by using a reversed technique of the "elephant trunk" procedure.

CASE REPORT

A 70-year-old man had progressively worsening shortness of breath and back pain. After a chest roentgenogram revealed a large aortic aneurysm, the patient was transferred to our institution for further evaluation and treatment. His previous history was significant for poorly controlled high blood pressure and chronic obstructive pulmonary disease caused by cigarette abuse for 40 years. A computed tomographic scan showed aneurysmal disease of the ascending aorta, transverse aortic arch, and thoracoabdominal aorta from the left subclavian artery down through the visceral vessels. Cardiac catheterization and aortography were also performed and showed normal left ventricular function with an ejection fraction of 70%. There were no signs of significant coronary artery disease. The aortic aneurysm extended to, but not below, the origin of the renal arteries (chronic type III aortic dissection) and involved the ascending aorta, transverse arch, and, separately, the innominate artery (Fig. 1). It was thought that the patient would not be a good candidate for total aortic replacement at one setting. Because the distal thoracic aortic aneurysm was symptomatic, the thoracoabdominal aortic portion of the aneurysm would need to be replaced first.

Resection and graft replacement of the thoracoabdominal aortic aneurysm was performed on October 31, 1994. The aneurysm was exposed through a standard left thoracoabdominal incision through the sixth intercostal space, and the abdominal viscera were rotated medially to give exposure of the entire abdominal aorta. Exploration revealed an aortic aneurysm extending from the left sub-

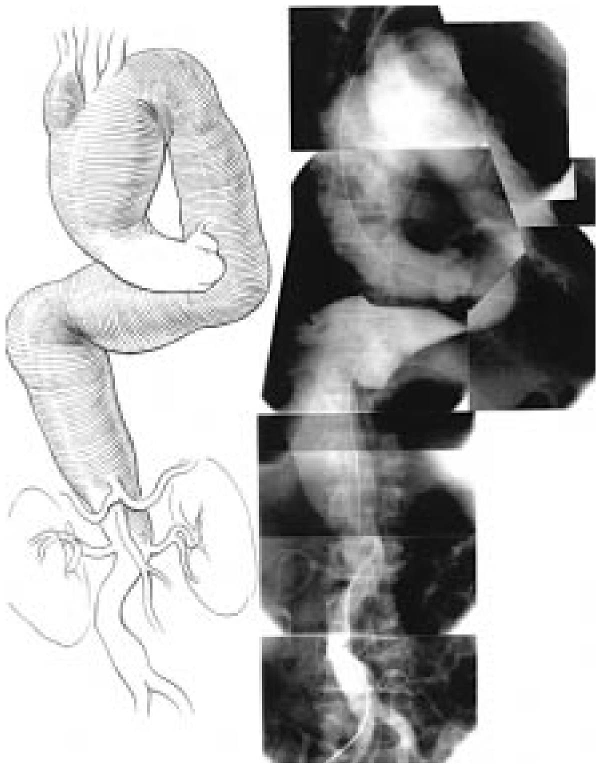

Fig. 1. Preoperative drawing and aortogram of patient with mega aorta. Chronic fusiform aneurysm of ascending aorta, innominate artery, transverse aortic arch, and thoracoabdominal aorta. Aneurysm is result of chronic type III aortic dissection (thoracoabdominal aortic aneurysm, Crawford extent III).

