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Přehledový článek | Review article

A pragmatic approach in aiming to do the right things in patients with thoracic aortic pathology involving the aortic arch

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SOUHRN

V posledním desetiletí byla chirurgická komunita zaplavena celou řadou možností léčby pacientů s onemocněním hrudní aorty postihujícím aortální oblouk do té míry, že nabídka převyšuje „poptávku". Před chirurgy tak vyvstala nutnost volby mezi klasickými výkony a několika dalšími možnostmi, z nichž některé jsou vhodné, některé nevhodné a některé vysloveně špatné. Tento článek má posloužit jako praktická příručka pro lékaře zajímající se o toto téma a léčící pacienty s onemocněním hrudní aorty, která lékaře seznámí s vývojem a průběhem tohoto onemocnění, poučí ho o správném načasování léčby s odpovídající stratifikací rizika, představí mu různé možnosti a upozorní ho na nutné kroky před zahájením samotné léčby.

Keywords:
Aortic arch
Combined approaches
Endovascular repair
Surgery

ABSTRACT

The last decade has overwhelmed the surgical community with options regarding the treatment of patients with thoracic aortic pathology involving the aortic arch as to a point where supply exceeds demand. Consequently, surgeons are confronted with a new challenge being weighing conventional surgery to several other options where some are good, some are bad and some are ugly. This manuscript is meant to serve as a pragmatic companion for the interested physician in accompanying patients with thoracic aortic disease through the natural history of the disease, to indicate the right time for treatment with adequate risk stratification, to balance options and to do the right things when advancing to treatment.

Background

The last decade has overwhelmed the surgical community with options regarding the treatment of patients with thoracic aortic pathology involving the aortic arch as to a point where supply exceeds demand. Consequently, surgeons are confronted with a new challenge being weighing conventional surgery to several other options where some are good, some are bad and some are ugly. This manuscript is meant to serve as a pragmatic companion for the interested physician in accompanying patients with thoracic aortic disease through the natural history of the disease, to indicate the right time for treatment with adequate risk stratification, to balance options and to do the right things when advancing to treatment.

Natural history

Interestingly, the scientific basis for our decision makings when indicating the time point for intervention is mainly

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based on historical morphological studies as we continue to rely on maximum diameters and few advances have been made beyond conventional size criteria [1]. Anyhow we know that aneurysms will rupture sooner or later, dissections will occur with a dismal natural course without treatment and the natural history of penetrating atherosclerotic ulcers is an aggressive one without a clear correlation to diameter. Several approaches to add functional information are under way but functional imaging has not yet been fully entering the clinical arena so that maximum diameter remains our most robust surrogate of risk and thereby indication for treatment with a general consent of indicating treatment between 5 and 6 cm according to segment, accompanying valve disease, family history, additional risk factors or connective tissue component [2].

Timing/risk stratification

"Intervention is indicated when the probability of experiencing an aortic-related event is higher than the remaining risk of treatment." As easy as this sentence is written, as complex the decision making process may be. Finally, there is no risk stratification score in predicting the risk of treatment as there is in adult cardiac surgery [3]. So other approximations have to be chosen.

A fundamental difference between proximal thoracic aortic aneurysms, dissections type A/B as well as intramural hematoma (IMH) on the one hand and penetrating atherosclerotic ulcers (PAU) on the other hand is the fact that the latter ones have an obliterative basis where the first group is on the basis of dilatative arteriopathy [4,5].

This is important as patients with proximal thoracic aortic aneurysms, dissections type A/B as well as IMH will almost never be affected by obliterative components or in other words coronary artery disease (CAD) as these two are nearly mutually exclusive whereas patients with PAU will very often have severe CAD as they do have peripheral arterial occlusive disease which often challenges delivery of stent-grafts through the iliac axis.

