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The frozen elephant trunk technique for hyperacute aortic dissection type A

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Abstract

Introduction. *Acute aortic dissection is a current and urgent problem in modern cardiac surgery. In the early stages of the dissection, the surgeon is faced with the dilemma of choosing the volume of intervention from the ascending part reconstruction only or radically ascending and aortic arch replacement. Hybrid systems for one-stage reconstruction of the thoracic aorta are currently being actively developed. The Frozen Elephant Trunk (FET) technique allow us to replacement ascending and arch of the aortae combined with antegrade stent grafting into the descending aorta from the classical sternotomy access. This type of operation doesn't increase the time of the intervention, there isn't stage-by-stage reconstruction of the aorta, adequate blood flow in the* *descending aorta and aortic vessels is restored, and the risks of an adverse outcome are reduced.*

Objective. *To analyze the results of surgical treatment of acute aortic dissection type A, performed using the FET technique in a multidisciplinary surgical hospital - N.V. Sklifosovsky Research Institute for Emergency Medicine.*

Material and methods. *The research included 18 patients which were operated from 2022 to 2024 in acute stage of aortic dissection. All patients were operated using a hybrid technique FET.*

Results. *Multisystem organ failure developed in 5 patients (27.8%). Four patients (22.2%) required renal replacement therapy due to acute renal failure. In 38.9% of the subjects, prolonged artificial ventilation was complicated by pneumonia. Cerebral complications were observed in 6 patients (33.3%). Sepsis accompanied the course of the disease in 16.7% of cases. The 30-day mortality was 22.2%, in the study group.*

Conclusion. *Using the hybrid prosthesis allowed us to obtain relatively satisfactory results of reconstruction thoracic aortae in case of the acute dissection in the early postoperative period.*

Keywords*:* hyperacute aortic dissection, acute aortic dissection type A, Frozen Elephant Trunk, artificial blood circulation, hybrid technique of aortic replacement, organ malperfusion

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Asc.A, ascending aorta
AA, axillary artery
AC, assisted circulation
ACP, antegrade cerebral perfusion

AR, aortic root
BCT, brachiocephalic trunk
CA, circulatory arrest
CCA, common carotid artery
CE, contrast enhancement
DA, descending aorta
ECG, electrocardiographic
FET, Frozen Elephant Trunk
FL, false lumen
LCCA, left common carotid artery
LSA, left subclavian artery
LZ, Landing Zone implantation zone
MSCT, multislice computed tomography
NIRS, Near-Infrared Spectroscopy
PB, perfusion branch
RA, right atrium
RV, right ventricle
SG, stent-graft
TEE, transesophageal echocardiography
TL, true lumen
TV, transverse vein

Introduction

Acute aortic dissection is a serious condition with unpredictable consequences and remains a significant problem in modern cardiovascular and endovascular surgery [1]. Of all acute aortic dissections, 59–67% are Stanford type A aortic dissections [2–4], which determines the need for emergency surgery on the proximal thoracic aorta [5, 6]. The highest number of fatal outcomes occurs in the "most acute" stage of the disease (2 days from the onset of the disease), reaching a rate of 0.5% per hour with a cumulative mortality rate of more than 20%. [7, 8]. The frequency of complicated forms of the disease in combination with the pathophysiological aspects of the very fact of a dissected aortic wall determines the relatively unsatisfactory results of surgical treatment of patients in the early stages of the disease [6, 7, 9–12].

The basic principles of surgery for acute aortic dissection, defined by S. Crawford, focus on the root and ascending aorta, where primary fenestration is most often localized [13]. Being a life-saving surgery, it prevents rupture of the most vulnerable section of the aorta, but often does not solve the problem of the arch and descending aorta dissection. In the early stages of dissection, the surgeon is faced with a dilemma of choosing the extent of intervention: on the one hand, striving to limit the reconstruction to the ascending section and minimize surgical trauma, on the other hand, extending the reconstruction onto the aortic arch and prevent the development of early and late aortic-associated complications, such as malperfusion and late aortic remodeling, but with an increased risk of an unfavorable outcome of the surgery [6–8]. A number of authors point to increased rates of complications and unfavorable outcomes with total aortic arch replacement in the acute stage. On the other hand, there are studies demonstrating comparable results of using limited and extended reconstructions [14 – 16].