clavian artery to the renal arteries (Fig. 2, *A*). The diaphragm was divided in a circular fashion, leaving a rim of 2 cm laterally on the chest wall for later reattachment, in an attempt to preserve as much diaphragm as possible, along with preservation of the phrenic nerve, to preserve as much diaphragm function as possible. The size of the aneurysm from the left subclavian artery down to the level of the diaphragm was thought not to be suitable for placement of a distal aortic clamp. Consequently, left atrial–to–distal bypass with a Biomedicus pump was not performed. In addition, in this instance we did not use visceral arterial perfusion, spinal fluid drainage, or spinal cooling. After cross-clamping the aortic arch distal to the left common carotid artery and separately cross-clamping the left subclavian artery, the aneurysm was opened longitudinally using electrocautery along its posterolateral surface. The septum between the true and false lumen of the aortic dissection then was excised from the origin of the left subclavian artery down to the renal arteries, where it ended (Fig. 2, *B*). A 28 mm woven Dacron tube graft was then selected for replacement of the aneurysm. The graft was inverted so that the proximal part was invaginated into the tubular graft ("reversed elephant trunk"; Fig. 2, *C*). Proximal intercostal arteries were first oversewn, and the inverted edge of the graft was sutured end-to-end to the aorta distal to the left subclavian artery using a continuous suture of polypropylene after the aorta was completely transected (Fig. 2, *D*). The clamp was moved down onto the graft, and the left subclavian artery was released. After this, intercostal arteries T10 and T11 were reattached to the graft using 3-0 polypropylene in a continuous fashion. The distal end of the graft was beveled, and the distal anastomosis was carried out in such a way as to attach the graft end-to-end to the abdominal aorta, preserving the origins of the celiac axis, superior mesenteric artery, and both renal arteries using 3-0 polypropylene running suture (Fig 2, *E* and *F*). Before completion of the distal anastomosis, the graft and the native aorta were flushed proximally and distally to remove all air and debris (Fig. 2, *G*), then the vascular clamp was removed and flow restored to the viscera and lower extremities. Before closing the abdomen and the chest, the aneurysm wall was wrapped around the graft using 2-0 polypropylene.

After the operation the patient awoke neurologically intact and was extubated on the evening of the first postoperative day. The remainder of his hospital course was uneventful except for left true vocal cord paralysis, for which the patient underwent successful type I thyroplasty on the eleventh postoperative day. He was discharged from the hospital the next day with significantly improved vocal capabilities. Five months later the patient was readmitted for the second stage of his "reversed elephant trunk" procedure (Fig. 3). The primary reason for the delay of 5 months was patient choice.

At the second operation, the chest was entered through a standard median sternotomy. After systemic administration of heparin (3 mg/kg), total cardiopulmonary bypass was established with arterial cannulation in the left common femoral artery and bicaval venous cannulation via the right atrium. A left ventricular sump was inserted through the right superior pulmonary vein. The patient was systemically cooled until the electroencephalogram was isoelectric and the rectal temperature was 18° C. With the patient in a Trendelenburg position, circulatory arrest was initiated. Retrograde cerebral perfusion was initiated via the superior vena caval cannula. Flow through the superior vena cava cannula was maintained at between 300 to 600 ml per minute, with the pressure measured proximally and kept at 25 mm Hg or less. The ascending portion of the aneurysm and the origin of the innominate artery were then opened longitudinally; no evidence of dissection was identified (Fig. 4, *A*). The aortic valve and the coronary arteries were normal, and there was no dilatation of the sinus segment of the ascending aorta. Reaching within the opened aortic arch, the graft segment left invaginated in the previous proximal descending thoracic aortic graft ("reversed elephant trunk") was then withdrawn and brought to its full length. An oval opening was made in the graft, and the left common carotid and left subclavian arteries were reattached (Fig. 4, *B* and *C*). The innominate artery was transected, and a 14 mm

