



Total arch replacement in the treatment of acute type A aortic dissection

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Abstract: The role of total arch replacement (TAR) in patients with acute type A aortic dissection (ATAD) has been much debated. There are numerous factors that contribute to the clinical decision-making process. These include patient cohort, clinical status of the patient, aortic anatomy, dissection morphology, and expertise of the surgeon and the center. In this review, we summarize early and late outcomes of TAR in ATAD patients and discuss the specific patient populations that may benefit from an aggressive surgical approach at the time of the initial acute presentation. We discuss techniques for TAR, differences in aortic remodeling, and long-term aortic prognosis of these patients.

Keywords: Aortic dissection; surgery; aortic arch

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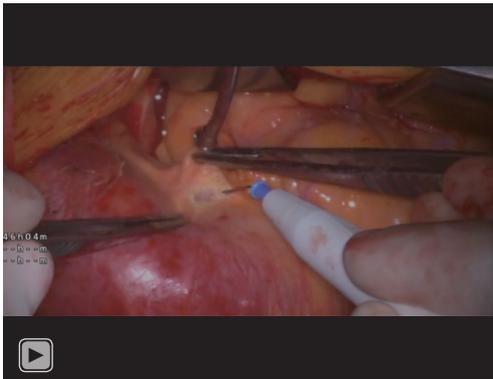
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Introduction

The operative standard of care for acute type A aortic dissection (ATAD) consists of ascending aortic and hemiarch replacement with an open distal anastomosis performed under hypothermic circulatory arrest (1). Proximally, the aortic valve may be resuspended or the aortic root replaced (valve sparing or Bentall), based on anatomy of the dissection. The goal of this approach is to prevent aortic rupture, preserve coronary flow, and treat aortic regurgitation, whilst excising the primary entry tear from the ascending aorta and re-establishing distal true lumen perfusion. The primary objective of the operation is to yield an alive patient, even when operated on by cardiac surgical teams without specialized aortic expertise. Downstream aortic complications can be managed by dedicated aortovascular teams later.

However, when the tear involves the aortic arch, or if the patient has distal malperfusion, this traditional paradigm may not suffice, and a more aggressive management of

the aortic arch may be required. Despite the evolution of surgical techniques, cerebral protection strategies and perioperative care, surgical mortality for ATAD remains high, ranging from 10–20% (2,3). Presence of malperfusion significantly worsens outcomes, resulting in mortality rates of approximately 40% in a recent IRAD report (2,4). Several authors have recommended an aggressive early approach to the aortic arch with a total arch replacement (TAR) using either a classic elephant trunk technique (ET) (5,6) or a frozen elephant trunk (FET) (7,8). A more extensive early operation is justified by some to treat distal organ malperfusion and to induce positive aortic remodeling, aiming to reduce risk of late aneurysmal degeneration of the distal aorta. Presence of an ET or FET facilitates future treatment of the remaining type B component of the aortic dissection; in particular, with endovascular techniques due to creation of a robust proximal landing zone. In this review, we discuss the factors for patient selection, imaging characteristics and the operative strategies in the management of complex aortic dissection (*Video 1*).



Video 1 Total aortic arch replacement for acute type A aortic dissection.

Anatomical and technical considerations: dissection morphology and distal malperfusion syndromes

Presence of an intimal tear in the aortic arch mandates a more extensive operation to completely excise the intimal tear and allow a secure distal anastomosis. Population studies of type A dissection show that 25–30% of patients have additional arch tears and/or proximal descending thoracic aortic re-entry sites (5). Studies have implicated anatomical variants predisposing to dissections with entry tears in the aortic arch. In patients who underwent surgery for ATAD, 14% either have a common origin of the innominate artery and the left common carotid artery or an origin of the left common carotid artery from the innominate artery. The rate of arch entries in this ‘bovine aorta’ cohort was significantly higher (59% *vs.* 13%, $P < 0.001$) (9), making it more likely that these patients will require arch replacement. Distal aortic anastomosis can be challenging in cases where the intimal tear extends distally beyond the aortic arch and cannot be completely excised. In these situations, FET can reinforce the dissected aortic wall and at the same time allow proximalization of the distal anastomosis to a more easily accessible location in the arch. TAR with FET can also be a useful approach for patients with complicated acute type B dissection where the proximity of the dissection to the supra-aortic branches precludes safe placement of a TEVAR (10).

