PRESENT-DAY POLICY OF SURGICAL TREATMENT FOR TYPE A ACUTE AORTIC DISSECTION

RUKOSUJEW A.[1], USAI M.V.[2], MARTENS S.[1], IBRAHIM A.[2], SHAKAKI M.[1], BRUENEN A.[3], DELL'AQUILA A.M.[1]

[1] *Department of Cardiothoracic Surgery,*
[2] *Department of Vascular and Endovascular Surgery,*
[3] *Department of Anesthesiology, Intensive Care and Pain Medicine, University Hospital Muenster, Muenster, Germany*

A surgical intervention for type A acute aortic dissection is the only effective method of treatment making it possible to prevent the development of life-threatening complications and to attain clinical recovery of the patient. Supracoronary replacement of the ascending aorta and the proximal portion of the aortic arch is considered to be the classical and most commonly used method of an open operative intervention. On the one hand, it is technically the simplest and shortest operation, and on the other, this surgical technique is often accompanied by long-term proximal and distal complications, and first of all those caused by a persistent false lumen. The accumulated surgical experience and contemporary operative techniques, as well as advances of intensive therapy in treatment of type A acute aortic dissection make it possible to currently perform more extensive primary resections in order to improve the remote results. Total aortic arch replacement, including the use of the "frozen elephant trunk" technique leads to fast thrombosis of the false lumen, preventing progression of the disease of the thoracic aorta and promoting its positive remodelling.

The article describes the perioperative therapeutic policy accepted and pursued in our medical facility, also presenting the authors' opinion on the role and place of the "frozen elephant trunk" technique in rendering medical care for patients with type A acute aortic dissection.

Key words: *aortic dissection, cannulation, cerebral protection, prosthetic repair of the ascending portion and aortic arch, frozen elephant trunk.*

INTRODUCTION

Acute aortic dissection type A (AADA) is a lethal disease in which only an emergency operative intervention gives surgeons a chance to save the patient's life. From the moment of the onset of first symptoms of the disease, every hour approximately 3% of patients die unless appropriately treated [1]. Despite the experience gained in this area of cardiac surgery, the early postoperative mortality rate according to the literature data, remains relatively high, ranging from 5.3 to 25.7% [2–8]. The most tried-out classical operative intervention is considered to be supracoronary prosthetic repair of the ascending aorta and proximal aortic arch as the simplest and fastest operation which can emergently be performed by any actively operating cardiac surgeon [9]. However, this technique is associated with long-term proximal and distal complications, primarily due to a persistent false lumen [4, 10, 11]. To proximal complications belong secondary dissection or an aneurysm of the aortic root, suture incompetence with formation of a pseudoaneurysm which not uncommonly are accompanied by severe aortic insufficiency. To distal complications induced by a functioning false channel belong formation of a descending aortic aneurysm or its rupture, as well as organic and/or peripheral malperfusion. In approximately 70% of patients after surgical treatment for AADA regardless of the technique of establishing a distal anastomosis and its localization, long-term results of examinations are indicative of the presence of dissection in the distal aorta and antegrade perfusion of the false lumen [11]. All these complications require a repeat operative intervention by an open or endovascular

technique with a high risk of a lethal outcome [12, 13]. According to the findings of F.S. Schoenghoff, et al., 42% of patients presenting with Marfan syndrome and previously operated on for AADA, in the remote period required re-operation on the descending aorta [14]. Therefore, the policy of a more radical approach in surgical treatment of AADA, i. e., total aortic arch replacement using a hybrid graft along with stenting of the descending aorta seems sufficiently substantiated and promising as to the improved long-term outcomes [15–17]. On the other hand, the question of how aggressive an approach in operative treatment of AADA should be has been discussed for more than one year. The concepts suggested so far are controversial and not void of an emotional background, whereas the data of studies are heterogeneous and complicated for comparison. A substantial problem is the fact that it is difficult to carry out prospective randomized studies. Therefore, the currently existing guidelines, including those belonging also to class 1 recommendations, rely on the data reaching only the grade C evidence, i. e. based on follow up of a limited number of patients, expert opinions, and standards of treatment [18, 19].

The purpose of the present work is to describe the perioperative technique of treatment accepted in our medical facility, as well as the role and place of the "frozen elephant trunk" technique, or FET, in rendering care for patients with AADA. In the present article we did not seek to give either comprehensive coverage of the problem concerned or answers to all disputable questions, but we found it necessary to discuss such aspects as the clinical course and diagnosis of AADA, which may influence therapeutic decision-making.