Currently, in the literature, close attention is focused on the results of using hybrid technology Frozen Elephant Trunk (FET) in the acute stage of aortic dissection, a technique that allows for simultaneous total aortic arch replacement with stenting of the proximal descending aorta using a hybrid prosthesis. This technology has proven itself in the treatment of aneurysms and chronic dissections of the arch and proximal descending thoracic aorta [7, 15, 17–19]. However, given the complexity and duration of the procedure, the results of this technology raise questions about its routine use in the acute stage of aortic dissection.

The objective was to analyze the results of surgical treatment of acute type A aortic dissection performed using the Frozen Elephant Trunk technique, in the multidisciplinary clinic of the N.V. Sklifosovsky Research Institute for Emergency Medicine.

Material and methods

The study group consisted of 18 patients with acute type A aortic dissection operated on between 2022 and 2024 (Table 1). All patients underwent hybrid surgery using the FET technique. The gender distribution was as follows: 12 men (66.7%) and 6 women (33.3%). The mean age in the group was 54.4±11.36 years old.

Table 1. Comorbidity background in the study group

Parameters	Value, abs. (%)
Arterial hypertension	15 (83.3)
Chronic heart failure	4 (22.2)
Body mass index	7 (38.9)
Atrial fibrillation (history)	1 (5.6)
History of stroke	1 (5.6)
Chronic renal failure (history)	1 (5.6)

Note: ACE, acute cerebrovascular accident

In 100% of cases, patients complained of chest pain upon admission. Fifteen patients (83.3%) had long-standing hypertension. Seven patients (38.9%) had a high body mass index. Left ventricular ejection fraction, as determined by echocardiography, kept normal in all 18 cases.

All patients underwent multislice spiral computed tomography (MSCT) with electrocardiographic (ECG) synchronization and contrast enhancement (CE) to verify the diagnosis. Some patients (n=13; 72.2%), were admitted to the clinic with MSCT results from other medical institutions. In 3 patients (16.7) a repeat MSCT was necessary due to the unsatisfactory quality of the study, which did not allow preoperative planning of the intervention. Based on the results of MSCT with ECG synchronization and CE, the type of aortic dissection was determined according to the DeBakey classification, as well as the morphology of the process, the localization of primary and distant fenestrations, the presence of hemopericardium, the involvement of the aortic lateral branches with/without the malperfusion development were studied (Figs. 1, 2). The clinical status of the patient was assessed according to the University of Pennsylvania (Penn) classification [20], taking into account the total ischemic load on the body. The GERAADA (German Registry of Acute Aortic Dissection Type A) score was used to assess perioperative risk [21].

