Perspective

When and how to replace the aortic arch for type A dissection

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Acute type A aortic dissection (AAAD) remains one of the most challenging diseases in cardiothoracic surgery and despite numerous innovations in medical and surgical management, early mortality remains high. The standard treatment of AAAD requires emergency surgery of the proximal aorta, preventing rupture and consequent cardiac tamponade. Resection of the primary intimal tear and repair of the aortic root and aortic valve are well-established surgical principles. However, the dissection in the aortic arch and descending untreated aorta remains. This injury is associated with the risk of subsequent false lumen dilatation potentially progressing to rupture, true lumen compression and distal malperfusion. Additionally, the dilatation of the aortic arch, the presence of a tear and retrograde dissection can all be considered indication for a total arch replacement in AAAD. In such cases a more aggressive strategy may be used, from the classic aortic arch operation to a single stage frozen elephant trunk (FET) technique or a two-stage approach such as the classical elephant trunk (ET) or the recent Lupiae technique. Although these are all feasible solutions, they are also complex and time demanding techniques requiring experience and expertise, with an in the length of cardiopulmonary bypass and both myocardial and visceral ischemia. Effective methods of cerebral, myocardial as well visceral protection are necessary to obtain acceptable results in terms of hospital mortality and morbidity. Moreover, a correct assessment of the anatomy of the dissection, through the preoperative angio CT scan, in addition to the clinical condition of the patients, remain the decision points for the best arch repair strategy to use in AAAD.

Keywords: Aortic dissection; aortic; arch; cerebral protection; elephant trunk (ET)

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Introduction

Acute type A aortic dissection (AAAD) remains one of the most challenging diseases in cardiothoracic surgery and, despite numerous innovations in medical and surgical management, early mortality still remains high. Although the preoperative status of the patient is an important risk factor for hospital mortality, the different techniques of aortic repair used are well-known influencing factors of the postoperative course.

There are many important aspects of the surgical management of this condition that are still yet to be clarified in order to refine selection criteria for each technique and decide the extension of the replacement. Indeed, among the various open issues in this field, the management of the dissected aortic arch is one of the most discussed topics.

There is still not a full consensus in the cardiothoracic surgery community about the best management of the aortic arch in AAAD. Some surgeons advocate a more conservative tear oriented approach (hemiarch replacement) to reduce postoperative mortality and morbidity (1). On the other hand, other authors support a more aggressive approach for AAAD, mainly consisting of total arch replacement with or without the use of the frozen elephant trunk (FET) or classic elephant trunk (ET) technique (2-5). The rationale behind this more invasive operation is to mitigate the risk of late aneurysm formation at the distal aorta and to avoid distal malperfusion due to the compression of the true lumen. Our purpose is to delineate when and how to replace the aortic arch in AAAD, analyzing different solutions and approaches.

Indications for aortic arch replacement

The standard treatment of AAAD is represented by emergency surgery of the proximal aorta, preventing rupture and consequent cardiac tamponade. Resection of the primary intimal tear and repair of the aortic root and aortic valve are well-established surgical principles.

Even though many surgeons advocate this kind of approach, with the replacement of the proximal arch in addition to the repair of the aortic root, in such cases the dissection in the aortic arch and descending untreated aorta remains, with the risk of subsequent false lumen dilatation potentially progressing to complete rupture, true lumen compression and distal malperfusion.

Using serial magnetic resonance imaging, Fattori and associates closely followed a cohort of seventy patients after surgical intervention for acute type A dissection. They reported a growth rate of the descending aorta of 3.7 mm/year in patients with a patent false lumen, a rate that was significantly higher than in patients without patent false lumen (only 1.1 mm/year) (6). Zierer demonstrated that the expansion of the aorta was most common and more rapid at the level of the descending segment, and identified three independent predictors for aortic dilatation: aortic diameter, elevated systolic blood pressure at late follow-up and a patent false lumen (7). Another study by Park *et al*. (8) evaluated the postoperative computed tomography (CT) images of 122 patients who underwent aortic repair for AAAD. All patients underwent open distal repair with a resection of the primary entry tear. The thoracic false lumen remained patent in 85 patients (69.7%) although a thrombosis occurred in the remaining thirty-seven patients. The false lumen of the abdominal aorta was more frequently patent, namely 91% (111 of 122) of the patients. Enlargement of the descending aorta, during follow up, occurred in fifty-eight patients (47.5%) and in fifty of these cases the proximal thoracic aorta was involved. Dilatation of the aorta was significantly related to the false lumen characteristics. It occurred more frequently when the false lumen was patent or larger than the true lumen.