GENERAL PRE- AND INTRAOPERATIVE PREREQUISITES

Patients with AADA die without surgical treatment predominantly of haemorrhage from a ruptured false lumen, more often into the pericardial cavity, with the development of acute tamponade or due to acute myocardial ischaemia resulting from compression of ostia of the coronary arteries. Therefore, the sooner we can get the patient on the operating table, the more chances he or she will have to survive and the better the operative and long-term outcomes will be. The strategy of treatment of a particular patient is primarily influenced by his or her condition, age, and the severity of comorbidities. Besides, the scope of the aortic reconstruction to be performed is also determined by the experience of the operating surgeon and the equipment of a cardiovascular centre involved. Interventions on the aorta regarded as a surgical emergency are performed by not only "aortic" but also "non-aortic" surgeons. On the one hand, transportation of a patient with AADA to a more distant cardiovascular surgery centre possessing wide experience in interventions on the thoracic aorta takes a lot of time, is associated with a high risk for the development of complications of the disease, and any delay of the intervention is life-threatening to the patient. On the other hand, in the majority of centres an average of 25–30 patients with AADA are operated on annually. This number is determined by not the surgeons' experience but by remoteness of a particular cardiosurgical clinic from the hospital wherein the patient was diagnosed. Such a compelled regional principle of emergency treatment of patients with AADA does not seem to favour accumulation of sufficient experience "in the same hands", and hence hampering both carrying out prospective randomized trials and working out common recommendations on the extent of reconstruction of the thoracic aorta for this acute pathology.

A special group is represented by patients admitted with signs of an advanced stage of the disease, namely with clinical manifestations of extensive infarction of the brain, disseminated ischaemia of abdominal-cavity organs or in conditions of continuing resuscitation. All these patients appear to have an extremely unfavourable prognosis which cannot virtually be altered by an urgent operative intervention. Still, resuscitated patients of young age with tamponade of the pericardium should as an ultima ratio be subjected to subxiphoid pericardiotomy for decompression of the heart, with an attempt to attain stabilization of haemodynamics up to emergency connection of a heart-lung machine (HLM) via femoral vessels or by means of direct cannulation of the aorta.

Elderly patients (over 75 years of age) in whom severe concomitant pathology is not uncommon also belong to the cohort of patients with a limited prognosis. If stable haemodynamics, the absence of signs of multiple organ failure or pathological symptomatology allow of performing an operative intervention with the HLM, it should be limited to a minimally invasive and well-tied method, i. e., supracoronary resection of the ascending aorta with formation of a distal anastomosis in an open manner.

In determining the strategy of surgical treatment of patients with AADA on the background of hereditary syndromes of connective tissue dysplasia, for example, Marfan syndrome, Loeys–Dietz syndrome or Ehlers–Danlos syndrome, the main objective should be not only to immediately save the patient's life but also to improve the long-term prognosis, for these are predominantly young adults. This is achieved at the expense of more aggressive operative policy consisting in prosthetic repair of the aortic root with a valve-containing conduit. Performing valve-sparing resection in conditions of an emergency operation and on the background of significantly altered tissues due to dissection

is a technically complicated procedure and requires a great personal experience of the operating surgeon and does not exclude in the future a possibility of a redo operation but this time with the use a conduit. A repeat operation on the aortic root is, as a rule, fraught with risks and complications. Therefore, in primary operation it is necessary to sequentially use a technique preventing late complications. A bicuspid aortic valve should be considered as a sign of congenital predisposition to aortic diseases. It assumes a more radical approach during intervention for AADA, undoubtedly, with due regard for the patient's age and accompanying pathology.

The scope of preoperative diagnosis depends upon stability of the condition of the patient with AADA. Patients with unstable haemodynamics are referred immediately to the operating room wherein after induction of narcosis they are subjected to transoesophageal echocardiography in order to assess myocardial contractility, the degree of aortic valve insufficiency, extension of dissection of the wall of the aorta in its descending portion and if possible revealing secondary intimal defects. Patients with stable haemodynamics, if indicated, undergo additional examinations. First of all, this concerns coronary angiography which in standard conduction increases the risk of acute myocardial ischaemia which is associated with direct catheterization of the aorta. Therefore, patients over 50 years of age and with the presence of risk factors or a history of ischaemic heart disease (IHD) should be subjected to multislice CT coronary angiography (MSCT-CA). This will make it possible to in a timely manner perform myocardial revascularization within the framework of the intervention on the aorta in patients with IHD and to avoid haemodynamic complications while weaning the patient off the heart-lung machine.

Recent trends are clearly towards the use of higher temperatures in combination with selective uni- or bilateral antegrade cerebral perfusion (SACP) during hypothermal circulatory arrest. Deep hypothermia is characterized by a number of complications associated with impairment of blood coagulation, renal function, as well as prolonged phases of cooling and warming up. Since 2011, we have consistently been performing in AADA patients moderate hypothermal circulatory arrest (MHCA) with a body temperature of 28–30 ºC with obligatory control of cerebral regional saturation of blood with oxygen (rSO_2) with the help of near-infrared spectroscopy (NIRS). First we virtually always use unilateral SACP with permanent monitoring of rSO_2, but the line for SACP is initially prepared for bilateral perfusion just in case of a drop of oxygen saturation by more than 10% (NIRS) during MHCA as compared with the baseline values. Conversion from unilateral perfusion to bilateral is carried out by means of direct cannulation of the left common artery with a retrograde cardioplegia delivery catheter. In some cases, bilateral SACP is used initially in patients with MSCT-revealed signs of narrowing of the right common carotid artery due to dissection.