Furthermore, cuspidity of the aortic valve is an issue as patients with bicuspid aortic valve disease are less likely to have CAD as this also seems a kind of protecting issue [6]. After all these considerations are vital as the let us call it "obliterative load" in patients with PAU is high as is the risk of collateral injury by stroke and myocardial infarction (MI) whereas the obliterative load in patients with proximal thoracic aortic aneuryms, dissections type A/B as well as IMH is very low and collateral injury with regard to stroke and MI is very low.

Finally, and this is interesting, ventricular function in the vast majority in patients with thoracic aortic disease is regular which should be seen as a prerequisite for successful treatment as – this is a lesson of the personal experience of the author – patients with thoracic aortic disease and severely reduced ventricular function are at risk to die with thoracic aortic disease but not to die from thoracic aortic disease.

Summarizing, successful treatment of extensive thoracic aortic pathology will be achieved when disease of the aorta is the only limiting problem of the presenting individual, any other limiting disease burden will put success into perspective.

Balancing options and doing the right things

The most misused sentence by non-aortic surgeons is "Conventional aortic arch surgery is still associated with significant morbidity and mortality." There is overwhelming evidence that thoracic aortic surgery involving the aortic arch is a safe and highly efficient procedure with low perioperative morbidity and mortality in the elective setting as well as in emergencies – predominantly acute type A aortic dissection – as long as they are uncomplicated meaning without irreversible organ malperfusion, cerebral or visceral [7–9]. Without doubt, we aim at reducing neurological injury – predominantly cerebral – to a minimum but there is work to do. Modified perfusion protocols, the routine implementation of selective antegrade cerebral perfusion and the move to warmer hypothermic circulatory arrest temperature have substantially aided in optimizing outcome [10].

Nevertheless, there are options available and some of them are important adjuncts to the armamentarium of the aortic surgeon in the decision algorithm. When discussing treatment of aortic arch pathologies we have to be very clear upon the underlying pathology as well as the segmental affection. *Proximal thoracic aortic pathology* originating from secondary heart fields, from the aortic root or from the ascending aorta up to the aortic arch and beyond are a very clear domain of conventional aortic surgery [10–12].

Here a relatively new approach has gained increasing acceptance being the so-called "frozen elephant trunk technique". The principle is the combination of a distal stent-graft with a continuing transition to a conventional Dacron prosthesis for treating patients with Megaaortas thereby reducing a potentially two-step approach to a one-step operation or to treat type A/type B acute aortic dissections with malperfusion and an entry tear at a level where conventional surgical repair is ineffective or finally patients where distal thoracic or thoracoabdominal aortic repair is needed, this approach is a valuable alternative to conventional surgery. The European Association of Cardio-Thoracic Surgery recently published a position paper on the recommendations for use of the method [13]. Fig. 1 depicts a completion CT scan after FET implantation.

Isolated aortic arch pathology is rare and may be approached by open surgical approach, a combined vascular and endovascular approach or by total endovascular aortic arch repair according to the individual situation [14–16]. We will go into detail later in this chapter.

The vast majority of patients suitable for combined vascular and endovascular approaches are the ones with *multisegmental thoracic aortic pathology* originating at the level of the aortic arch. The aim of transposition always is to create a sufficient landing zone length for safe deployment of the stent-graft. General consent through all scientific societies recommends at least 2 cm of proximal (or distal) landing zone for a durable result [17]. However, evidence increases that 2 cm might not be sufficient to guarantee a stable long-term result, in other

Fig. 1 – Postoperative CT scan after FET implantation.

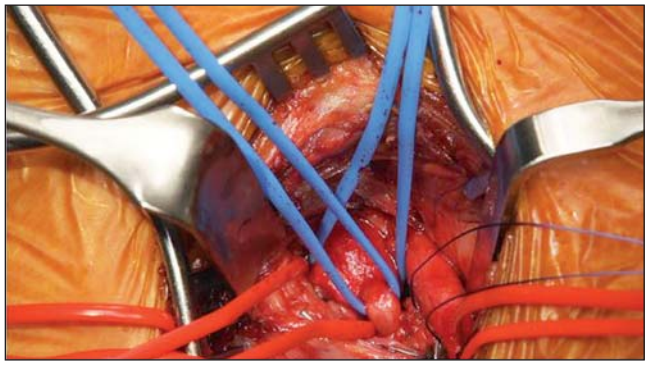

Fig. 2 – Intraoperative situs during subclavian-to-carotid artery transposition.
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words, the longer the landing-zone, the more durable the result. Finally, other aspects as respecting geometry and angulations are important details distinguishing success from failure [18].