Another subgroup of dissection patients that an extended arch operation should be considered for, are those presenting with acute end organ malperfusion (*Figure 1, Video 1*). End-organ malperfusion affects up to 30% of patients and increases mortality rates to 40–50%

(11,12). A standard hemiarch replacement will relieve distal malperfusion in approximately only 60% of the patients (13). A more aggressive operation may be warranted in these situations. Distal malperfusion is often related to large re-entry tears and true lumen collapse in the descending aorta causing impairment in abdominal visceral and renal circulations (5,14,15). In these cases, true lumen re-expansion in the descending aorta may help restore blood supply to the visceral organs. Addition of a TEVAR to hemiarch replacement has been shown to improve mortality in patients presenting with acute aortic dissection and malperfusion (16). Trivedi *et al.* demonstrated improved outcomes with aggressive aortic arch and carotid artery replacement for patients presenting with cerebral malperfusion in the setting of ATAD (15,16).

At our institution, we have adopted an approach of “verified complete reperfusion” (VCR) for all DeBakey type I dissections (10). This involves an early discussion between the cardiac and vascular surgery teams regarding the operative plan, and utilization of the hybrid operating room for all cases. After central aortic repair, distal true lumen expansion and reestablishment of visceral perfusion is confirmed using transesophageal echocardiogram (TEE), intravascular ultrasound (IVUS) and angiography. In case of ongoing compromise, additional interventions are performed immediately (generally antegrade via the ascending aortic graft) (*Figure 2, Video 1*).

Strategies to treat distal aortic malperfusion include descending thoracic aortic stenting, dissection membrane fenestration or direct target vessel intervention. Use of bare metal stents across the aortic arch to treat distal dynamic malperfusion is currently being investigated and has shown promising early results with resolution of malperfusion in 90% of patients (17). Further studies are required to validate these findings, but this technology provides another option to treat distal malperfusion in ATAD patients without arch tears.

Patient considerations—age and connective tissue disease

In addition to anatomical factors, patient age and presence of connective tissue disorder must be considered when determining the extent of aortic resection. It must be noted that no specific age cut offs have been developed to distinguish young from old when treating ATAD. IRAD reports age ≥ 70 as a significant predictor of in-hospital surgical mortality (18). Although some centres have