ANAESTHESIOLOGICAL SUPPORT

Anaesthesiological support during an emergency intervention on the thoracic aorta is carried out according to the conventional scheme of induction of narcosis in heart surgery. Invasive measurement of arterial pressure is performed simultaneously in the left radial and left femoral arteries for comparative control of distal perfusion after prosthetic repair of the thoracic aorta. The right subclavian and femoral arteries, as well as femoral vein are left free in case of extracorporeal connection of the HLM. Endotracheal intubation is followed by inserting a transducer of transoesophageal echocardiography for diagnosis of aortic insufficiency, haemopericardium, perioperative dynamic assessment of the function of the chambers and valves of the heart, primarily of the aortic valve.

Prevention of excessive blood loss in the early postoperative period is an important component of anaesthesiological support. Prior to intervention, the patient is given fibrinolysis inhibitor – tranexamic acid (TXA (Cyklokapron®)) at a dose of 30 mg/kg body weight as short perfusion, then uninterruptedly during the intervention at a dose of 4 mg/kg/h. In renal insufficiency the dose is reduced to 2 mg/kg/h. For patients receiving haemodialysis, a bolus dose of 1000 mg is introduced directly into the HLM.

For optimal assessment of the blood coagulation system condition at the moment of weaning the patient off the HLM the final diagnosis is made with the use of thromboelastography simultaneously with activated clotting time (ACT) control after administration of protamine sulphate. Blood platelet activity is optimized by Desmopressin (Minirin®) given at a dose of 0.4 μg/kg body weight of the patient in the form of short infusion, as well as 1000–5000 IU prothrombin complex concentrate (PPSB or Cofact®), fibrinogen (2–4 g). If indicated, we perform transfusion of fresh-frozen plasma, thrombocytic and erythrocytic (Hb<8 g/dl) mass.

OPERATIVE TECHNIQUE

CANNULATION FOR EXTRACORPOREAL CIRCULATION

Success of an emergency intervention on the aorta largely depends on the method of connecting the arterial line of the HLM, which may be performed extra- or intrathoracally – antegrade connection to the right subclavian artery, retrograde connection to the femoral artery or direct cannulation of the dissected aorta. Other methods of connecting the arterial line include

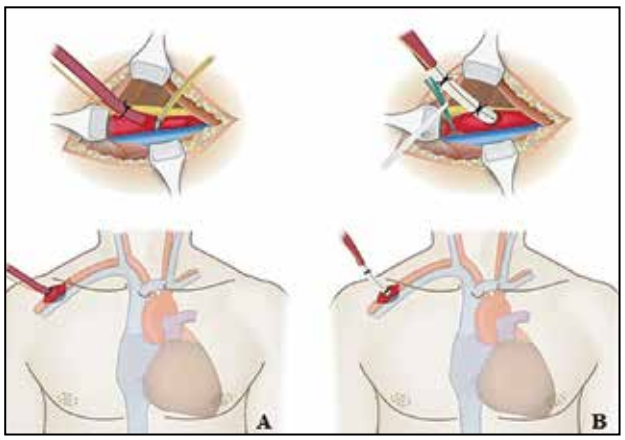

Fig. 1. Schematic representation of extracorporeal antegrade connection of arterial cannula by means of direct insertion of the cannula into the arterial lumen (A) or with the help of a vascular graft (B)

cannulation of the left ventricle via its apex or even left atrium, which was recommended by A. Rahimi-Barfeh, et al. This option should be considered as an exclusion wherein insertion of the cannula into the cavities of the left heart makes obligatory deep hypothermia with a body temperature of 18–20 ºC and may induce, in our opinion, overextension of the left ventricle and overfilling of the lesser circulation [20]. Cannulation of the brachiocephalic trunk which is often involved in acute dissection of the aortic wall has no advantages over direct cannulation of the aorta, and, as we believe, bears more risks associated with impaired perfusion of the right half of the brain. We do not use in our practice cannulation of the carotid artery, which envisages simultaneous connection of the HLM to the femoral artery [21]. The limitations for using this methodology include frequent arteriosclerosis and ipsilateral cerebral hyperperfusion. Extrathoracic antegrade connection may be performed by means of direct insertion of the cannula into the arterial lumen or with the help of a vascular graft (Fig. 1). We prefer direct cannulation of the right subclavian and axillary arteries rarely involved in aortic dissection. The cannula's size should be not less than 18 Fr. We perform connection of the arterial line with the use of a vascular graft in a small diameter of the artery or in patients with acute myocardial ischaemia, who have high probability of the development of postoperative acute heart failure, thus necessitating the use of extracorporeal life support (ECLS).

Connection to the femoral artery has clear advantages: the approach is fast and simple, the cross-section of the vessel is sufficiently large, thus rendering this method the most suitable for patients with unstable haemodynamics. However, there are significant disadvantages – high risk of cerebral embolism due to retrograde blood flow, organ malperfusion (including the brain) as a result of predominant blood flow through the false lumen. In the postoperative period not uncommonly encountered are local wound infection, lymphedema and lymphorrhoea, more often in patients with emergency connection of the HLM.