Regarding transposition, in-general three options are available being subclavian-to-carotid transposition, double transposition or total arch rerouting, we will shortly go through all three methods.

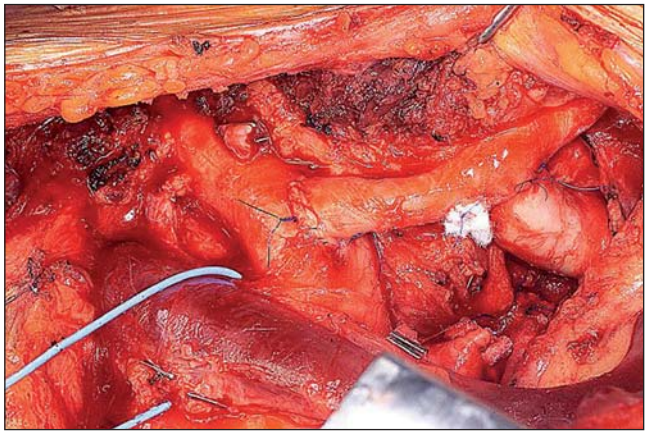

Fig. 3 – Intraoperative situs during double transposition.
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Subclavian-to-carotid transposition. This operation has gained recurring interest as it has been primarily developed for occlusive disease where intervention is the primary strategy. Our preferred approach is the medial one where surgical access is gained between the insertions of the sternocleidomastoid muscle. This approach minimises need for dissection, reduces collateral nerve injury and simplifies exposure. If needed, an alloplastic graft may be used but autologous transposition is feasible in the majority of cases. Results are very good [15,19]. Fig. 2 shows the intraoperative situs during subclavian-to-carotid artery transposition using the medial approach – surgical exposure between the two insertions of the sternocleidomastoid muscle.

Double transposition. This approach extends the concept of subclavian-to-carotid transposition to the level of the brachiocephalic trunk. Surgical access is gained via an upper median hemi-sternotomy, the left common carotid artery is transsected at its origin and inserted into the brachiocephalic trunk in an end-to-side fashion. Afterwards an intrathoracic subclavian-to-carotid transposition is performed. Results are very good [15]. Fig. 3 shows the intraoperative situs during double transposition.

Total arch rerouting. This operation extends transposition to the level of the ascending aorta by using either a reversed bifurcated graft or a tube graft with side-branches. We have stopped this approach due to the high incidence of retrograde type A aortic dissection. There are several reasons for observing retrograde type A aortic dissection with the probably most important ones being the underlying pathology of an acute type B aortic syndrome as well as an ectatic ascending aorta where – due to the lessons learned – prophylactic ascending aortic replacement in diameters above 37 mm is recommended [15,20,21]. Fig. 4 shows the intraoperative situs during total arch rerouting.

Total endovascular approaches. Recently, trade-offs have entered the clinical arena using so-called chimney/periscopes and snorkels for preserving side-branch perfusion in the aortic arch as well as in the thoracoabdominal aorta. These strategies are not substantiated by scientific

evidence and potentially dangerous as the method relies on counteracting radial forces of the main graft and the supplying side-branch graft with the potential of material fatigue of one or the other [22]. Furthermore, type I endoleakage is very high and has to be regarded as a treatment failure despite attempts to downgrade the importance of type I endoleaks.