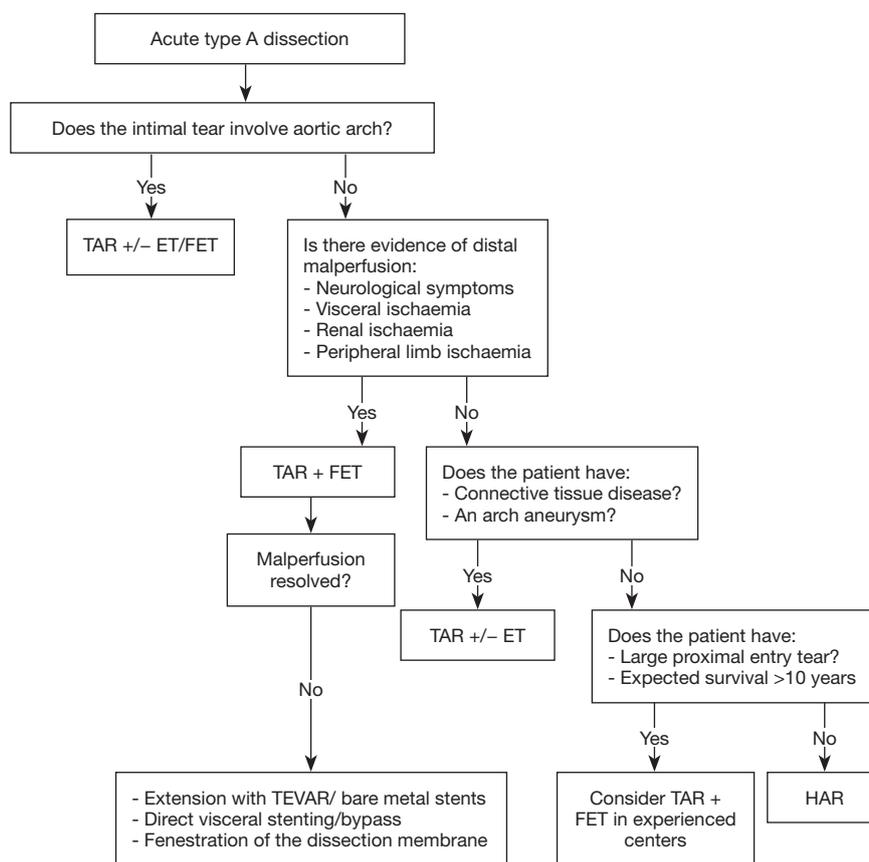


Figure 1 Outline of treatment algorithm for consideration of TAR in acute type A dissection. TAR, total arch replacement; HAR, hemi arch replacement; FET, frozen elephant trunk; TEVAR, thoracic endovascular aortic repair.

reported good short-term surgical outcomes for elderly patients with ATAD (19), exposing elderly patients to a more extensive arch operation might increase short-term risk without long-term benefit. Younger patients who are expected to live longer are at risk of further degeneration of residual dissected aorta over time and may stand to benefit more in the long-term. Data from the Yale aortic database have demonstrated average annual growth rate of 1 mm for ascending and 2.9 mm for descending aortic aneurysms (20), which may be further accelerated in the presence of aortic dissection and may result in a need for distal aortic reoperation in younger patients who are expected to survive longer (14). An individual approach that considers each patient's medical history, health condition and expected survival is warranted.

For patients with connective tissue disorders, such as Marfan and Loeys Dietz syndromes, recommendations for intervention in aneurysmal disease are clear; an earlier aggressive surgical treatment is warranted to prevent

the risk of dissection and rupture (21,22). The aorta is structurally abnormal throughout and that drives the need for multi segment surgery over time (23) (Figure 3). Marfan Syndrome (~4% of ATAD) has also been shown to be a significant risk factor for recurrent aortic dissection and distal reoperation (hazard ratio 8.6) (24). In a single large series, the rate of reintervention was approximately 50% at 10 years, regardless of the index operation at dissection (23). The reoperation rate in patients with dissected arch at the time of presentation was much higher when compared to those without arch dissection. In a recent study, Chen *et al.* reported a 78% freedom from reoperation, and 90% freedom from death at 10 years with TAR and FET for Marfan patients in whom the dissection was limited to the thoracic aorta (25). Considering the young age at presentation and an aggressive natural history of these syndromes, early comprehensive surgical treatment might be reasonable for these patients.

High throughput genome sequencing techniques have

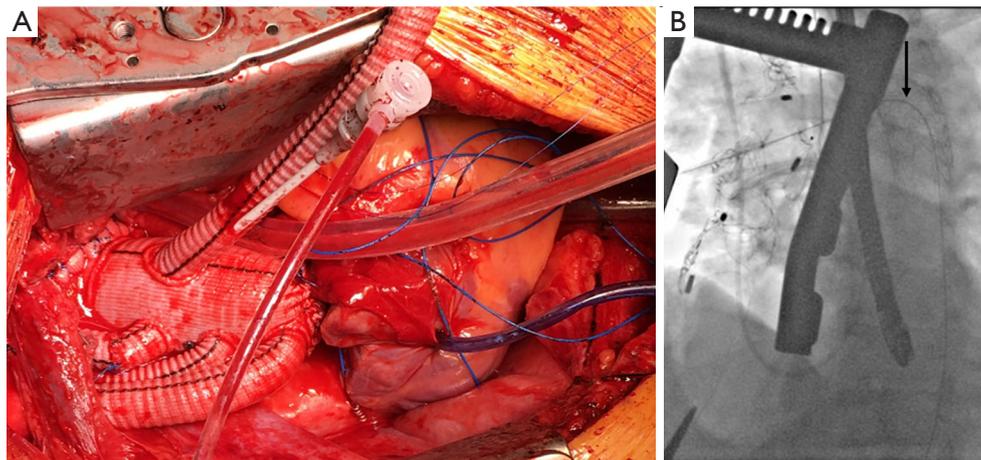


Figure 2 Confirmation of distal true lumen flow following TAR and TEVAR to proximal descending thoracic aorta. (A) Antegrade cannulation of the perfusion limb of the ascending aortic graft following a TAR for a DeBakey type I aortic dissection allows easy wire access to the true lumen of the descending thoracic aorta. (B) Fluoroscopy of the FET [the guide wire going down the proximal descending thoracic aorta (arrow)].



