Research Article
https://doi.org/10.23934/2223-9022-2023-12-1-152-160

The Management of Patients With Acute Aortic Syndrome in A Hospital Setting on the Example of an Emergency Hospital

R.A. Yakubov ✉, U.U. Akhmedov, M.R. Sharafutdinov, M.F. Mukhamadeev

Department of Cardiovascular Surgery
Emergency Care Hospital
18, Naberezhnye Chelny Ave., Republic of Tatarstan, Naberezhnye Chelny, 423803, Russian Federation

✉ **Contacts:** Ramis A. Yakubov, Cardiovascular Surgeon, Department of Cardiovascular Surgery, Regional Center for Emergency Medical Care. Email: ramsesj@yandex.ru

ABSTRACT Today, the issue of the effectiveness of emergency specialized care for patients with acute aortic syndrome (AAS) is extremely relevant in Russian healthcare. Much attention is paid to logistics and management in the AAS. There is a tendency to increase the share of hybrid treatment of aortic pathology due to the rapid development of endovascular technologies in Russian healthcare institutions. This article presents the scheme of logistics at the prehospital stage, perioperative management and options for surgical treatment, including hybrid and endovascular options of AAS. Particular attention is paid to the resolution of the malperfusion syndrome. The main studies were carried out on the basis of SAHI RT Regional Center for Emergency Medical Care.

AIM OF STUDY Development of a logistics scheme and tactics for the treatment of patients with acute aortic pathology.

MATERIAL AND METHODS This article provides demographic data and incidence statistics. Not only the hospital stage of effective treatment is important, but logistics with routing and anesthesia management as well. Examples of the routing schemes used by us in practice for patients with AAS starting from 2017 are given. Variants of hybrid treatment and resolution of malperfusion syndrome in patients with AAS are shown on the example of clinical cases.

CONCLUSION The applied schemes for transporting patients with AAS allowed the optimal treatment strategy to be chosen, where time is of the essence. Proper perioperative management in patients with aortic pathology will allow deaths to be minimized and/or prevented. The options of performed surgical treatment showed a good result, a decrease in mortality.
Penn classification, especially in a situation of high perioperative risk, made it possible to predict in-hospital mortality and outcomes of surgical treatment, and also helped choose an adequate treatment strategy.

Keywords: acute aortic syndrome, aortic pathology, aortic dissection, outside and in situ, fenestration, FTEVAR, TEVAR, stent graft
For citation Yakubov RA, Akhmedov UU, Sharafutdinov MR, Mukhamadeev MF. The Management of Patients With Acute Aortic Syndrome in A Hospital Setting on the Example of an Emergency Hospital. Russian Sklifosovsky Journal of Emergency Medical Care. 2023;12(1):152–160. https://doi.org/10.23934/2223-9022-2023-12-1-152-160 (in Russ.)
Conflict of interest Authors declare lack of the conflicts of interests
Acknowledgments, sponsorship The study has no sponsorship

Affiliations

Ramis A. Yakubov	Head of the Department of Cardiovascular Surgery, Emergency Care hospital; https://orcid.org/0000-0001-7162-963X, ramsesj@yandex.ru; 35%, surgical treatment strategy, text writing
Umid U. Akhmedov	Cardiologist, Department of Cardiovascular Surgery, Emergency Care hospital; https://orcid.org/0000-0001-8683-8370, umid_wise@mail.ru; 30%, development and implementation of hybrid and endovascular technologies, text writing
Marat R. Sharafutdinov	Radiologist, Department of X-ray Surgical Methods of Diagnosis and Treatment, Emergency Care hospital; https://orcid.org/0000-0003-2821-9525, marat-gil@mail.ru; 20%, development and implementation of hybrid and endovascular technologies, text editing
Marat F. Mukhamadeev	Candidate of Medical Sciences, Chief Physician, Emergency Care hospital; https://orcid.org/0000-0003-4371-7151, mmaratfan@yandex.ru; 15%, organization of triage and medical care processes, approval of the final version of the manuscript

AAS - acute aortic syndrome
BP - blood pressure
CCA - common carotid artery
CT - computed tomography
Echo-CG - echocardiography
EH - emergency hospital
F-TEVAR - TEVAR method with fenestration
FET - Frozen Elephant Trunk
ICU - intensive care unit
PETTICOAT - (eng. "skirt") a technique that consists in implantation of a bare metal stent at the level of the visceral arteries in addition to the stent graft in the descending aorta
TEVAR - thoracic endovascular aneurysm repair, endovascular treatment of thoracic aortic aneurysm

RELEVANCE

Currently, in Russia, acute aortic syndrome (AAS) is becoming more and more often a topic for discussion among specialists (cardiovascular and endovascular surgeons, cardiologists). A key aspect of the effective provision of medical care for this pathology is, first of all, well-established logistics. How much do we know about the logistics of aortic syndrome? Often we limit this concept to ideas about transportation, but in fact it is a more capacious term. The essence of logistics lies in the optimization of parallel processes: reducing time spent at the stages of diagnosis, preoperative preparation, choosing the optimal surgical treatment, as well as developing a patient routing scheme.