Direct cannulation of the aorta should be performed in the area of the inner curvature of the aortic arch distally wherein the tissue of the aortic wall is denser and, according to our observations, less frequently is involved by dissection, which, probably, is conditioned by obliteration of the Botallo's duct. Transoesophageal echocardiography is used to identify the true lumen of the descending aorta into which according to the Seldinger technique first a guidewire is inserted followed by inserting an arterial cannula. Correctly performed direct cannulation of the dissected aorta is reliable, ensuring adequate antegrade blood flow, making it possible to avoid additional incisions, and has been acknowledged as the only possible technique in patients with acute dissection of peripheral vessels. One of the options of such method is open cannulation of the aorta wherein the ascending aorta is taken into a tourniquet and transected, with the patient exsanguinated through a venous cannula and in the Trendelenburg position. Under visual control a straight arterial cannula is inserted directly into the true lumen of the aorta. The HLM is switched on simultaneously with thorough deaeration and the tourniquet tightened. Such a technique of central cannulation should be performed in exceptional cases in patients with unstable haemodynamics and involvement of peripheral arteries into dissection. The technique of arterial cannulation (Penza catheterization) through the ostium of the left subclavian artery (LSA) proposed by E. Rosseikin, et al. envisages an extended to the neck approach, control of the cannula position in the true lumen of the descending aorta by means of transoesophageal echocardiography, like in case of direct cannulation of the aorta [22]. However, the LSA is often involved into dissection or has such peculiarities of the anatomical structure that make it unsuitable for connection of the HLM, which is mentioned by the authors in their work.

In general, the choice of the optimal arterial cannulation proportionately depends on the patient's condition, peculiarities of his or her anatomy, and the surgeon's experience. In conditions of performing resuscitation there is no possibility to carry out a time-consuming and technically difficult approach for cannulation. On the other hand, in tamponade of the pericardium or suspicion for occult perforation of the aorta it is feasible to perform extracorporeal connection of the HLM. In patients with stable haemodynamics it is necessary to use extrathoracic antegrade connection of the arterial line of the HLM to the right subclavian or axillary artery. This ensures better perfusion of cerebral vessels through the true lumen as compared with retrograde connection to the femoral vein, simplifying

SACP and making it safer during hypothermic circulatory arrest, providing more "technical" freedom in prosthetic repair of the aortic arch.

TECHNIQUE OF CLASSICAL PROSTHETIC REPAIR OF THE ASCENDING AORTA

Supracoronary reconstruction of the ascending aorta with formation of a distal anastomosis by an open technique is currently the key element in surgery of AADA and has extensively been described in scientific literature, with the obligatory condition being considered open formation of a distal anastomosis according to the hemiarch technique. In so doing, the resection of the internal curvature of the aortic arch along the oblique line requires cutting out of a «tongue» measuring in width ½ circumference of the tubular prosthesis (Fig. 2).

The possibility to spare the aortic root depends on several circumstances. If the aortic wall dissection involves only the non-coronary sinus and a portion of the right coronary sinus (and this is the most frequently encountered finding in AADA) and there is no aneurysmal dilatation of the sinuses of Valsalva, the performance of supracoronary resection of the aorta is feasible. Insufficiency of the aortic valve is present virtually in all patients and is conditioned by commissural detachment. Removal of insufficiency and restoration of the integrity of the aortic root wall are achieved by resuspension of commissures with U-shaped transaortic sutures on felt pledgets, as well as by application of the two-component BioGlue® Surgical Adhesive (Cryolife, Inc.). Applying the anastomosis is preceded by periaortally fixing a felt strip with a mattress suture in order to enhance hermetic sealing. Another variant may consist in excision of the non-coronary sinus with cutting out of a «tongue» in the Dacron prosthesis which is sewn to the aortic ring. Such a technique of forming a proximal anastomosis is also referred to as "partial modification of the Yacoub procedure" (Fig. 3). In case of a combination of aortic wall dissection with degenerative alterations in the aortic valve and dilatation of the sinuses of Valsalva, prosthetic repair of the aortic root should be performed using a mechanical or biological valve-containing conduit. It should be taken into consideration that permanent administration of anticoagulants prevents thrombosis of the false lumen. In our clinic biological conduits are implanted to patients over 60 years of age.

A disadvantage of the classical method is persistent perfusion of the false lumen both retrogradely through secondary ruptures of the intima of the descending and abdominal aorta, and antegradely in the postoperative period through defects in the area of sutures of the distal anastomosis. This technique of treatment for AADA makes it possible to directly prevent the lethal outcome of the disease, but it does not protect the patient from subsequent aneurysmatic transformation of the aorta, i. e., the development in remote terms of a new disease which is not less dangerous for the patient's life.