Figure 3 Residual aortic arch dissection with aneurysmal degeneration in a Marfan patient. The patient had a previous type A dissection repair with replacement of ascending aorta and mechanical Bentall.

identified non-syndromic forms of ATAD in 11–19% of the patients (21,26,27). These patients may have first degree relatives with sudden cardiac death. This additional cohort

of patients, when identified, would be potential candidates for early aggressive management of ATAD.

Operative considerations

Several cannulation and perfusion strategies have been described for repair of type A dissection. Operative outcomes utilizing right axillary artery, femoral artery or the ascending aorta for cannulation have been reported, with certain advantages and disadvantages described for each (21,22,28,29). Femoral vessels can be rapidly cannulated, especially in emergency situations using a percutaneous approach, allowing CPB to be established prior to sternotomy. The main disadvantage is retrograde flow through dissected aorta, which can alter flow dynamics and worsen organ perfusion in some cases. Central aortic cannulation allows rapid institution of bypass and provides systemic perfusion in an antegrade fashion. However, this technique requires familiarity, and positioning of the cannula within the true lumen must be confirmed by TEE. True lumen cannulation may be challenging if the intimal tear involves the aortic arch. Right axillary artery cannulation requires extra time and an additional incision to expose the artery. The right axillary artery can either be cannulated directly (*Figure 4, Video 1*) or via a side-graft. The main advantage of using the axillary artery is that it facilitates institution of antegrade cerebral perfusion during circulatory arrest. Alternative cannulation sites like the proximal innominate or right subclavian artery have also

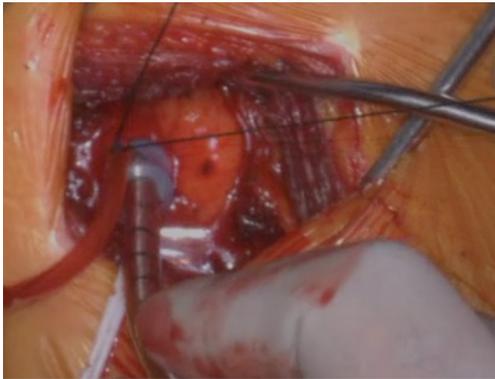


Figure 4 Direct cannulation of the axillary artery using an EOPA[®] cannula for instituting cardiopulmonary bypass and antegrade cerebral perfusion.

been described. In extreme situations, LV apex cannulation or cannulating the ascending aorta under direct vision (“samurai technique”) can be used (30). Several studies have compared the impact of cannulation site on outcomes after surgery for type A dissection repair. Kreibich *et al.* reported similar mortality (aortic: 10% *vs.* axillary: 11% *vs.* femoral: 13%; $P=0.680$) and stroke rates (aortic: 13% *vs.* axillary: 10% *vs.* femoral: 12%; $P=0.701$) with central aortic, axillary or femoral cannulation (31). However, majority of the patients in this series underwent hemiarch replacement with relatively short circulatory arrest times. Interestingly, axillary artery cannulation was the predominant cannulation strategy for patients undergoing TAR. A recent large study from the STS database reported lower risk of postoperative stroke when axillary artery was used for cannulation when compared to femoral artery cannulation (OR 0.6, $P<0.001$); innominate cannulation was not different from axillary cannulation (OR 0.88; 95% CI: 0.57–1.35; $P=0.5$) (32).

Debate also continues regarding the optimal cerebral protection strategy during circulatory arrest. While safety of both RCP and ACP has been demonstrated for short duration of circulatory arrest (<30–40 min), most surgeons favor antegrade cerebral perfusion for longer durations of circulatory arrest, as may be required for TAR (33). Selective myocardial perfusion during arch repair—the “beating heart” concept) has also been described to reduce cardioplegic arrest time (34).