A very important aspect in the treatment of AAS is the fight against malperfusion syndrome. This syndrome limits the decision-making time due to the extremely high mortality of patients. To date, there are no clinical guidelines in Russia for the treatment of patients with AAS complicated by malperfusion syndrome.

Our proposed algorithm for the treatment of patients with AAS largely overlaps with the updated American guidelines for aortic disease, published in 2022.

INTRODUCTION

Acute aortic syndrome is a dynamically incomplete concept that combines: classic aortic dissection with the presence of an anastomosis between the true and false aortic canals; intramural hematoma; penetrating atherosclerotic aortic ulcer due to plaque rupture; asymptomatic aortic dissection with bulging of the aortic wall; iatrogenic or traumatic aortic dissection with intimal detachment during aortic catheterization.

The incidence of aortic dissection is 5 to 10 cases per 100,000 population in the Russian Federation, 2 to 8 cases per 100,000 population in the United States, and 0.5 to 2.95 cases per 100,000 population worldwide. Acute aortic dissection type A according to the Stanford classification is characterized by high mortality, which, if untreated, reaches 35% during the first 24 hours, 50% within 48 hours, and from 80 to 94% in the 1st week. The increase in mortality since aortic dissection is estimated at 1–2% per hour [1–4].

Demographic indicators of the Republic of Tatarstan in 2020: the population is 3,902,888 people (data for 2020); mean age — 39.62 (±3.6) years; the main cause of death is diseases of the circulatory system (48.6%).

RESULTS

We have analyzed various forms of acute aortic pathology, most of which are ruptured abdominal aorta (51%).

Epidemiological data on the number of deaths in 2020 in the Republic of Tatarstan: 109 deaths and 66 deaths with traumatic aortic injury were observed with AAS. A large proportion of AAS is aortic dissection (80–95%). The incidence increases many times with age (data from global clinical studies): patients aged 64–74 years - up to 27 cases per 100,000 population; patients older than 75 years - up to 35 cases per 100,000 population.

According to the literature, it is possible to consider various schemes for providing emergency specialized medical care to a patient with aortic syndrome in Russia.

The first scheme: on a call by the ambulance team, acute aortic syndrome is suspected, and the patient is taken to a specialized vascular center.

The second scheme: the patient is in a non-specialized vascular center with a clinic of acute aortic syndrome, a hospital representative contacts the on-duty vascular surgeon of the vascular center, and the issue of transporting the patient to a specialized vascular center is considered.

The third scheme: the patient is in a non-specialized center with an AAS clinic in a serious condition, when it is impossible to transport him anywhere due to the severity of the condition (the presence of signs of organ malperfusion, unstable hemodynamics). In this case, the issue of leaving the cardiovascular team, including the X-ray endovascular surgeon, is considered to perform a salvage surgical or endovascular operation with resolution of the organ malperfusion syndrome by creating a wide distal fenestration as the first stage of treatment on the spot. We know that often under the guise of surgical pathology, patients can end up in non-specialized centers. At this stage, diagnostics are very important, including: ultrasound examination of the abdominal organs and computed tomography (CT). Today, for the implementation of the third scheme for the provision of emergency surgical and / or endovascular care in non-specialized centers, it is necessary to have on the staff such specialists as a cardiologist, an ultrasound doctor, a radiologist and a surgeon. An operating room with C-arm X-ray navigation, an operating room team, and an intensive care unit (ICU) are also needed.

When transporting a patient with suspected AAS to a specialized hospital under the guise of acute coronary syndrome, "acute abdomen" at the level of the emergency room, imaging diagnostics should be performed: chest X-ray, echocardiography (EchoCG) and ultrasound of the abdominal organs. Only when the diagnosis of AAS is confirmed, CT in the angio mode is performed. At the stage of determining the type and timing of highly specialized medical care, the Penn classification is used , which is necessary to predict hospital mortality after surgery in patients with AAS. The Penn classification makes it easy and quick to predict in-hospital mortality and treatment outcomes (Table 1) [5].

Table 1

Penn classification for acute aortic dissection

Class	Criteria
A	No malperfusion
Ab	Impaired perfusion with signs of organ ischemia
Ac	Circulatory disorders with or without heart involvement
Abc	Impaired perfusion of all vessels and circulatory collapse shock

Patients with a confirmed diagnosis of AAS and complications of Aa, Ac and Abc according to the Penn classification, with the manifestation of the disease in less than 6 hours, undergo laboratory and diagnostic detailed examinations. After that, the patient is transported to the cardiac intensive care unit with subsequent transfer to the cardiac or roentgen surgery operating room.