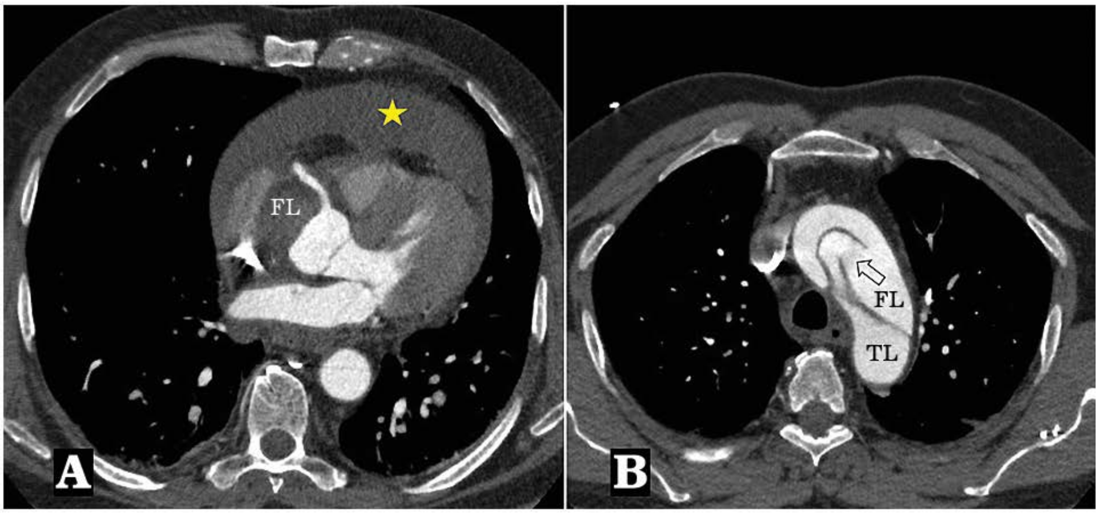

Fig. 1. Contrast-enhanced CT scans (axial sections) at the level of the thoracic aorta. Type A aortic dissection. At the level of the aortic root, the false lumen (FL) is filled with thrombotic masses, and the pericardial cavity contains hemorrhagic contents of approximately 350 cm^3 (asterisk in image A). A large primary fenestration is visible at the level of the aortic arch (arrow in image B)

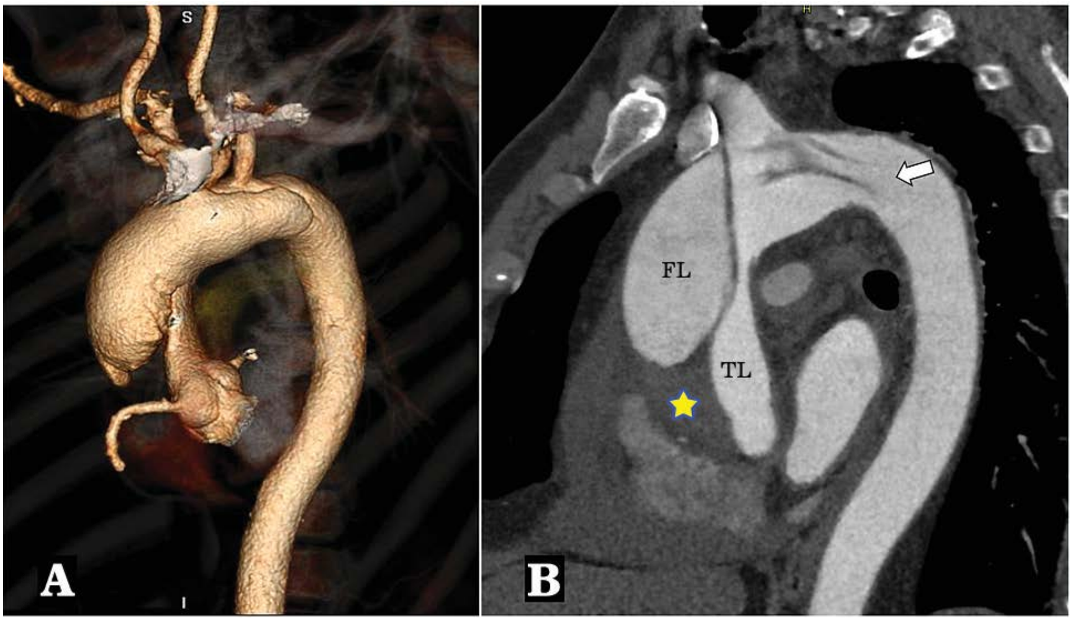

Fig. 2. Three-dimensional and sagittal reconstructions of computed tomography data. Dissection from the level of the aortic root to the isthmus of the aorta with primary fenestration at the level of the aortic arch (type A retrograde). TL, true lumen; FL, false lumen. The asterisk indicates hemorrhagic contents in the pericardial cavity

Table 2 presents the rates of ischemia in patients.

Table 2. Severity of patient condition associated with ischemia

Parameters	Value, abs. (%)
Cardiac tamponade	8 (44.4)
Cerebral malperfusion	2 (11.1)
Visceral malperfusion	2 (11.1)
Renal malperfusion	4 (22.2)
Spinal malperfusion	1 (5.6)
Peripheral malperfusion	10 (55.6)

According to instrumental examinations and clinical manifestations, 8 patients (44.4%) had a complicated condition with circulatory shock due to cardiac tamponade. GERAADA Risk score was Me (Q_1;Q_3) = 23.7 (19.3;31.6).