Studies have compared the ‘island’ technique (where the cephalad portion of the aortic arch that includes the arch vessels is re-implanted as a patch on the aortic graft) versus individual branch reimplantation; most have reported

similar results (35). There is some concern that the island patch may degenerate over time and lead to aneurysm. The island technique may not be technically feasible if the intimal tear extends to the greater curvature of the aortic arch. Individual branch reimplantation is generally preferred in the setting of aortic dissection, especially in patients with connective tissue disease. Individual reimplantation of the supra aortic vessels has the advantage of removing the dissected tissue in the aortic arch. Additionally, individual branch reimplantation allows early distal reperfusion after the distal anastomosis is performed as opposed to the island technique where both the distal anastomosis and the island reimplantation must be completed before visceral perfusion can be resumed. Several “off the shelf” branched grafts are available and can be used according to surgeon preference. Proximalization of the distal anastomosis to zone II rather than zone III can simplify the distal aortic anastomosis and reduce visceral ischemia time and risk of recurrent laryngeal nerve injury (35,36). The base of the left subclavian artery is ligated, and the distal end of the subclavian artery is anastomosed to a branch of the aortic graft. Alternatively, an extra-anatomic bypass can be performed from the aortic graft to the axillary artery.

TAR can be combined with antegrade delivery of a stent graft into the descending aorta—the “frozen elephant trunk” technique as originally described by Borst in 1983 (36–38). Since then there have been several new FET devices with various prefabricated grafts, such as the E-vita[™] (39), Thoraflex[™] (40), Cronus (41) and Frozenix-J graft (42). These hybrid devices consist of a conventional surgical graft that is mated to a stented endovascular graft, thus eliminating the possibility of a type I endoleak. Presence of a sewing cuff facilitates the distal anastomosis. The endograft helps seal the surgical suture line and reduces the risk of bleeding from fragile aortic tissues. If a distal aortic intervention is required later, shifting the treatment level to the mid thoracic aorta with the use of either a classic or FET facilitates a technically easier re-operation that avoids hypothermic circulatory arrest and reduces risk of recurrent laryngeal nerve injury. If no pre-mated hybrid FET devices are available, the surgeons can use a commercially available TEVAR graft that is deployed into the descending aorta during circulatory arrest and can be then incorporated into the distal aortic anastomosis (43–45).

When deploying TEVAR antegrade during ATAD, care must be taken to ensure that stent graft is positioned in the true lumen distally. As direct visualization is not always possible, this can be accomplished by passing a guidewire

into the descending aorta under IVUS or TEE guidance prior to initiating circulatory arrest. Alternatively, a sterile bronchoscope can be inserted into the distal aorta during circulatory arrest to confirm true lumen deployment of the stent graft. Oversizing the stent graft is not necessary; the FET/TEVAR component is true sized to the aortic lumen to prevent aortic rupture. Spinal cord ischemia remains a concern with use of FET. Spinal drains are usually not advisable due to the emergency nature of the operation. Risk of spinal cord ischemia can be reduced by using a short segment (usually 10 cm) stent graft (46).

FET is a useful technique when the intimal tear or rupture extends to the distal arch, and the aortic tissue is fragile and dissected. A stented graft can reinforce the aortic wall and provide a robust zone for anastomosis. An alternative but more invasive technique to address an intimal tear that extends beyond the aortic arch is to perform the anastomosis in the descending aorta. This can be accomplished by extending the sternotomy transversely using a left thoracotomy, usually in the fourth intercostal space (47). The right pleura is opened to allow retraction of the heart to the right side. This provides excellent exposure of the descending aorta down to the level of the inferior pulmonary veins.

In the absence of an aortic arch tear, it is reasonable to consider replacing an aneurysmal aortic arch that would otherwise meet guideline criteria for replacement (21,28).

Early outcomes

Several authors have reported good operative results with TAR in the setting of ATAD, leading some to recommend TAR for all patients with ATAD (7,48). This recommendation is based on early results and favorable long-term remodeling after TAR compared to hemiarch only. If a distal re-operation is required, presence of an elephant trunk facilitates open and endovascular treatment for ATAD patients. When considering hemiarch versus TAR for ATAD, the short-term risk of complications of TAR must be considered. There is no debate that TAR is a more technically complex operation compared to hemiarch replacement. Surgeon expertise must be considered in this decision-making. Although some studies have reported higher mortality with TAR than with hemiarch replacement, the IRAD and GERAADA registries showed no significant difference in mortality between the two approaches (2,49-52). However, risk of neurologic, renal and respiratory complications may be higher with TAR (32,52). It must also