If a patient has Ab and Abc complications according to the Penn classification with a manifestation of the disease in more than 6 hours, then it is necessary to conduct a minimum of examinations at the level of the emergency room: ultrasound Doppler scanning and CT angiography of the vessels of the lower and upper extremities; brachiocephalic arteries; abdominal organs and kidneys. Next, the patient is transported to the ICU for preoperative preparation for endovascular or surgical treatment aimed at resolving the malperfusion (example below).

At the stage of transfer to the ICU, we carry out standard preoperative preparation, including catheterization of: the central vein (right internal jugular) with 4-5-channel central catheters; radial artery on the right or left; left femoral artery for invasive pressure monitoring and acid-base control. The right subclavian and femoral arteries, the right femoral vein are left free in case of extrathoracic connection of the heart-lung machine.

Blood pressure monitoring is carried out. Target heart rate (HR) is less than 60 bpm and target systolic blood pressure (BP) is 100 to 120 mmHg. Reducing pulse pressure is a priority, and intravenous infusion of β-blockers is a first-line treatment [6].

Important aspects of anesthesia in the perioperative period are:

1. Cancellation of any use of anticoagulants.

2. Aggressive treatment of nausea and pain with intravenous analgesics such as fentanyl to reduce the release of endogenous catecholamines associated with pain.

3. Anti-impulse therapy (slow decrease in blood pressure) to a target heart rate of less than 60 bpm: intravenous administration of short-acting β-blockers with a fast onset of action (esmolol, bolus 500 mcg/kg with an infusion rate of 50 to 300 mcg/kg/min), propranolol or α1-blockers (urapidil, 5 mg).

4. If there are contraindications to the use of β-adrenergic blockers or their ineffectiveness, start non-dihydropyridine calcium channel blockers (verapamil and diltiazem). In the absence of an effect, dihydropyridine calcium channel blockers such as nicardipine or clevidipine are an excellent option for reducing afterload through a purely arterial vasodilatory mechanism of action .

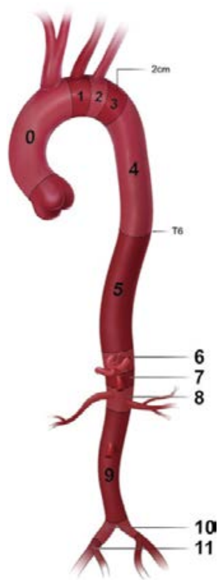
5. If therapy according to paragraphs 3 and 4 is impossible: administration of intravenous infusions of sodium nitroprusside or nitroglycerin (1–2 mcg/kg/min).

6. After endotracheal intubation, insertion of a transducer into the esophagus to perform transesophageal echocardiography and primary assessment of aortic valve function (excluding aortic insufficiency), diagnosis of hemopericardium, as well as perioperative dynamic assessment of the function of heart chambers and valves.

7. Prevention of excessive blood loss in the early postoperative period as an important component of anesthesia, for which transfusion of platelet blood components, as well as coagulation factors, is carried out.

Next, consider the options for surgical treatment, based on the level of damage to the aorta.

To do this, in our practice of surgical treatment of AAS, we use the Z-score aortic zoning scale (Fig. 1) [7].



Zone 0 (includes the ascending thoracic aorta to its distal end and the beginning of the innominate artery)
Zone 1 (department of the thoracic aorta, including the orifice of the left common carotid artery (CCA); between the innominate and left subclavian arteries)
Zone 2 (includes the gap between the aorta and the orifice of the left subclavian artery)
Zone 3 (includes the proximal descending thoracic aorta down to the T4 vertebral body; first 2 cm distal to the left subclavian artery)
Zone 4 (end of zone 3 to middle descending aorta - T6)
Zone 5 (descending aorta to celiac trunk)
Zone 6 (includes the celiac trunk to the superior mesenteric artery)
Zone 7 (includes origin of the superior mesenteric artery)
Zone 8 (includes origin of the renal arteries)
Zone 9 (infrarenal abdominal aorta to the level of aortic bifurcation)
Zone 10 (origin of the internal iliac arteries)
Zone 11 (branch of external iliac arteries)

Fig. 1. Aortic zoning scale Z-score

To determine the tactics of surgical treatment, our aortic team developed a decision-making algorithm (Fig. 2) based on the presence of malperfusion syndrome in three types of aortic dissection (Stanford classification): type A, type B, type neither A nor B. The algorithms for the surgical treatment of aortic pathology that we widely use are in many ways similar to the recommendations updated and adopted by the American Heart and Cardiology Association (2022) [7].

