11.1 The Conventional Elephant Trunk Technique

Anatomy determines that the proximal segment of the descending aorta is less accessible via median sternotomy than the aortic arch. Therefore most surgeons prefer a multiple-stage approach to treat combined lesion of the aortic arch and the descending aorta. The introduction of the elephant trunk technique by Borst et al. [4] in 1983 has greatly facilitated surgery on this kind of pathology. The basic principle of the Borst operation for the replacement of the aortic arch resides in the protrusion of a length of tubing into the downstream aorta distal to the actual graft to aortic anastomosis at the level of the left subclavian artery. In the subsequent operation performed through lateral thoracotomy, the graft segment in the descending aorta may be used for further replacing the diseased vessel. More importantly, the difficult and often dangerous dissection of the original distal graft to aortic anastomosis is avoided.

After earlier publications from our own group and Crawford’s landmark paper published in 1990, this method became more and more popular for treating patients with complex aortic diseases [1, 3, 5, 8–10, 26, 27, 31]. Today, the elephant trunk operation is employed in the two classic conditions: aneurysms and chronic dissection of (1) the aortic arch and (2) the descending thoracic aorta involving the respective downstream portions of the vessel. It may also be chosen for selected patients with acute proximal and distal dissection [9, 23, 24].

Meanwhile, several modifications of the original technique have been reported. Coselli et al. [8] introduced the reversed elephant trunk technique, while Carrel et al. [5, 6] described a bidirectional variant for the replacement of the descending aorta, thereby facilitating second- and third-stage procedures for the replacement of the aortic arch and the thoracoabdominal aorta.

The idea of using an elephant trunk prosthesis as a stent graft, introduced into the descending aorta, was born and popularized by Buffalo's group [23, 24], who employed this approach in a large series of patients with acute type B dissection. Along with the advent of transfemoral stent grafts for the treatment of descending aortic aneurysms it became even possible to securely anchor a stent graft in an elephant trunk prosthesis previously placed during arch surgery [11].

Even though complications following the insertion of elephant trunk grafts have been rare and appear largely avoidable, concerns were reported with regard to increased tension on the suture line distal to the left subclavian artery, thereby increasing the risk of rupture at or near that site during the waiting period for the second-stage operation [18, 32]. This fear has prompted further modifications of the original technique by preparing this anastomosis at an upstream and less dilated aortic level. Thus, Svensson et al. [32] have suggested placing the anastomosis in the aortic arch between the left carotid artery and the left subclavian artery. Another, even more radical approach in this regard was published by Kuki et al. [18], who reported a series of 17 patients in whom the elephant trunk anastomosis was made at the base of the innominate artery. Using this technique, they reconnected the supracircular branches to the ascending aortic vascular graft by three small-caliber interposition grafts. The authors suggest that this modification yields a secure and rapid anastomosis, and reduces the risk of aortic tearing even in the case when the suture line that is tailored down to the smaller size of the graft [18]. While the length of the elephant trunk depends on the extent of the downstream aortic enlargement and should be at least
7–8 cm according to Borst’s original suggestion, the technical modification described by Kuki et al. requires a length of about 15 cm. Here may reside a potential problem of this variant, because a long elephant trunk is more likely to cause complications due to kinking and graft occlusion. This suspicion is supported by Crawford’s finding that there are increased risks of peripheral embolisation caused by flapping action of the elephant trunk and paraplegia as a result of clot formation around the graft, if the trunk is too long [10].

Another concern with regard to staged repair of extensive thoracic aortic aneurysms using the conventional elephant trunk operation resides in the fact that the risks of two major surgical procedures and the risk during the time interval between the two interventions add up cumulatively. This was highlighted in a more recent report by Estrera et al. [12]. They calculated early mortality rates of 9% after the stage one operation and 7% mortality after the stage two procedure. Among the 124 patients who survived the stage one operation, there were 56 patients discharged from hospital who failed to return for the second-stage repair. In this group of patients follow-up surveys at 5 years revealed as many as 18 out of 56 (32.1%) deaths. In addition, a mortality rate within the small time window between 4 and 6 weeks following the stage one operation of 8% with the majority of fatalities due to aortic rupture clearly indicates the limitations of staged approaches. A similar observation was made by Schepens et al. [29], who reported survival rates between 80 and 90% in patients who completed the stage two procedure within 4 years, compared with as low as 50% survival in patients, who did not.

11.2 The Frozen Elephant Trunk Technique

The complications that may be attributed to the elephant trunk itself and the cumulative risks of the staged approach are drivers for change towards new procedures and implants, which allow for risk reduction in the surgical treatment of large aortic aneurysms. Extensive one-stage repair techniques performed through a clamshell incision or through the left chest bear remarkable technical challenges and risks, too [17, 19, 28, 35]. They may therefore be limited to selected patients.

A new wave of the elephant trunk technique that may accomplish this goal approached with reports using a new type of homemade vascular prosthesis carrying a stent at its distal end. Suto et al. [30] described a patient with an aneurysm of the distal aortic arch and the descending aorta which was replaced via median sternotomy during circulatory arrest by antegrade implantation of a Gianturco stent connected to a conventional vascular prosthesis. Based on Buffolo’s earlier experience and Kato’s description of endovascular covered stent grafting through median sternotomy, Usui et al. [33] reported a series of 12 patients who underwent implantation of a covered stent graft for distal aortic arch aneurysm via median sternotomy under pigtail catheter guidance. Two patients in this cohort underwent additional procedures such as aortic arch replacement and aortocoronary bypass grafting, respectively. Shortly thereafter, Orihashi et al. [22] published a report on a cohort of 15 patients, mainly with descending aortic aneurysms not treatable with transfemoral stent grafts. Again, homemade grafts were prepared from a Gianturco stent introduced in a conventional vascular prosthesis prior to antegrade implantation during circulatory arrest. Almost half of the patients underwent additional procedures, including ascending and/or aortic arch replacement using separate vascular grafts, which were connected to the stented graft in the descending aorta. While these reports describe the use of the frozen elephant trunk technique in patients with aneurysms or chronic dissections, more recent publications focus on its use in patients with acute A aortic dissection, too [15, 16, 21]. Both, early and midterm results using this approach appear favourable, particularly with regard to the promotion of thrombus formation in the false channel. In the vast majority of patients in the study of Ishihara et al. [15] the false channel had even disappeared as distal as at the diaphragmatic aortic level at a maximum follow-up at 38 months postoperatively. In accordance with this finding, Kato et al. [16] observed a marked reduction of the diameter of the false lumen in the descending aorta excluded by the stent graft in their cohort comprising 19 patients. Whether these promising results justify the use of a frozen elephant trunk in patients with arch tears only or possibly in all patients with acute type A dissection is debatable. Given the fact, that up to 25% of patients who undergo ascending aortic replacement with an open distal anastomosis of the proximal aortic arch will develop critical downstream dilatation of native dissected aortic segments, this option should be taken into consideration [14].

11.3 Own Experience Employing the Frozen Elephant Trunk Technique Using a Hybrid Prosthesis with a Stented and a Nonstented End

11.3.1 Patients and Surgery

Between September 2001 and April 2004, 22 patients with combined pathologies of the aortic arch and the descending aorta were operated on using a “hybrid prosthesis” (Chavan–Haverich endograft, Curative, Dresden, Germany) made of a woven vascular prosthesis with stainless steel stents affixed to the inner aspects