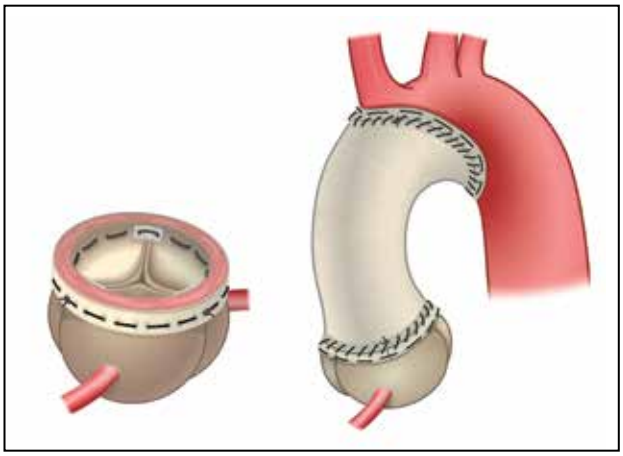

Fig. 2. Schematic representation of supracoronary prosthetic repair of the aorta with formation of the distal anastomosis by an open method according to the hemiarch technique

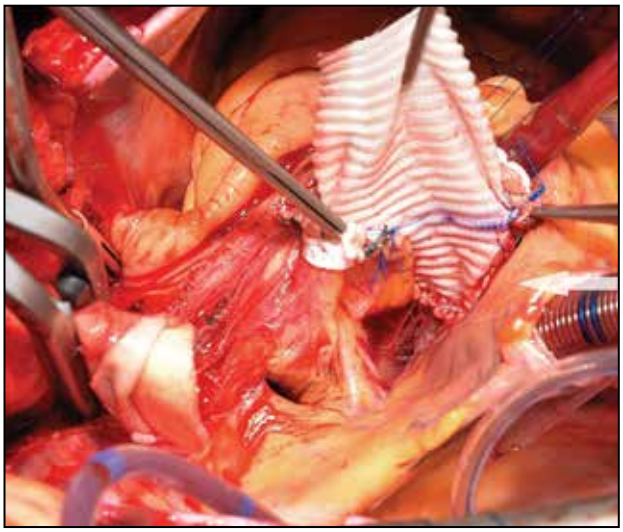

Fig. 3. Intraoperative photograph of the technique of formation of a proximal anastomosis with cutting out a "tongue" in a Dacron graft (arrow)

TECHNIQUE OF TOTAL AORTIC ARCH REPLACEMENT

The technique of total prosthetic repair of the aortic arch supposes dissection of the supraaortic vessels along sufficient length for carrying out SACP and creation of anastomoses with the respective branch of the graft. We do not resort to transection of the left innominate vein in order to simplify the approach to the aortic arch branches. "Skeletonization" of the left innominate vein all along its length contributes to sufficient mobilization of the vessel.

The modern technique of total prosthetic repair of the aortic arch envisages the obligatory use of the "elephant trunk" procedure both it its classical variant of the Borst operation (conventional elephant trunk, or CET) and with the use of a hybrid graft for simultaneous

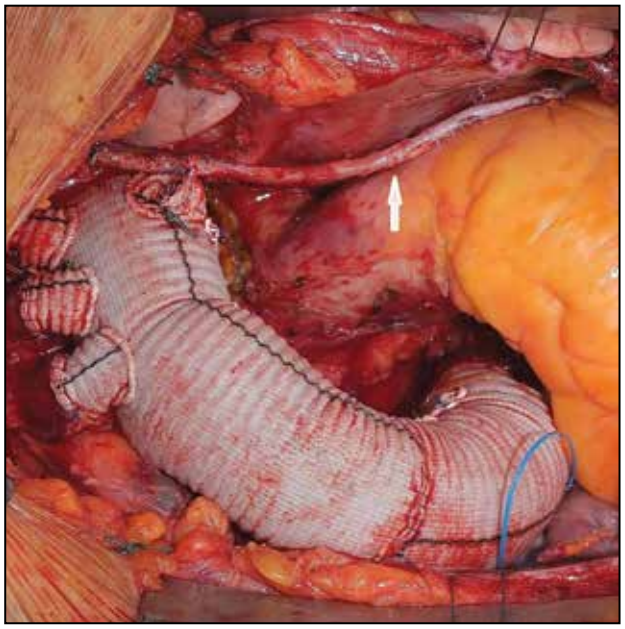

Fig. 4. Intraoperative photograph of prosthetic repair using the Vascutek Siena™ Plexus 4 multi-branched graft with additional shunting of the left internal thoracic artery in situ to the anterior interventricular branch (arrow)

stenting of the proximal portion of the descending aorta (FET). Both cases envisage a second endovascular stage, less often – an open intervention. Total prosthetic repair of the aortic arch with an end-to-end anastomosis with the descending aorta has no advantages over the hemiarch technique in relation to long-term prognosis, it takes longer time and is more traumatic, not uncommonly accompanied by uncontrolled haemorrhage in the area of the distal anastomosis. Such scope of the intervention is indicated in rare cases when dissection of the aortic wall is limited by the aortic ascending portion and the arch.

USE OF A MULTIPLE-BRANCHED GRAFT

The Vascutek Siena™ Plexus 4 multi-branched graft for surgical treatment of patients with AADA was actively used in the Clinic of Cardiac Surgery of Munster from January 2011 to March 2015 before we began to use a hybrid graft in total aortic arch replacement, with 18 such implantations performed for AADA (Fig. 4). The technique of total aortic arch replacement with the help of this graft was described in detail in our previous publication [6]. We believe that using a multi-branched graft creates better conditions to control haemorrhage versus the island technique. The distal, inserted into the lumen of the true channel part of the graft is shortened to a length of 5–6 cm at the level of the third radiopaque marker on the "elephant trunk" in order to prevent thrombus formation and/or malperfusion which may lead to spinal ischaemia. The collar of the graft is cut for the diameter of the descending aorta by eye and its width varies depending on peculiarities of the technique of the operating surgeon. Currently, we use this modification of the graft mainly in patients with thoracic aneurysms or chronic aortic dissection, with the second stage envisaging open prosthetic repair of the descending and abdominal aorta.