A direct association between patency of the false lumen and reoperation on the remaining distal aorta has been also demonstrated (9-11). The presumed rate of distal reoperation is 15% to 30% at ten years; however, this has probably been underestimated because most publications have not differentiated between extension of false lumen beyond the arch and extension solely in the proximal aorta (12).

Differences in the rates of late reoperation rates after total arch replacement, may also be due to the number and the dimension of the intimal tears in the descending and abdominal aorta. These are important factors that influence the fate of the distal false lumen. In fact, complete resection of all entry sites is required for thrombosis of the residual false lumen but initial surgery for AAAD fails to achieve this objective, particularly in patients with primary or secondary entry located in the descending thoracic or abdominal aorta.

Complete thrombosis of the false lumen is one of the main objectives. However, formation of a partial thrombosis in the distal aorta after surgery is not desirable because it may occlude the distal tears, impede outflow, and in the most extreme situation result in a blind sac. An increase in false lumen pressure will increase wall tension, which may elevate the risk of distal aortic aneurismal change and eventually result in rupture (13). This pathophysiologic effect has been clearly demonstrated by Tsai and colleagues for patients with type B aortic dissection. They were also able to demonstrate that partial thrombosis of the false lumen represents a predictor of poor late events (14).

Recently, similar results have been also reported after AAAD repair. Song *et al*. (13) evaluated a series of 118 patients operated on for acute aortic dissection and a total of 66 out of the 97 survived patients had sufficient imaging data to be analyzed. The incidence of residual patent false lumen was 77% (51/66): 24 (47%) had a completely patent false lumen and in the remaining twenty-seven patients (53%) a partial thrombosis was observed. Moreover, partial thrombosis occurred more frequently after ascending or hemiarch replacement than total arch replacement [55% (47/86) *vs*. 34% (11/32); P=0.0001]. The median segmental aortic growth rate for the aortic arch, proximal descending thoracic aorta and abdominal aorta was higher in the partially thrombosed group than in the completely patent or completely thrombosed group. Nine of the thirteen patients that underwent late aortic reoperation had partial thrombosis of the false lumen. The study was thus able to demonstrate that partial thrombosis of the false lumen was an independent risk factor for rapid aortic dilatation and aorta-related repeat procedures.

To reduce the risk of distal reoperation, surgeons have attempted to extend the replacement, especially when, after careful inspection, the primary entry tear is found directly on the aortic arch. Considering that the mainstay of therapy of aortic dissection is closing the entry site, this may be considered a rationale for a total arch replacement. In fact, avoiding proximal perfusion of the false lumen should, at least theoretically, reduce the pressurization and the subsequent dilatation of the false lumen over time. Evangelista was able to demonstrate in 184 patients,108 surgically treated type A and 76 medically treated type B, that in addition to Marfan syndrome and aortic diameter, large and proximal entry tears were independent risk factor for dissection related adverse event (15).

Another consideration has to be made for patients with a previous history of severe and untreated hypertension, and chronic aneurysm of the ascending aorta and aortic arch that eventually progressed to evolved to an AAAD. Often in such cases, a severe dilatation of the aortic arch can be found and has to be replaced independently from the primary entry tear location.

In the last few decades progress has been made with the introduction of the well known endovascular technique "thoracic endovascular aortic/aneurysm repair" (TEVAR), for treatment of aortic pathologies.

TEVAR is a less invasive treatment option for patients with thoracic aortic aneurysm and dissection. Moreover, growing technical experience and improving stent graft devices have resulted in better patient outcomes and expanded clinical indications. However, TEVAR bears the risk of unusual and severe complications. One of the most feared complication is retrograde ascending aortic dissection (RAAD), which has been highlighted as a potentially lethal complication, ranging from 1.3–3% (16-18). This event does not only occur during the procedure but occurs a long time after the operation (17). In those cases patients require an immediate operation and replacement of the aortic arch is mandatory.

Aortic arch replacement represents a more complex and time-consuming procedure, requiring expertise and experience. However, even if conflicting data are available in the literature (19), aortic arch replacement does not seem to be associated with higher early mortality and morbidity. Kazui, in a series of 130 patients, investigated the in-hospital mortality of three groups of patients having different extents of distal aortic replacement. The study reported an overall in-hospital mortality of 19.2% without significant difference in the three groups: 26% in the ascending aorta replacement group, 14% in the hemiarch replacement group, and 17% in the total arch replacement group (20). Similar results are also reported by other well experienced 'aortic' surgeons (21).