be noted that distal aortic reintervention is required in only 10–30% of patients after hemiarch repair for ATAD (53). Thus, a policy of “total arch for all” exposes a majority of patients to additional risks with potentially limited and possibly no benefit. Several studies have compared outcomes of hemiarch to TAR for ATAD. Omura *et al.* reported similar in-hospital mortality rates for total arch (10.2%) and partial arch replacement (14.7%, $P=0.47$). In multivariate analysis, TAR was not a significant risk factor for in-hospital mortality (54). Sun *et al.* have reported operative mortality around 8% with a 2% stroke and a 3% paraplegia rate for TAR in ATAD (48). A meta-analysis of several single center studies reporting outcomes in TAR for ATAD show a pooled hospital mortality rate of 8.6% (95% CI: 7.2–10) (55) (Table 1). Rates of stroke and spinal cord ischemia were 5.7% (95% CI: 3.6–8.2) and 2% (95% CI: 1.2–3) (54,55). Other meta-analysis data suggest no significant differences in-hospital mortality between hemiarch and TAR (52,56). While individual center studies report excellent short-term outcomes, these results are to be interpreted with caution as they may suffer from a publication bias as most reports come from centers with specialized expertise in aortic surgery. It should be kept in mind that analyses from contemporary large registries continue to show in-hospital mortality rates of 18–20% for all-comers with ATAD (14,49).

Medium- and long-term outcomes—survival, aortic remodeling and reoperation

Late survival after ATAD repair is reduced as compared to the general population with estimated 5, 10 and 15 year survival rates of 82%, 64%, and 48% respectively (57). Aortic events in the descending thoracic aorta account for majority of the late deaths with up to 12–24% of patients die from late distal aortic rupture (58,59). This includes aneurysm rupture or complications related to aneurysm repair during re-operation. In a large series of 728 patients, late survival and freedom from reintervention were 89% and 85% respectively at 8 years. Other series with over 2 decades of follow-up demonstrate freedom for reoperation at 10 years at 74% (60). Twenty percent of ATAD patients remain at risk for secondary intervention, based on negative remodeling in subsequent surveillance scans (61-63). A non-resected primary entry tear and Marfan syndrome are known independent predictors of late reoperation (60). The onset of enlargement is unpredictable but risk factors include initial aortic diameter at presentation, elevated

Table 1 Summary of the meta-analyses comparing ascending aorta, hemiarach and TARs in acute type A aortic dissection