USE OF A HYBRID GRAFT (FET)

We began to regularly use the Thoraflex™ Hybrid FET for operative treatment of patients with AADA since April 2015 and till December 2018 performed a total of 23 such implantations. More active use of the graft for AADA became possible owing to the appearance in January 2017 of an improved modification with a stent graft of a smaller diameter (24–26 mm).

The technique of total aortic arch replacement using the hybrid graft was described in detail in our publication [23]. Herein, we would like to once again draw attention to the technique of implantation depending on its modification. The use of a single-branched graft of the Ante-Flo modification envisages sewing the supraaortic vessels to the graft using the island technique. Acute dissection virtually always extends to the left subclavian artery and requires proximal resection followed by separate connection with a vascular graft-interponate. Sewing the brachiocephalic trunk and left common carotid artery in the form of a vascular island may be performed in an open fashion, which increases the duration of distal circulatory arrest, or with marginal pooling aside of the aortic arch graft, but this is technically more difficult due to rigidity of the straightened stent graft and antegrade perfusion of the branch located in the same place. Because of these peculiarities a hybrid graft in the Ante-Flo modification was used only in two of the 23 patients. The Plexus 4 version hybrid graft has, in our opinion, a series of technical advantages. After prosthetic repair of the left subclavian artery with the respective branch and in case of supracoronary replacement of the ascending aorta it is necessary first to establish a proximal anastomosis and renew perfusion of the heart, and only then to sequentially sew the branches to the left common carotid artery and brachiocephalic trunk in an off-pump procedure. This shortens the time of cardioplegic cardiac arrest and prevents cerebral embolism, once the clamp is removed from the aortic arch graft.

In all 23 patients, the distal anastomosis was formed in zone 3. A companion document of the 2018 European Association for Cardio-Thoracic Surgery and the European Society for Vascular Surgery expert consensus document addressing current options and recommendations for the treatment of thoracic aortic pathologies involving the aortic arch suggests "proximalization" of the distal anastomosis from zone 3 to zone 2, which facilitates placement and shortens the time of distal circulatory arrest [24]. However,

in practice we often encounter secondary intimal ruptures in this area, which is conditioned, in our opinion, by peculiarities of the anatomical structure of the transition of the distal arch to the descending aorta.

In case of retrograde AADA where the dissection does not propagate proximally to the brachiocephalic trunk, it is possible to perform aortic prosthetic repair as an off-pump procedure. Permanent perfusion of the heart is provided by a needle vent catheter used for antegrade perfusion, through which from the cardioplegic circuit is fed cooled to 32–34 ºC blood in the amount of 300–400 ml/min. The aorta is double-clamped in its proximal and distal portions and then transected in order to perform manipulations on the aortic arch.

Aortic arch prosthetic repair using a FET is also effective in patients with acute aortic dissection type B (AADB) when a large-sized intimal tear is located directly beneath the left subclavian artery. In such cases commonly adopted in AADB endovascular intervention does not yield the desired result, hence requiring distal prosthetic repair of the arch with stenting of the descending aorta, which is also feasible on the beating heart (Fig. 5).

In our opinion, total aortic arch replacement with the help of FET is the most effective operative technique for AADA, leading to rapid thrombosis of the false lumen, promoting remodelling of the thoracic aorta and prevention from the development of a pseudoaneurysm and eventually improvement of the remote results (Fig. 6).

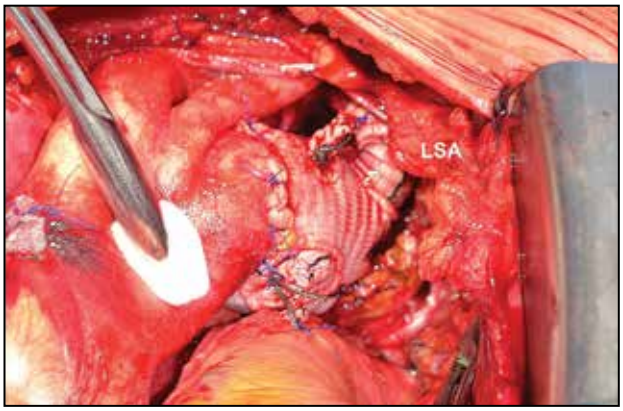

Fig. 5. Intraoperative photograph of distal prosthetic repair of the aortic arch with stenting of the descending aorta using the Thoraflex Hybrid™ graft in Plexus 4 modification (LSA – left subclavian artery)