Branched prostheses for the aortic arch. This approach is here to stay, does already and will continue to complete the armamentarium of the aortic surgeon in treating thoracic aortic pathology involving the aortic arch. Recent literature confirms safety and reproducibility of this approach [16]. The concept basically is a modular prosthesis with a cabrio portion for the arch vessels with inner branches where the extensions to exclude the pathology from bloodstream are inserted via a cutdown at the level of both common carotid arteries. As these devices have two branches, revascularization of the left subclavian artery has to be done in advance when needed [23]. Fig. 5 shows a completion CT scan after total endovascular arch repair using a branched prosthesis.

After having gone through all available options and after having gained an overview, we would aim at suggesting an algorithm how to balance available options and aiming to do the right things.

Conventional proximal thoracic aortic surgery remains the proven best option when aortic pathology is the limiting disease. It remains to the discretion of the individually treating physician which surgical technique is chosen, branched grafts, island reimplantation, in case of anticipated secondary distal extension either conventional elephant trunk technique or the frozen elephant trunk technique. Regarding concomitant treatment of the aortic root, we follow a liberal approach in root replacement in patients where the Sinus of Valsalva has a diameter above 4 cm, in particluar in bicuspid aortic valve disease but the intraoperative clinical hinge point is the wall quality of the non-coronary sinus as this is in the author's experience the weakest segment. Trade-offs during primary surgery have also been identified as the main reason for the need of aortic root redo surgery [24].

Recent literature confirms a trend in Europe towards warmer circulatory arrest temperatures and an increased application of selective antegrade cerebral perfusion [2,10]. The author's strategy is to aim for a core temperature between 26 °C and 30 °C dependent onto the expected hypothermic circulatory arrest time with bilateral antegrade cerebral perfusion not exceeding a flow of 6 ml/kg bodyweight in order to avoid pontential hyperperfusion. In any case, perfusion is adjusted to bilateral near infrared spectroscopy (NIRS) measurements.

In case of aneurysmal dilation after previous repair, the decision making process has two components – clinical condition including concomitant cardiovascular disease as well as the underlying aortic pathology. Unless we will have a risk score aiding in predicting, experience and personal opinion will lead the direction and it is difficult to provide an algorithm. Finally, clinical assessment will set the path. Regarding the underlying disease it is of fundamental difference if there is classical aneurysmal disease or post-dissection aneurysmal disease as the latter one needs thorough assessment as to the efficacy of any endovascular approach due to the fact that there is usually no distal landing zone and exclusion of the false lumen may be challenging but forms the basis of long-term success. Regarding the application of rerouting procedures, we always aim at creating a landing-zone of at least 2–3 cm, the longer the better as there is multiple evidence that the length of the landing zone is an independent predictor of success or failure [15,17,18]. Dependent onto the needed length subclavian-to-carotid transposition or double transposition is applied. Total arch rerouting is not routinely used as to the unpredictable issue of retrograde type A aortic dissection and in case of an ascending aorta of more than 37 mm, prophylactic ascending aortic replacement is pursued [20,21].