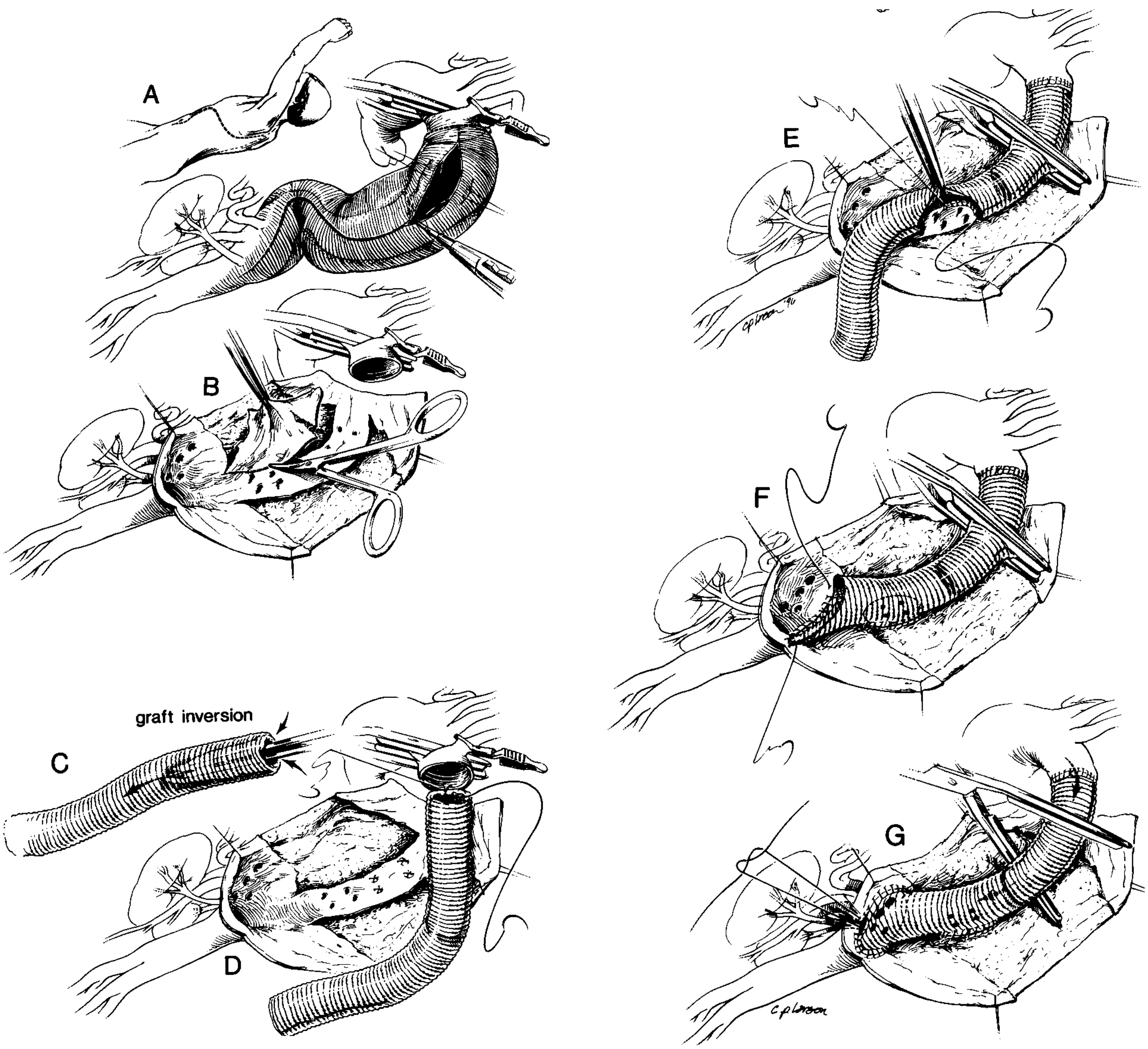

Fig. 2. Steps in first stage of repair of mega aorta using "reversed elephant trunk technique." **A,** Incision for left thoracoabdominal approach. **B,** After cross-clamping distal aortic arch and left subclavian artery, the aneurysm is opened and the wall between true and false lumen is excised. **C,** Inversion of graft ("reversed elephant trunk"). **D,** Suturing of inverted graft to proximal descending aorta after proximal intercostal arteries have been oversewn. **E,** After completion of proximal anastomosis, clamp is moved onto graft and intercostal arteries T10 and T11 are reattached. **F,** Attachment of visceral and both renal arteries at distal anastomosis. **G,** Flushing of graft and completion of reconstruction.

woven Dacron tube graft was anastomosed just below the bifurcation using 3-0 polypropylene. An opening was made in the aortic graft, and the smaller graft was attached end-to-side to the aortic graft using 4-0 polypropylene in a continuous technique (Fig. 4, *D*). Cardiopulmonary bypass was resumed from the femoral artery after carefully flushing the graft of air and debris. A cross-clamp was placed on the aortic graft proximal to the innominate artery graft. Rewarming was begun. The superior vena caval cannula was taken off arterial pump return and placed back on venous drainage. Cold (4° C) hyperkalemic dilute blood cardioplegic solution was instilled into both coronary ostia, and the ascending aorta was transected superior to the coronary artery origins. The aortic graft was sutured end-to-end to the native aorta just above the coronary artery ostia (Fig. 4, *E*). Before completion of the final anastomosis, careful de-airing of the graft and the heart was carried out, and after adequate