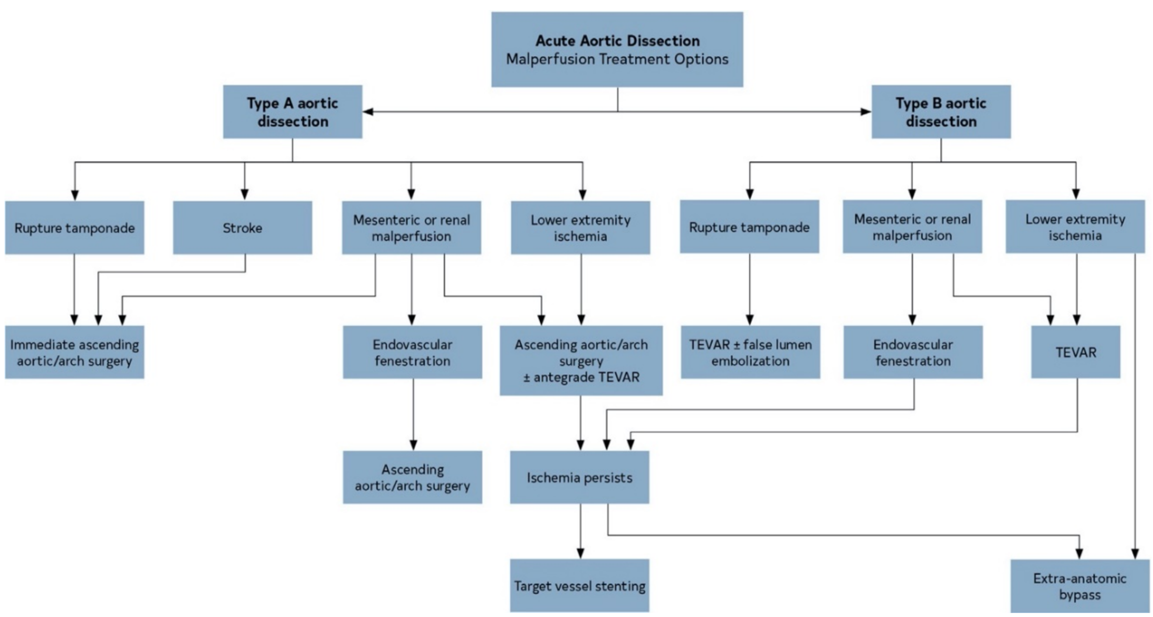


Fig. 2. Decision-making algorithm based on the presence of malperfusion syndrome in three types of aortic dissection (Stanford classification)

1. A dissection have a clinical picture of cardiac tamponade without cerebral stroke, then in most cases we perform an open operation in the volume of prosthetics of the ascending thoracic aorta, combined with or without reconstruction of the aortic arch.

2. Patients with cerebral malperfusion or those with a small ischemic stroke in the course are considered by us as a first-line strategy that involves a minimally invasive procedure on the brachiocephalic arteries in the amount of stenting and elimination of the false canal of the artery.

Clinical case #1.

Patient D., 37 years old, was transfer on an emergency basis to the EH in Naberezhnye Chelny with an ACS clinical picture from the infectious diseases hospital, where he was treated with a diagnosis of coronavirus infection, Covid -19, bilateral pneumonia.

The diagnosis was made: “Type I aortic dissection according to the DeBakey classification with dissection spreading to the brachiocephalic arteries, complicated by cerebral malperfusion syndrome” (Fig. 3 A , B).

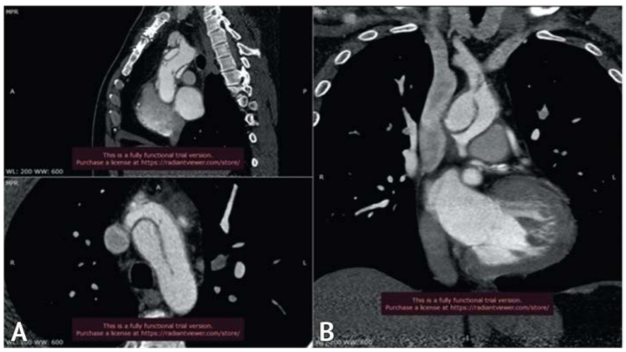


Fig. 3. CT image of the chest organs with contrast. Aortic dissection with extension to the origin of the left subclavian artery and occlusion of the left CCA