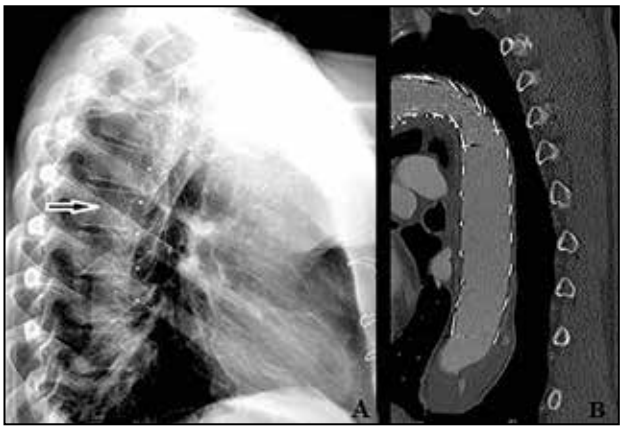

Fig. 6. Lateral chest X-ray image (A) after implantation of the Thoraflex Hybrid™ graft and sagittal thoracic CT (B), showing complete thrombosis of the false lumen

POSTOPERATIVE MANAGEMENT AND COMPLICATIONS

A peculiarity of the postoperative management of patients with AADA is a systemic alteration of haemostasis, conditioned by not only prolonged use of the HLM and hypothermia but also the effect of high doses of antiaggregant agents which prior to making the diagnosis are administered to patients when suspected as having acute coronary syndrome, based on the clinical signs of the disease. Therefore, maintaining stability of blood circulation in the early postoperative period is of paramount importance, namely continuation of the control of cerebral saturation until extubation of the patient, maintaining the mean arterial pressure (MAP) at 60–70 mm Hg, replacement therapy including blood components. Once vasoplegia occurs, primary treatment is performed with Noradrenaline (0.02–0.2 μg/kg/min) and, if necessary, by administration of Vasopressin (2–4 IU/h).

Metabolic acidosis control and regular hourly analysis of blood gases, including lactate concentration monitoring, although belong to conventional measures but influence the outcome of the disease as soon as in the early postoperative period. An increased lactate content is suggestive of anaemia of tissues, for example, of visceral organs or lower limbs due to malperfusion. Once oliguria develops, haemodialysis should be initiated in a timely manner.

The responsibilities of the attending resuscitator include regular transthoracic and, if necessary, also transoesophageal echocardiography, primarily to rule out haemopericardium and haemothorax, as well as for dynamic control of ventricular contractility.

A significant point is prevention of acute respiratory insufficiency up to ventilation in the prone position.

It is very important to timely assess neurological symptomatology. Patients with clinical manifestations of the lesion of the central nervous system (generalised convulsions at awakening) are subjected to perfusion CT with cerebral angiography first of all to exclude haemorrhage, as well as embolisms of cerebral vessels. If technically possible, this should be followed by embolectomy and stenting of cerebral vessels, which is clinically effective if performed within the first 4 hours. In patients with cerebral infarction, therapy is aimed at maintaining MAP

Table

Immediate outcomes and frequency of postoperative complications depending on the type of aortic arch reconstruction

Reconstruction type	30-day mortality		RETO / DSC		Stroke / PRIND		Paraplegia		Laryngeal paresis *	
	n	%	n	%	n	%	n	%	n	%
Hemiarch repair of the aorta (n=138)	23	16.7	24	17.4	20	14.5	4	2.9	3	2.2
End-to-end aortic arch reconstruction (n=13)	3	23.1	3	23.1	5	38.5	1	7.7	2	15.4
Aortic arch replacement using the CET technique (n=18)	3	16.7	2	11.1	4	22.2	1	5.6	3	16.7
Aortic arch replacement using the FET technique (n=23)	1	4.3	4	17.4	3	13.0	1	4.3	4	17.4
Total (n=192)	30	15.6	33	17.2	32	16.7	7	3.6	12	6.3

*Note: CET – conventional elephant trunk (Borst's technique); FET – frozen elephant trunk (hybrid aortic graft); RETO – rethoracotomy for haemorrhage; DSC – delayed sternal closure; PRIND – prolonged reversible ischaemic neurological deficit; * – paresis of the left recurrent nerve.*

at 80–90 mm Hg, decreasing central venous pressure, improving oxygenation and the value of haematocrit. Anticoagulation with heparin is carried out in therapeutic doses. The resuscitator is in constant contact with neurosurgeons, performing dynamic monitoring of patients for timely clinical and roentgenological diagnosis of ischaemic stroke – dislocation of the brain. Once intracranial hypertension develops it should immediately be followed by deciding upon performing decompression craniotomy.

Paraparesis of lower limbs resulting from ischaemia of the spinal cord develops after FET implantation in 0–24%, as evidenced by the literature reports [25–27]. This complication may develop several days or even a week after the intervention and requires immediate diagnosis and treatment. Preventive drainage of cerebrospinal fluid is not carried out by us. However, even in suspicion for ischaemia of the spinal cord we perform drainage of cerebrospinal fluid during up to 72 hours. An obligatory examination is MRI of the spinal column.