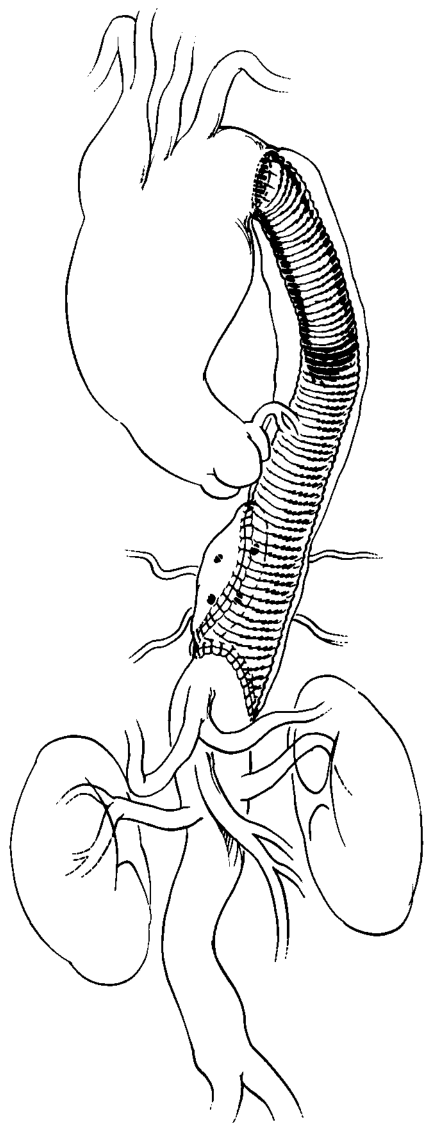

Fig. 3. Postoperative drawing after completion of thoracoabdominal repair with "reversed elephant trunk" invaginated in proximal portion of graft.

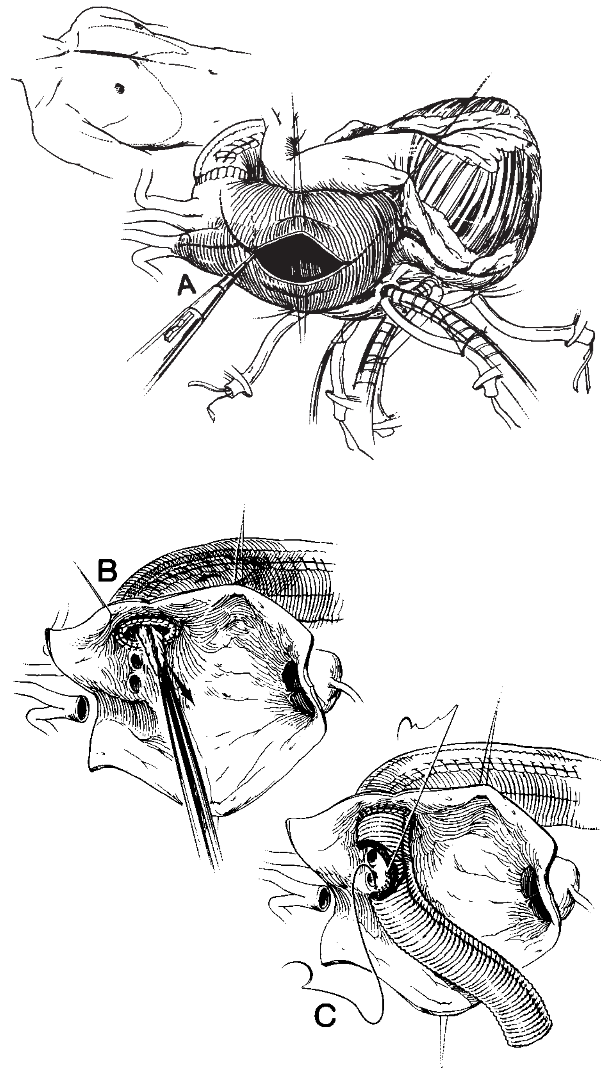

Fig. 4. Steps in second stage of "reversed elephant trunk" procedure. **A,** Median sternotomy, total cardiopulmonary bypass, deep hypothermic circulatory arrest, together with the use of retrograde brain perfusion, are used. **B** and **C,** Withdrawing of invaginated graft segment ("reversed elephant trunk") from previous proximal descending aortic graft to its full length, and reattachment of left common carotid and left subclavian arteries.