According to echocardiography, aortic valve insufficiency of the 2nd or 3rd degree was revealed. According to vital indications and in order to eliminate cerebral malperfusion, the first stage was stenting of the left internal carotid artery (ICA), and the second stage was supracoronary prosthetics with root plasty by simultaneous aortocoronary bypass grafting to the obtuse marginal artery under hypothermia (28.0°C). The patient was discharged home in a satisfactory condition on the 10th day without neurological deficit. In 8 months, the dissection at the level of the branches of the aortic arch remained on the control CT angiography, and therefore we performed arthroplasty of the entire arch using a wide fenestration under the brachiocephalic arteries, outside on-a-table technique, followed by stenting of the brachiocephalic arteries. Thus, a landing zone was created to place the graft into the descending thoracic aorta. Fig. 4 shows an intraoperative photo, where an additional graft overlapped the false canal of aortic dissection in the area of the distal anastomosis of the vascular prosthesis and proximal to it. The second linear graft was installed from the sinotubular ridge to the mouth of the left CCA, and this graft was fenestrated in situ under the brachiocephalic trunk and the left CCA with the installation of a stent.

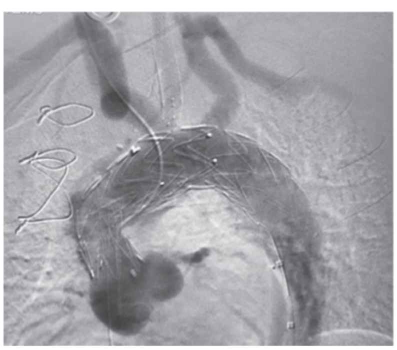


Fig. 4. Angiography: final result. A stent-graft in the thoracic aorta, a stent in the left CCA, in the left ICA, and in the left accessory artery are visualized

3. If the patient has a clinic of malperfusion of the kidneys or visceral organs, then at the first stage we consider the option of endovascular or surgical fenestration of the thoracoabdominal aorta, and then at the second stage we perform the "open stage" or endovascular FTEVAR prosthetics of the ascending thoracic aorta with or without correction of the aortic arch.

Case Study #2

Patient X., 67 years old, was admitted in February 2022 with a COVID-19 clinical picture and type A aortic dissection (according to the Stanford classification), complicated by mesenteric ischemia (Fig. 5, CT angiography data).

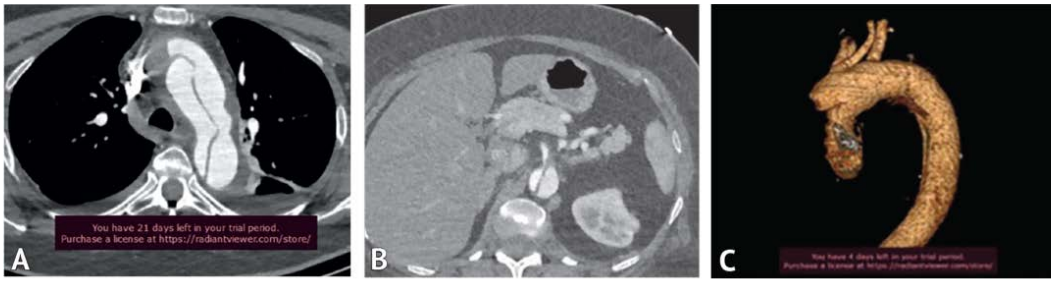


Fig. 5. A , C - dissection of the aortic arch. B - dissection of the superior mesenteric artery and malperfusion of the visceral organs

At the first stage, the patient underwent stenting of the superior mesenteric artery and elimination of intestinal malperfusion.

The second stage (Fig. 6) was a complete hybrid arthroplasty of the ascending aorta and thoracic aortic arch with a fenestrated graft under the brachiocephalic arteries with a combined “in-situ and outside on a table” fenestration technique in position Z 0–2.

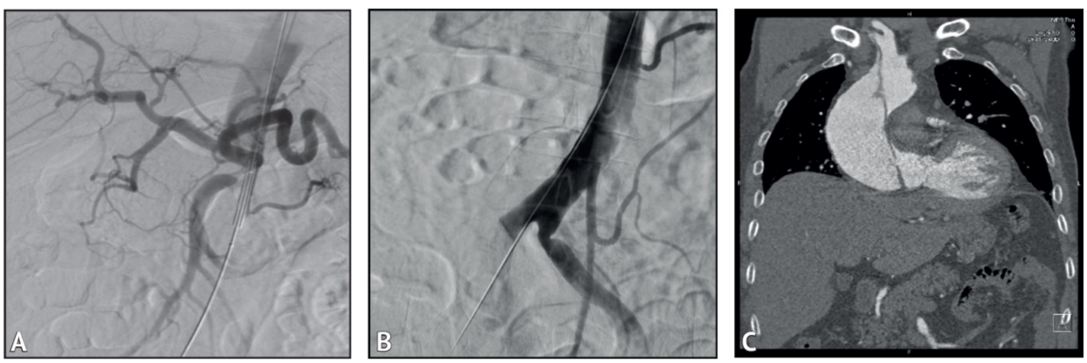


Fig. 6. A , B — angiogram after the stage of endoprosthesis of the ascending and arch of the aorta with a combined fenestration technique “in-situ and outside on a table”; C — CT angiography after the stage of endoprosthesis of the ascending and arch of the aorta with a combined fenestration technique “in-situ and outside on a table”