We analysed own experience in surgical treatment of AADA starting form January 2011 when in our practice we began to regularly use multi-branched grafts. Over this period of time (till December 2018 inclusive) we operated on a total of 129 patients presenting with AADA. The overall 30-day mortality rate amounted to 15.6% (30 of the 192 patients). The immediate results and the frequency of postoperative complications depending on the technique of aortic arch reconstruction are shown in the Table below. The lowest postoperative lethality was noted in patients after implantation of the hybrid graft, and the highest one after prosthetic repair of the aortic arch according to the end-to-end technique. The frequency of central neurological complications remained high in all groups but again higher in the group of the end-to-end technique. Damage to the left recurrent nerve still remains a serious problem in total aortic arch replacement. Therefore, some authors recommend fixation of CET or FET in zone 2 for prevention of pharyngeal paresis [28].

POSTOPERATIVE DISPENSARY FOLLOW-UP

Dispensary follow up of patients operated on for AADA envisages an interdisciplinary approach in diagnosis of long-term postoperative complications, which should be carried out in specialized cardiovascular centres possessing sufficient experience in operations on the thoracic aorta. It should include regularly performed and appropriately scheduled CT or MRI of all portions of the aorta, echocardiography, as well as adequate treatment of arterial hypertension, postoperative cognitive impairments and accompanying diseases with the aim of prevention or early diagnosis of proximal and distal complications (Fig. 7). The proposed scheme also depicts a wider but currently only still being implemented into clinical practice approach to dispensary follow up of patients. Such an approach envisages an active policy while carrying out neurophysiological monitoring, assessment of quality of life of the patient, genetic and instrumental examination of his or her relatives of first degree in order to evaluate the level of the risk for the development of aortic disease. Patients with hereditary syndromes of connective tissue dysplasia should be followed up at a specialized cardiotherapeutic ambulatory clinic.

CONCLUSION

The accumulated experience, improved surgical technique, advances in diagnosis and intensive therapy in treatment of this complicated disease of the aorta make it possible to currently perform increasingly more extensive primary resections of the thoracic aorta. Total aortic arch reconstruction, including the use of a FET hybrid graft leads to thrombosis of the false lumen, promoting remodelling of the thoracic aorta and prevention of the development of a pseudoaneurysm and eventually the improvement of the remote outcomes. Such extended resections of the thoracic aorta, beginning form its root, are feasible in patients without severe accompanying diseases, being in a stable condition, as well as in young adults, focusing the efforts on prevention of late complications influencing the long-

term prognosis. Herein the decisive role appears to be played by the operating surgeon's experience and skills, as well as capabilities of a referral cardiological centre in comprehensive approach to individual treatment of the patient. In the absence of these conditions it is necessary to confine to supracoronary prosthetic repair of the ascending aorta in its classical performance for the sole purpose of preventing the patient's death.

In patients with aggravating concomitant diseases, as well as in elderly and aged patients over 75 years we should seek to the a limited extent of resection, trying to diminish the injury and to shorten the duration of circulatory arrest and the operation as a whole, thereby accomplishing the mission of directly preserving the patient's life.

In emergency situations when the patient is admitted to the clinic in the condition of a coma with signs of a severe neurological complication manifesting itself by malperfusion of abdominal organs or in conditions of continuous resuscitation it is advisable to abstain from immediate operative intervention. In rare cases of stabilization of haemodynamics it is necessary to perform repeat assessment of the patient's state for a possibility of surgical intervention.

An important prerequisite for successfully performing the operation on the aorta in conditions of circulatory arrest is antegrade connection of the arterial line of the HLM to the right subclavian or maxillary artery. This provides better perfusion of cerebral vessels through the true lumen as compared with the retrograde connection to the femoral artery. Cerebral protection during hypothermic circulatory arrest is achieved with the help of uni- or bilateral ASCP with compulsory control of efficacy of cerebral perfusion of vessels of the brain with the help of NIRS.

Currently, due to a number of circumstances in the majority of AADA patients the scope of the intervention is still confined to the classical supracoronary replacement of the ascending aorta along with open formation of a distal anastomosis.

Obligatory postoperative dispensary follow up with timely diagnosis of proximal and distal complications makes it possible to perform a redo operation in an elective manner and thereby to dramatically reduce the risk of a lethal outcome, as well as the development of severe postoperative complications.

Conflict of interest: none to declare.

Cardiovascular centre (polyclinic)

CT/MR angiography
- prior to discharge from hospital
- after 3, 6, and 12 months
- annually thereafter

Echocardiography
- prior to discharge from hospital
- after 3, 6, and 12 months
- annually thereafter

Control and actualization of medicamentous therapy
(antihypertensive, hypoglycaemic and cholesterol-lowering agents)

Neurophysiological monitoring and assessment of quality of life
(control over restoration of full physical and mental status of the patient)

Screening of first-degree relatives
- CT/MR angiography
- echocardiography
- genetic testing

Fig. 7. Algorithm of postoperative dispensary follow up

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Адрес для корреспонденции:
Рукосуев А.
Тел.: +49 251-83-561-11
E-mail: andreas.rukosujew@ukmuenster.de

Correspondence to:
Rukosujew A.
Tel.: +49 251-83-561-11
E-mail: andreas.rukosujew@ukmuenster.de