Even registry data demonstrated no differences in early mortality in patients who had more extensive aortic replacement (22,23). The German Registry for Acute Aortic Dissection Type A (GERAADA) (23), that represents the largest registry worldwide documenting patients undergoing surgery for AAAD, showed a lower postoperative mortality in those receiving hemiarch replacement compared with total arch replacement (18.7% *vs.* 25.7%), but the difference was not statistically significant. Similar results have been also reported by the International registry of Acute Aortic Dissection (IRAD), early mortality rate was 22.9%, 20.9%, and 23.7% for patients that underwent ascending aorta replacement, hemiarch replacement, and total arch replacement respectively (24). Unfortunately, registry papers did not give any significant follow-up information about reoperation rate related to the extension of aortic replacement.

Technique of aortic arch replacement

The classic aortic arch operation consists of the replacement of the arch with re-implantation of the supra-aortic vessels. Effective methods of cerebral, myocardial as well visceral protection are necessary to obtain acceptable results in terms of hospital mortality and morbidity. The best method to protect the brain has demonstrated to be the bilateral antegrade selective cerebral perfusion (ASCP) with moderate hypothermia according to Kazui's technique (25). In fact, very favorable outcomes are reported in literature, indicating ASCP is the best method to protect the brain, especially when time consuming and complex arch repairs are required (26).

Total arch replacement in AAAD may be an effective strategy, especially when, in complex cases, the left subclavian artery reimplantation is not feasible or in cases of excessive dilatation of the distal arch. In such cases the distal anastomosis can be performed after the left carotid artery, thus allowing the necessary landing zone for a further endovascular extension. However, the left subclavian artery must be ligated, and a carotid-subclavian bypass performed.

The ET procedure (27) can be an alternative technique for total arch replacement. This technique, in which a segment of prosthetic graft beyond the distal arch anastomosis floats freely within the descending aorta, facilitates interval repair of distal aortic aneurysms. The ET was initially studied to facilitate the second-stage operation where the descending aorta would be replaced trough left thoracotomy access, allowing an easier end-to-end anastomosis during this phase. With increasing experience with this technique, the indication has been progressively expanded from the arch and descending aorta aneurysm, to chronic type A, acute type B and finally to AAAD.

However, in case of acute dissection, the ET can present some technical difficulties due to the small dimension of the true lumen. Furthermore, if the false lumen is pressurized, the floating graft can subsequently be compressed. In this case the dissected layers should be united during the anastomosis using Teflon felt strips in order to avoid tearing of the fragile tissue. Moreover, the graft should be slightly oversized so that the ET presses against the dissected aorta.

In case of cannulation of femoral artery for cardiopulmonary bypass, it is essential to switch perfusion from retrograde (femoral artery) to antegrade, preventing ET kinking. Over the years, several graft modifications have occurred. Modern grafts with four side branches as well as sewing collars for the distal anastomosis simplified the ET implantation. These modern grafts incorporate radio-opaque markers at the distal end. These are helpful to identify the proximal lending zone in case of endovascular extension as a second stage of the procedure.

A recent modification of the ET is the 'FET' technique, initially developed by some Japanese authors (28-30). This technique mainly consists of treating complex lesions of the thoracic aorta in a single-stage procedure combining endovascular treatment with conventional surgery. The graft is composed of a proximal part consisting of vascular prosthesis and a distal part of self-expandable nitinol stent graft. During the early experience with this technique, the prostheses used were basically custom made. Afterwards the first prosthesis that was made commercially available was the E-VITA Jotec Hybrid graft (JOTEC GmbH, Hechingen, Germany) (31), and recently the Thoraflex Hybrid multi-branched graft and distal stent (Vascutek, Renfrewshire, Scotland, UK) (32).

The technique consists of the implantation of the stented distal segment of the hybrid-prosthesis into the descending aorta through the opened aortic arch, while the proximal non-stented segment is used for conventional replacement of the upstream aorta. Indications for the use of the FET are chronic aneurysm of the ascending, arch and descending aorta, chronic dissection involving all the thoracic aorta, retrograde type A aortic dissection after TEVAR procedure, rupture of the arch and also chronic aneurysms involving the distal part of the aortic arch and the upper part of the descending aorta. The FET technique facilitated single-stage arch and descending Aorta replacement in a complex lesion. Afterwards the indication has been extended to selected patients with AAAD (33).