4. In some cases, when the clinic of cardiac tamponade is accompanied by malperfusion of visceral organs, our aortic team performs antegrade placement of a stent-graft into the descending aorta with occlusion of the aortic arch with simultaneous open replacement of the ascending aorta by the type of supracoronary prosthetics.

Case Study #3

Patient K., 47 years old, was admitted urgently to EH on 08.12.2020. Based on the results of the examination, the diagnosis was made: “Aortic dissection (DeBakey type 1) involving the cerebral, visceral arteries and arteries of the lower extremities. Malperfusion of internal organs. Hydronephrosis of the left kidney. Acute renal failure. Moderate hemothorax on the left. Minor hemopercardium.

Congenital heart disease: Bicuspid aortic valve. Coronarosclerosis. Hypertension 3-th stage, 1st stage, risk 4. Dyslipidemia. Mild anemia. Thrombocytopenia".

Performed: hybrid antegrade total aortic arch arthroplasty with simultaneous switching of the branches of the arch to a supracoronary prosthesis in combination with coronary artery bypass grafting. Subsequently, four more stages were carried out for complete replacement of the entire thoracoabdominal aorta and iliac arteries with fenestration of the graft under the mouths of all visceral arteries.

As a result, in the presented cases, total endovascular repair of the aortic arch (total arch) was performed using the new outside (ona-table) and in situ fenestration technology (Fig. 7).

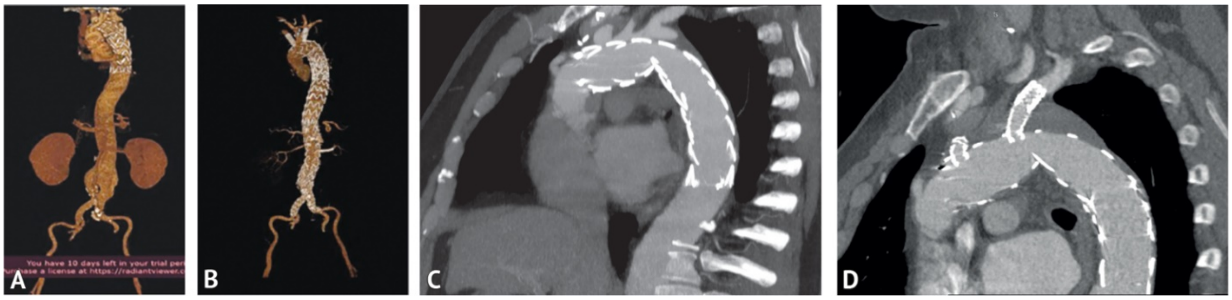


Fig. 7. A–B — Computed tomography-angiography of stages of hybrid endovascular aortic repair. A - hybrid prosthesis of the thoracic aorta to the diaphragm; C - total hybrid aortic grafting. CD - final result, complete debranching of the aorta (computed tomography-angiography). Recanalization of the right (C) and left (D) subclavian arteries by retrograde graft fenestration

5. Patients with aortic dissection type A (according to the Stanford classification) with a clinical picture of ischemia grade 2 A–B of the lower extremities (according to the classification of A.V. Pokrovsky) are operated on first of all: the ascending part of the thoracic aorta in the volume of supracoronary prosthesis or prosthetics of the root and ascending thoracic aorta with or without aortic arch correction. In case of ischemia of the lower extremities in the perioperative period, angiography is performed with the elimination of the false channel of the vessel by stenting the aortoiliac-femoral segment with bare-metal stents.

Case Study #4

Patient K., 65 years old, type A aortic dissection (according to Stanford classification), complicated by malperfusion syndrome of visceral organs and lower extremities (Fig. 8).