Author, year, journal	No. of studies, no. patients, level of evidence	In-hospital mortality	Mid-late mortality	Stroke	Aortic reoperation
Hsieh <i>et al.</i> , 2019, Eur Rev Med Pharm Sci	15 cohort studies; N=2,822 (HA 1911 vs. TAR 911); level of evidence: IIa	RR 0.77, 95% CI: 0.61–0.96, P=0.02; HA 20.3–46.9%; TAR 2.7–27.2%; TAR with elephant trunk 31.7–68.3%	No significant difference in 5-year survival between HA and TAR	Overall: RR 0.79, 95% CI: 0.48–1.28, P=0.34; Permanent: RR 1.15, 95% CI: 0.78–1.69, P=0.50, I ² =0%; Temporary: RR 0.89, 95% CI: 0.53–1.48, P=0.65, I ² =0%	5.3% in TAR group vs. 7.6% in Ascending group: RR 1.39, 95% CI: 0.94–2.07, P=0.109, I ² =0%; HA group with similar risk of aortic re-operation as compared to the TAR: RR 2.20, 95% CI: 0.40–12.05, I ² =12%, P=0.36; HA combined with AS and partial arch surgical procedure insignificantly high risk of aortic re-operation as compared to the TAR: RR 1.23, 95% CI: 0.61–2.48, I ² =50%, P=0.57
Smith <i>et al.</i> , 2017, Inter Cardiovasc Throac Surg	38 retrospective studies; N=2,140; HA + FET =582; TAR =322; TAR + FET =1,079; TAR + TEVAR (staged) =157	HA + FET 6.3%, 95% CI: 4.5–8.3; TAR 11.9%, 95% CI: 7.0–17.8; TAR + FET 8.6%, 95% CI: 7.0–10.2; TAR + TEVAR 5.5%, 95% CI: 3.3–8.3	HA + FET 2.4% per patient year, 95% CI: 1.5–3.6; TAR 2.1% mortality per patient year, 95% CI: 1.3–3; TAR + FET 1.7% per patient year, 95% CI: 1.2–2.2; TAR + TEVAR 0.5% per patient-year, 95% CI: 0.0–1.9	HA + FET 3.0% (95% CI: 1.5–5.0), SCI 2.9% (95% CI: 0.8–6.4); TAR CVA 7.7% (95% CI: 4.9–10.8), SCI 1.6% (95% CI: 0.1–4.3); TAR + FET CVA 3.7% (95% CI: 2.1–5.7), SCI 1.9% (95% CI: 1.0–3.1); TAR + TEVAR no CVA or SCI	HA + FET 4.4% per patient-year, 95% CI: 2.4–7.0; TAR 2.2% per patient year, 95% CI: 1.3–3; TAR + FET 1.4% per patient year, 95% CI: 1.09–2.0; TAR + TEVAR 0.9% per patient-year, 95% CI: 0.0–2.3%
Poon <i>et al.</i> , 2016, Ann Cardiothorac Surg	15 retrospective studies; N=2,221 (HA 1,435 vs. TAR 786); level of evidence: IIa	RR 0.84, 95% CI: 0.65–1.09, P=0.20, I ² =0%; HA 3.6–24.1%; TAR 3.85–28.57%	Not reported	Overall: RR 0.88, 95% CI: 0.48–1.62, P=0.68, I ² =0; Permanent: RR 0.82, 95% CI: 0.52–1.31, P=0.42, I ² =15%; Temporary: RR 0.77, 95% CI: 0.56–1.07, P=0.13, I ² =0%	Overall the rate of aortic reoperation for proximal and; distal aorta was 5.6%, 12 studies, N=1,651; HA 7.3%, TAR 3.3%; RR 1.45, 95% CI: 0.93–2.28, P=0.10, I ² =23%

HA, hemiarach; TAR, total arch replacement; FET, frozen elephant trunk; TEVAR, thoracic endovascular graft; CVA, cerebrovascular accident; SCI, spinal cord ischaemia; RR, relative risk; CI, confidence interval; I², measure of heterogeneity.

blood pressure and patent false lumen post-repair (57,58). The main risk factor for reintervention on the arch or descending thoracic aorta after proximal aortic repair is the persistent flow in the false lumen, which is associated with aneurysmal degeneration of the dissected aorta (52,55,56). Presence of a tear in the descending aorta on post-operative scans predicts failure of the aorta to remodel (64,65) as these communications between lumina infer pressurization of the false lumen and unlikely false lumen thrombosis (66). Analysis of pre-discharge CT scans after ATAD repair demonstrate additional entry tears in the proximal descending thoracic aorta in 38% of cases, distal descending thoracic aorta in 25% and abdominal aorta in 41% of patients (67). Freedom from reintervention is significantly lower patients with an intimal tear in the proximal descending aorta. These aortas are likely to expand at a much faster rate of up to 7.6 mm/year proximally and 6.8 mm/year distally. Multivariate analysis showed that proximal re-entry tears are an independent variable for risk of aortic reintervention (HR 4.99, $P=0.004$) and significant aortic expansion (HR 4.21, $P=0.002$) (67).

In cases where the primary entry tears are located in the aortic arch and/or proximal descending thoracic aorta, arch replacement with FET allows false lumen exclusion leading to false lumen thrombosis and its obliteration (61,65,68). Available long-term data suggest that aortic remodeling with partial or complete thrombosis of the persistent false lumen can be expected in approximately 90% of cases along the length of the stent graft (69-71). Having an ET or FET facilitates tackling the remaining dilated and dissected aorta, either using endovascular or open approach.

Omura *et al.* reported late outcomes for patients undergoing partial arch *vs.* TAR for ATAD (54). During a mean follow-up period of 60 ± 48 months, 5-year survivals in the TAR and hemiarch/partial arch replacement groups were $88.6\pm 4.2\%$ and $83.8\pm 4.4\%$, respectively ($P=0.54$). Rates of distal aortic events (defined as freedom from surgery for distal aorta dilation or distal arch diameter expanding to 50 mm) at 5 years were significantly better in the TAR group than in the non-TAR group ($94.9\pm 3.5\%$ *vs.* $83.6\pm 4.9\%$, $P=0.01$). However, freedom from surgery at 5 and 10 years was $94.9\pm 3.5\%$ and $91.7\pm 4.6\%$ in the TAR group, respectively, and $90.9\pm 3.6\%$ and $83.3\pm 5.3\%$ in the hemiarch/partial arch group, with no significant difference between the groups ($P=0.20$) (54).