In some patients with AAAD this technique can resolve the entire aortic pathology, especially in cases of Type I or retrograde dissection limited to the descending thoracic aorta. Moreover, another viable indication for the use of FET is in patients with visceral ischemia secondary to true lumen collapse in the thoracoabdominal aorta or for branch vessel obstruction due to an extension of the dissection in to the visceral arteries with a narrowed true lumen in the being compressed by the false lumen. In such cases the stented part of the prosthesis can easily re-expand the compressed true lumen in the descending aorta.

FET is undoubtedly a major aortic procedure and requires very accurate pre-operative planning. For this reason, assessment of the aortic anatomy is essential. Great care has to be taken when assessing the extent of the intimal flap, the relationship between the true and false lumen, the location of entry and re-entry tears and the origin of visceral vessels from the false lumen. In fact, in patients with visceral arteries arising from the false lumen that do not communicate with the true lumen due to the presence of near re-entry tears, organ malperfusion can be a lethal complication after FET (34). Moreover, oversizing of the stent graft is not indicated in patients with aortic dissection, whereas a 10-20% oversizing should be performed in patients with degenerative aneurysms. Furthermore, if the patients are not selected carefully, or the disease progresses into the downstream aorta, a second-stage procedure may be necessary even with FET.

A recent development for the treatment of AAAD is the Lupiae technique. While originally studied for the treatment of complex pathologies of thoraco-abdominal aorta, recently it has also been used for the treatment of AAAD. The prosthesis used is the Vascutek Lupiae Graft (Vascutek Terumo, Renfrewshire, Scotland, UK), designed for this procedure. The main features of this graft are the presence of a bovine trunk at the proximal end dividing into three branches for the neck vessels and a fourth branch opposite to the bovine trunk used to resume the antegrade perfusion once the distal anastomosis is completed.

The technique consists of a first surgical step, in which the ascending aorta and aortic arch are replaced while the rerouting of the supra aortic vessels on the proximal ascending aorta is performed. This creates a Dacron landing zone in Criado zone 0, which allows a TEVAR procedure as a second step to exclude any residual intimal tear. Rerouting the origin of the epiaortic vessels closer to the sinotubular junction allows the necessary distance between the bovine-like trunk and the distal anastomosis, normally positioned for the Lupiae between the origin of left common carotid artery and the left subclavian artery, never shorter than 2.5 cm.

Factors that could reduce endoleaks include the length and the position of the proximal landing zone, together with the systematic re-implantation of the left subclavian artery. Additionally, the choice to address the problem of the patent/partially thrombosed false lumen when the descending aorta is not already extremely dilated, could probably reduce complications related to endoleak (35).

It is well know that AAAD represents one of the most feared and catastrophic pathologies in cardiothoracic surgery. All recent developments in this field have stimulated the cardiothoracic surgeons to perform a more complex and time demanding procedure, replacing the aortic arch with or without two-staged approach techniques. However, in some cases the aortic arch replacement has to be considered as part of a complex operation that may also include an aortic root procedure, root replacement or valve sparing operation. This has to be taken into consideration, especially due to the myocardial ischemia and cardiopulmonary bypass time, the expertise and the experience required for the surgeon and the patient's clinical condition at admission.

The condition of the patient represents one of the most important factors in the decision making process. Sometimes, even if the anatomy of the dissection is suitable for a multi-stage or a single stage approach, total arch replacement may be not indicated, as in patients with advanced age or in extremely poor clinical condition. On the other hand young patients, those with Marfan syndrome and patients in stable condition, can benefit more from a radical treatment of the thoracic aorta even in terms of hospital mortality and above all in the long term.

Conclusions

In the last few decades different techniques for total arch replacement have been developed, allowing more complex operation with satisfactory results. Dilatation of the aortic arch as well as the presence of a tear and retrograde dissection can all be considered indications for a total arch replacement in AAAD. The ET and the Lupiae technique are viable two-stage strategies that can offer a solution for the problem of the fate of the false lumen in the descending thoracic aorta, reducing the rate of future reoperation, dilatation and rupture. Furthermore, FET is a single stage approach that can be extremely useful in cases of Type I dissection, retrograde dissection or in the case of true lumen compression with consequent malperfusion syndrome. However, a correct assessment of the anatomy of the dissection in addition to the clinical condition of the patients remain the decision points for the best arch repair strategy to use in AAAD.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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