rewarming the patient was slowly weaned from cardiopulmonary bypass. The total pump time was 94 minutes, and circulatory arrest time was 48 minutes. The patient awoke without any neurologic deficit and was extubated 18 hours after the operation. Postoperative aortography confirmed satisfactory repair (Fig. 5). The remainder of his hospital recovery was uneventful, and the patient was discharged on the twelfth postoperative day. Follow-up 1 year after operation revealed the patient to be doing well.

DISCUSSION

Patients with aortic aneurysmal disease have a high incidence of multiple aortic segmental involvement. In patients with "mega aorta," that is, those patients who have ascending, transverse aortic arch, and distal aortic involvement including the descending thoracic and thoracoabdominal aorta, we have preferred to approach the procedure in stages. The proximal aortic disease, ascending aorta, and transverse aortic arch are replaced as the initial phase of operative treatment. This allows for treatment of aortic or other valvular disease, as well as coronary

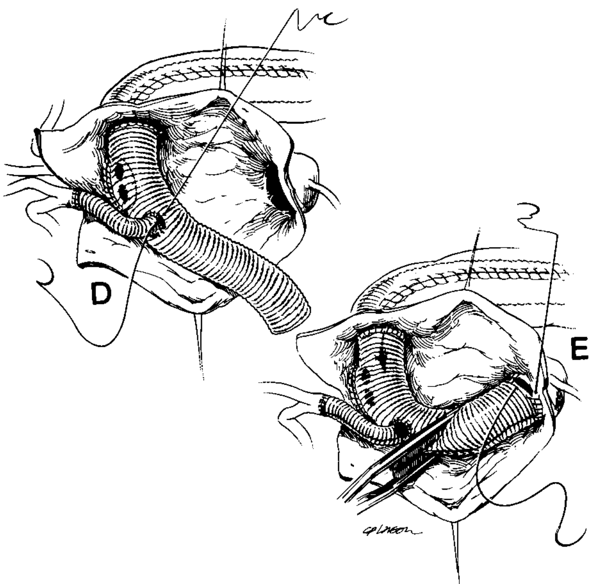

Fig. 4—cont'd. Steps in second stage of "reversed elephant trunk" procedure. **D,** Separate interposition graft replacement of innominate artery using a 14 mm woven tube graft. **E,** Completion of proximal graft anastomosis in supracoronary position after reinstituting cardiopulmonary bypass and rewarming with clamping of graft just proximal to innominate artery.

artery occlusive disease at the initial operation. In addition, patients generally tend to recover from a median sternotomy more quickly than a thoracotomy, allowing for a shorter period of time between staged procedures and reducing the risk of delay; the planned treatment can be completed in an overall shorter period of time. Although clinically capable of undergoing a second stage operation in several weeks, our patient for personal reasons elected to delay 5 months. Our preferred initial procedure for ascending aorta and arch replacement has been the "elephant trunk technique" as introduced by Borst and colleagues.[3] The approach facilitates the second stage of operative treatment by reducing the risk of injury to the phrenic nerve, recurrent laryngeal nerve, pulmonary artery, and esophagus because less dissection and manipulation is needed at the level of the distal transverse aortic arch during the second operation. In patients with "mega aorta" in which the descending thoracic or thoracoabdominal aorta is disproportionately larger than the proximal aortic segment, is symptomatic as manifested primarily by back pain, or shows evidence of impending rupture such as intramural hematoma on computed tomographic scan, the distal aortic segment is treated as the initial procedure followed by staged repair of the ascending aorta and transverse aortic arch.