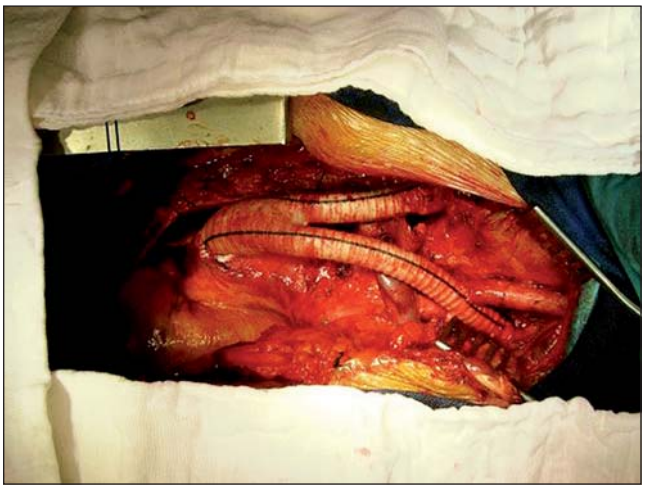

Fig. 4 – Intraoperative situs during total arch rerouting.
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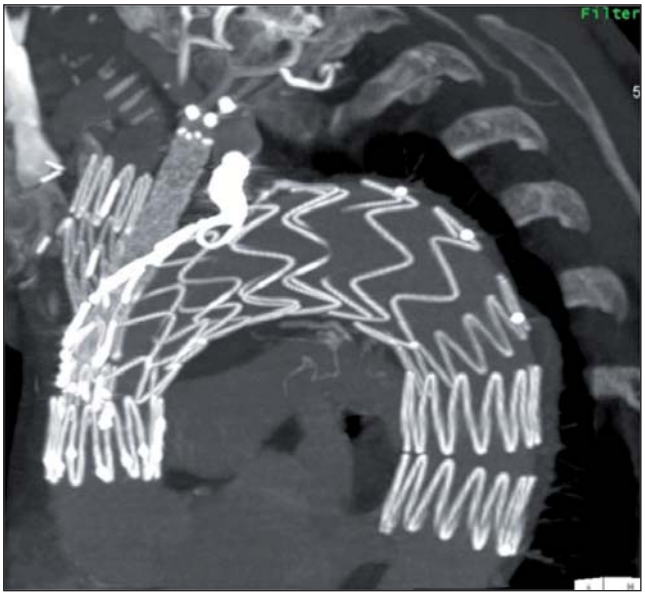

Fig. 5 – Completion CT scan after total endovascular arch repair using a branched prosthesis. Courtesy of Dr. Timothy Resch, University Hospital Malmö, Sweden.

In case of extensive thoracic aneurysmal disease with the potential need for distal extension the author uses the frozen elephant trunk techniques also in cases where a conventional secondary surgical procedure is planned as the FET technique provides ideal stability and an anastomosis between the stent-graft and a conventional Dacron prosthesis is feasible [25].

In case of post-dissection aneurysmal disease several aspects have to be considered in particular number and size of the communications between the lumina as the more in number and the larger in diameter, the less likely remodelling becomes [26]. Ideally, there is no communication between the lumina at the thoracic level as this increases the probability of complete exclusion of the false lumen from the circulation. Recently, several additional approaches to enhance exclusion of the false lumen from the circulation have been described and should be considered if needed [27,28].

In patients with PAU, the author recommends a thorough cardiovascular workup as the atherosclerotic load of these patients is very high and might be more limiting that the aortic component. Usually, after work-up it becomes evident that other interventions are warranted such as percutaneous coronary interventions or carotid artery surgery, up to 21% in the author's experience [5].

Need for centralization of aortic pathology. Aortic centers. The logical consequence of the evolution of aortic surgery and to reconcile heterogeneity of treatment modalities is the creation of aortic centers capable of treating the entire organ with all diagnostic and therapeutic options. The leaders of such centers are likely to be cardio-vascular surgeons with experience in both cardiac and vascular surgical disciplines including endovascular skills. All treatment options should be available for the individual patient with consensus of treatment choice being decided at multidisciplinary team meetings (MDT). These MDT meetings are expected to be populated by open and endovascular surgeons, cardiologists, cardiovascular physicians, interventional, diagnostic radiologists and neurophysiologists. Additional expertise including anesthesiology, rheumatology and microbiology will be essential when evaluating treatment options. The referral pattern of an aortic center must be similar to the referral pattern for percutaneous cardiological interventions with a 24/7 365 availability. Regarding referral patterns, cardio-vascular surgeons can have their own recruitment of aortic lesions if they screen more systematically the cardiovascular population they already have [29].

Summarizing, aortic pathology is a rapidly evolving field fascinating several specialities with the unique chance to work and grow together. It is our task to take appropriate advantage of this situation as the question today is not any more if open surgery or endovascular therapy of thoracic aortic pathology involving the aortic arch is chosen but the task is to do the right things by having the entire treatment armamentarium in one specialized environment.

Conflict of interest
There is no conflict of interest regarding this manuscript.

Funding body
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Ethical statement
No conflict as it is a review.

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