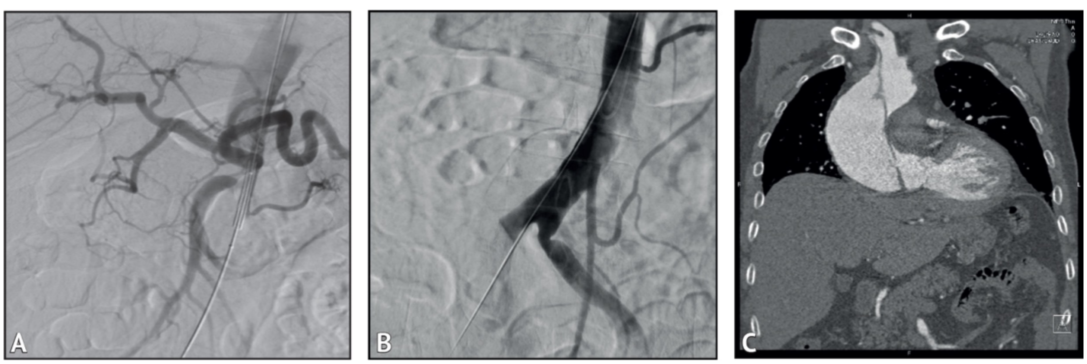


Fig. 8. A, B - occlusion of the right common iliac artery on the right; C — CT angiography of aortic dissection involving brachiocephalic arteries

The first stage was the elimination of malperfusion of the lower extremities and visceral organs by retrograde - stenting of the aorta in the thoracoabdominal region and stenting of the iliac region.

The second stage included supracoronary replacement of the ascending aorta with a synthetic prosthesis "Silverguard" (24 mm) under conditions of hypothermic cardiopulmonary bypass (25.0°C) (Fig. 9).

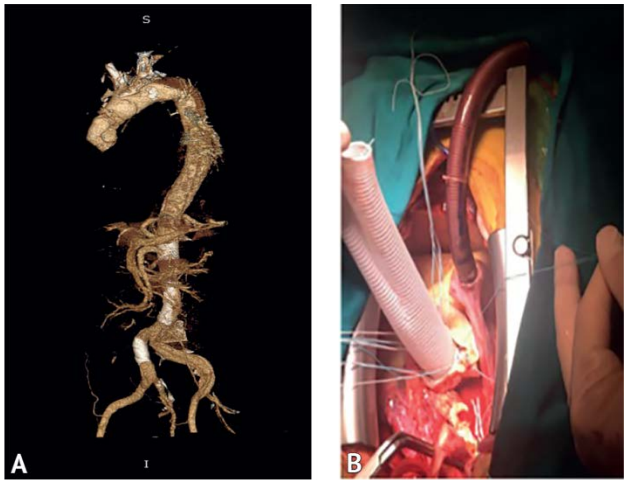


Fig. 9. A — CT-angiography of the final result of supracoronary replacement of the ascending aorta and endoprosthesis of the abdominal aorta and stenting of the common iliac artery on the right; B — stage of surgical treatment, supracoronary prosthetics

6. In type B (according to the Stanford classification) aortic dissection, the treatment tactics is different and almost always begins with the FTEVAR procedure, covering the proximal fenestra of the dissected aorta in zones Z 1–2. Moreover, one graft with a length of no more than 200 mm is used to prevent the occurrence of spinal cord ischemia. Subsequently, linear or conical grafts are used with staged stenting of the distal part of the thoracoabdominal aorta. In some cases, the “PETTICOAT” technique is used for positive remodeling of the true thoracic aortic canal or fenestration technique under the orifices of the visceral arteries.

7. When dissection of the thoracoabdominal aorta is combined with an aneurysm of the abdominal aorta, staged treatment is performed: the first stage is F-TEVAR , the second is TEVAR in the lower thoracic and thoracoabdominal sections, and the 3rd and 4th stages are endovascular prosthetics of the abdominal aorta.

8. In case of aortic dissection of type B (according to the Stanford classification) in combination with malperfusion of visceral organs, the first stage is the elimination of this syndrome by fenestration of the intima of the thoracoabdominal aorta and stenting of the visceral arteries.

F-TEVAR is a promising and smarter technique used to reconstruct the aorta without altering the anatomy. In our practice, we have taken advantage of the characteristics of the various stent grafts, which has made the planning, modification and orientation procedures much more efficient and effective. At the same time, as a result of aortic arch arthroplasty using the “outside” and “in-situ” fenestration techniques, in only two of 48 (4.16%) patients endoleak developed, which is consistent with recent publications that reported the frequency of this complication, which is 0–4.2% [8].

Thus, based on the individual advantages and limitations, as well as the encouraging results of these methods in the early and medium term, each of them can be used in the surgical treatment of AAS. Given the significant limitation of studies, expressed in a small number of patients and short-term observation, we consider it necessary to conduct further long-term observations involving a large cohort of patients [9, 10].

CONCLUSION

The routing schemes presented by us for patients with acute aortic syndrome will allow time to make a decision on the development of an optimal treatment strategy.

Standardized perioperative management of patients with acute aortic pathology will minimize and (or) prevent serious complications and avoid high mortality .