There have been three systematic reviews and meta-analyses published on extended repair of type A aortic dissections (Table 1) (52,55,56). These report outcomes in

about 2,000 patients from 38 studies. Patients underwent either TAR, TAR with FET, hemi-arch and FET or TAR with creation of a landing zone for antegrade or retrograde TEVAR. The results were compared to patients who had clamped ascending aorta replacement or open distal hemi arch replacement. The reports include a heterogeneous patient population within the cohort of ATAD. There were multitude of cannulation, cardiopulmonary bypass, myocardial and cerebral protection strategies deployed. The results were further confounded by inclusion of patients from the Far East, Europe, and North America, where patients may present at various stages of the evolution of ATAD. It is especially problematic to tease out patients who presented early or late or where there was a delay in diagnosis and end-organ malperfusion or shock. For geographical reasons certain centers, tend to receive patients which are “self-selected” as survivors by presenting 24–48 hours after the index event. A meta-analysis of 2,822 patients by Hsieh *et al.* showed that ascending aortic replacement had a significantly lower risk of in-hospital mortality, shorter cardiopulmonary bypass time, circulatory arrest time and antegrade cerebral perfusion time (56). Incidence of neurological dysfunction and renal dialysis were not significantly different between the groups. The pooled rate of aortic re-operation was lower in total arch group (5.3% *vs.* 7.6%), albeit not significantly (RR 1.39; 95% CI: 0.94–2.07; $P=0.10$). Meta-analysis by Poon *et al.* comparing hemiarch *vs.* TAR for ATAD (2,221 patients from 14 retrospective studies) showed no significant difference in in-hospital mortality between the two groups, however, TAR was associated with a higher risk of post-operative renal dialysis (52). The rate of re-operation for proximal and distal aorta was 7.3% in hemiarch and 3.3% in extensive TAR, although there was no statistical significance detected between groups (RR 1.45; 95% CI: 0.93–2.28; $P=0.10$, $I^2=23\%$). A pooled linearized rate of late mortality of 0.5% per patient-year (95% CI: 0.0–1.9) and late reoperation of as 0.9% per patient-year (95% CI: 0.0–2.3) have been reported for TAR with staged TEVAR. (55). This is compared to hemiarch repair with FET having late mortality of 2.4% per patient-year (95% CI: 1.5–3.6) and late reoperation rate of 4.4% per patient-year (95% CI: 2.4–7.0) (Table 1).

These data show that TAR with FET positively impacts distal aortic remodelling and suggest that it may potentially reduce distal reoperation rates. More studies that show a clear reduction in reoperation rate and improved survival are needed before considering TAR with FET can be

recommended for all patients with ATAD.

Conclusions

The optimal strategy for management of the aortic arch in aortic dissection remains controversial. High volume aortic centres with non-randomised data sets demonstrate equivalent early mortality between hemi arch and TAR patients and no significant increase in stroke or paraplegia rates. They also demonstrate superior late outcomes in the total arch patients with positive aortic remodelling. Some studies suggest high early mortality with TAR, while other studies have demonstrated excellent operative outcomes (53,72). There may be an inherent publication bias, with only high-volume centers with experience in TAR publishing their results, making it difficult to generalize those results to the entire cardiac surgical community. Even if these results are achieved in most centres; we must still focus on identifying those patients most likely to benefit from such an aggressive approach. This may include patients with dissection involving the arch, entry tears in the arch and/or proximal descending aorta, patients with connective tissue disease, younger patients and those with end-organ malperfusion that would not be corrected unless flow to the true lumen is restored (73). Some patients with large proximal descending thoracic aortic intimal tears or severe true lumen collapse may benefit from TAR and FET for long term aortic remodeling, but only when performed by experienced teams. Ongoing surveillance is mandatory for all patients after repair for ATAD. Risk stratification could allow a bespoke approach to aortic dissection surgery.

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