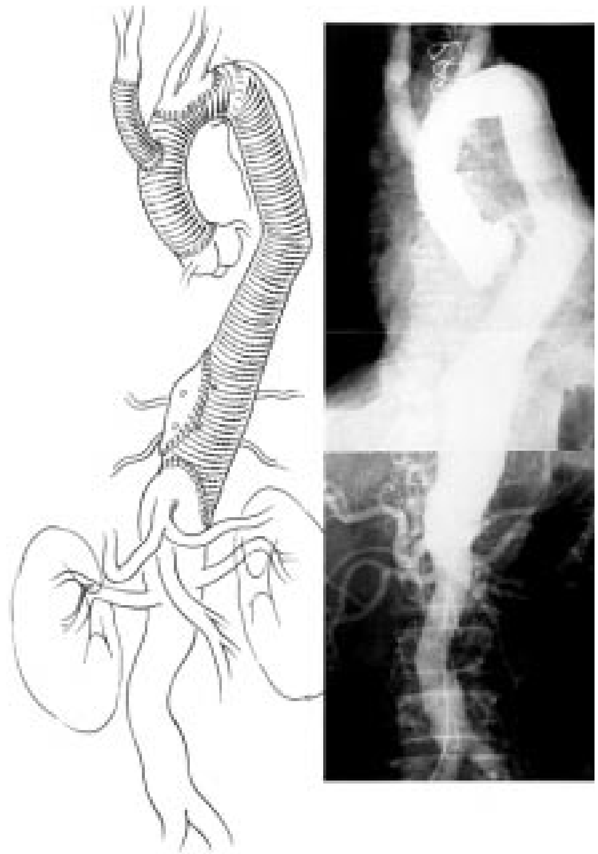

Fig. 5. Postoperative drawing and aortogram after complete repair of mega aorta shows satisfactory graft replacement of supracoronary ascending aorta, innominate artery, transverse aortic arch, and descending and proximal abdominal aorta.

An alternative treatment for staged operations has been the total replacement of the entire aorta at a single operation, as recommended by others.[9,10] Such procedures necessitate the use of cardiopulmonary bypass, profound hypothermia, and circulatory arrest.[11-13] This approach to total replacement of the aorta through the left chest is associated with an increased morbidity rate, including significant pulmonary morbidity resulting from parenchymal hemorrhage caused by retraction of the left lung in the face of systemic heparinization required for total cardiopulmonary bypass.[11,14]

The method described herein using a "reversed elephant trunk technique" provides for a two-staged approach to the treatment of patients with mega aorta in whom the distal aortic segment must be treated first, because it is either disproportionately larger than the proximal segment, symptomatic, or faced with impending rupture. Although the approach does not necessarily require extensive dissection and mobilization of the recurrent laryngeal, vagus, and phrenic nerves, the proximal involvement of these extensive aneurysms, such as in the patient described herein, may require mobilization of the recurrent laryngeal nerve. The latter may result in left vocal cord paralysis, necessitating thyroplasty for restoration of voice after the operation. Retraction of the left lung in a fully heparinized patient is avoided.

In the treatment of thoracoabdominal aortic aneurysms in which the entire descending thoracic aorta is involved, especially in patients with dissection, we prefer the use of atriodistal bypass.[15] The technique allows for perfusion of the distal intercostal arteries during the proximal reconstruction as well as perfusion of the visceral and renal vessels. The size, tortuosity, and anatomic nature of the aneurysm in the patient described herein did not allow for positioning clamps along the descending thoracic aorta; consequently, atriodistal aortic bypass was not used. In addition, it was assessed that the ischemic periods required for the replacement and reconstruction of the involved aorta would fall within a safe period.

In using the reversed elephant trunk technique as described herein, the second stage of treatment is facilitated by eliminating the need for distal anastomosis upon replacement of the transverse aortic arch and reducing the time period of circulatory arrest and potential for hemorrhage. Consequently, the technique of "reversed elephant trunk" is recommended as an alternative approach to the staged treatment of patients with mega aorta in whom replacement of the descending thoracic or thoracoabdominal aorta is required as the initial procedure.

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