The accumulated experience of our center, improved surgical technique, achievements in diagnostics and intensive care in the treatment of this complex and formidable disease of the aorta currently allow us to perform more and more complex operations, while at the same time with minimal trauma and economic costs.

Total aortic arch replacement, including the use of a hybrid FET prosthesis and the traditional open option, which promotes remodeling of the thoracic aorta and prevents the development of false aneurysms and, ultimately, improves long-term outcomes, is currently considered the treatment of choice in the treatment of acute aortic syndrome. This volume of surgery on the thoracic and abdominal aorta is appropriate in patients without severe comorbidities, who are in a stable condition, as well as in young patients; efforts are focused on the prevention of late complications that affect the long-term prognosis. However, in emergency cases, when a patient is admitted to the clinic in a coma with signs of a severe neurological complication, manifesting malperfusion of the abdominal organs or the brain under continuous resuscitation, the risk of open surgery exceeds its benefits and is the reason for refusing emergency surgery. In such cases, the treatment of choice for malperfusion of organs, in order to avoid cerebrovascular accident and major bleeding, is an endovascular option for correcting aortic pathology using fenestrated grafts on the table (out site on the table) or fenestration inside the aorta (in situ) as an option both staged and main type of treatment [11].

REFERENCES

[PubMed] Charchian ER, Belov IuV, Stepanenko AB, Gens AP, Fedulova SV, Nikonov RIu. Valve-sparing technique for type A aortic dissection with aortic valve insufficiency. Cardiology . 2014;54(6):91–96. PMID: 25178086 https://doi.org/10.18565/cardio.2014.6.91-96. (In Russian.).

2. Shket AP, Shumovets VV, Spiridonov SV, Shestakova LG, Krachak DI, Korzhova AV, et al. The Experience of Surgical Treatment of Thoracic Dissecting Aneurysms of a Type. Medical almanac. 2013:4(28):65–67.

] 3. Mokashi SA, Svensson LG. View Article PubMed Google Scholar Gen Thoracic Cardiovasc Surg . 2019;67(1):59–65. PMID: 29030719 https://doi.org/10.1007/s11748-017-0831-8

4. Belenkov YuN, Oganov RG (eds.). Kardiologiya. Moscow: GEOTAR-Media Publ.; 2012. (In Russ.).

5. Kimura N, Ohnuma T, Itoh S, Sasabuchi Y, Asaka K, Shiotsuka J, et al. Utility of the Penn classification in predicting outcomes of surgery for acute type a aortic dissection. Am J Cardiol. 2014;113(4):724–730. PMID: 24484863 https://doi.org/10.1016/j.amjcard.2013.11.017

6. Murphy DL, Danielson KR, Knutson K, Utarnachitt RB. Management of Acute Aortic Dissection During Critical Care Air Medical Transport. Air Med J. 2020;39(4):291–295. PMID: 32690306 https://doi.org/10.1016/j.amj.2020.04.017

7. Isselbacher EM, Preventza O, Hamilton Black III J, Augoustides JG, Beck AW, Bolen MA, et al. 2022 ACC/AHA Guideline for the Diagnosis and Management of Aortic Disease. A Report of the American Heart Association/American College of Cardiology Joint Committee on Clinical Practice Guidelines. Circulation. 2022;146(24):e334–e482. PMID: 36322642 https://doi.org/10.1161/CIR.0000000000001106

8. Shu C, Fan B, Luo M, Li Q, Fang K, Li M, et al. Endovascular treatment for aortic arch pathologies: chimney, on-the-table fenestration, and in-situ fenestration techniques. J Thorac Dis. 2020;12(4):1437–1448. PMID: 32395281 https://doi.org/10.21037/jtd.2020.03.10

9. Makaloski V, Tsilimparis N, Rohlffs F, Heidemann F, Debus ES, Kölbel T. Endovascular total arch replacement techniques and early results. Ann Cardiothrorac Surg. 2018;7(3):380–388. PMID: 30155417 https://doi.org/10.21037/acs.2018.04.02

10. Moulakakis KG, Mylonas SN, Markatis F, Kotsis T, Kakisis J, Liapis CD. A systematic review and meta-analysis of hybrid aortic arch replacement. Ann Cardiothorac Surg. 2013;2(3):247–260. PMID: 23977592 https://doi.org/10.3978/j.issn.2225-319X.2013.05.06

11. Rukosujew A, Usai MV, Martens S, Ibrahim A, Shakaki M, Bruenen A, Dell'aquila AM. Present-day Policy of Surgical Treatment for Type a Acute Aortic Dissection. Angiology and Vascular Surgery. 2020;26(3):82–101.(In Russ.) https://doi.org/10.33529/ANGIO2020217

Received on 01.11.2022

Review completed on 09.02.2023

Accepted on 09.02.2023