Of 18 patients with acute aortic dissection, 16.7% of patients were free of aortic-related complications (Penn A). Impaired perfusion along the aortic branches (Penn B) or hemodynamic instability (Penn C) were observed in 66.6% of cases (Table 3).

Table 3. Severity of patient condition as per Penn classification

Parameters	Value, abs. (%)
Penn A	3 (16.7)
Penn B	6 (33.3)
Penn C	6 (33.3)
Penn B+C	3 (16.7)

Surgical technique: The access was full median sternotomy. The approach to arterial cannulation was differentiated, with preference for organizing systemic antegrade blood flow through the left/right axillary arteries or the brachiocephalic trunk (BCT). The choice of cannulation site depended on the condition of the supra-aortic vessels and the patient's hemodynamic stability. If the brachiocephalic arteries were involved in the dissection process, especially when the dissection extended to the right axillary artery, this technique was considered unsafe. Cannulation of the axillary artery was also avoided in cases of patient instability. For the above-mentioned reasons, the femoral artery, not involved in the dissection, was used as the arterial return site in 3 patients (16.7%). In all cases where the axillary artery was used, its connection to the arterial line was achieved through a sutured vascular graft with a diameter of 8–10 mm. We did not use the central aortic cannulation in these patients due to a lack of proper experience. After the mobilization of the aortic arch vessels, both venae cavae were cannulated and cardiopulmonary bypass (CPB) was initiated. Perfusion was monitored using three-point blood pressure monitoring, true lumen blood flow monitoring in the descending aorta using transesophageal echocardiography (TEE), and cerebral oximetry (near-infrared spectroscopy (NIRS)). Aortic arch replacement in all patients in our series was performed according to the "distal first" principle under conditions of moderate-to-high hypothermia (24–28°C). After initiating CPB, cooling was started and the aorta was clamped, provided the antegrade arterial return had been achieved, with reassessment of perfusion adequacy. In cases of femoral arterial cannulation, the aortic clamping was avoided. If the aorta was clamped, the manipulations on the aortic root were performed during cooling. The range of proximal reconstructions performed is presented in Table 4.

Table 4. Volume of proximal reconstruction

Parameters	Value, abs. (%)
Plastic surgery of the proximal anastomosis zone using the "sandwich" technique	18 (100)
Aortic valve resuspension	5 (27.8)

Once the target temperature was reached, which depended on the surgeon's preference, CPB was stopped, the aortic clamp was removed, the BCT and left common carotid artery (LCCA) were dissected, and the aortic arch was partially excised down to the left subclavian artery orifice. In our series, we preferred the bilateral antegrade cerebral perfusion at a flow rate of 8–10 mL/kg/min under NIRS guidance. The choice of the distal anastomosis level depended on the accessibility and involvement of the left subclavian artery in the dissection, the presence of a fenestration in the distal arch, and the surgeon's preference. The distal anastomosis levels used for aortic reconstruction are presented in Table 5.

Table 5. Level of distal anastomosis on the thoracic aorta

Parameters	Value, abs. (%)
LZ 0	1 (5.6)
LZ 1	2 (11.1)
LZ 2	14 (77.7)
LZ 3	1 (5.6)

Landing Zone (LZ), implantation zone

In cases where the anastomosis was performed in LZ II, the left subclavian artery was ligated or cut and clipped, and its stump was sutured. In these cases, extraanatomical bypass of the left subclavian artery was performed, which was usually undertaken during the patient warming stage. The stented component of the hybrid prosthesis was introduced into the true lumen under visual control. We do not usually practice a routine use of a guidewire positioned in the true lumen. The anastomosis between the aorta and the vascular graft cuff was performed with a continuous suture (4/0 Prolene) reinforced externally with a Teflon strip. Usually, the anastomosis was covered with synthetic biodegradable glue Glubran 2 (GEM, Italy). The arterial line was connected to the perfusion branch of the hybrid prosthesis and the systemic perfusion was restored. After anastomoses with the brachiocephalic arteries had been made, the systemic rewarming was initiated. An intraoperative and schematic illustration of the thoracic aorta is shown in Fig. 3.

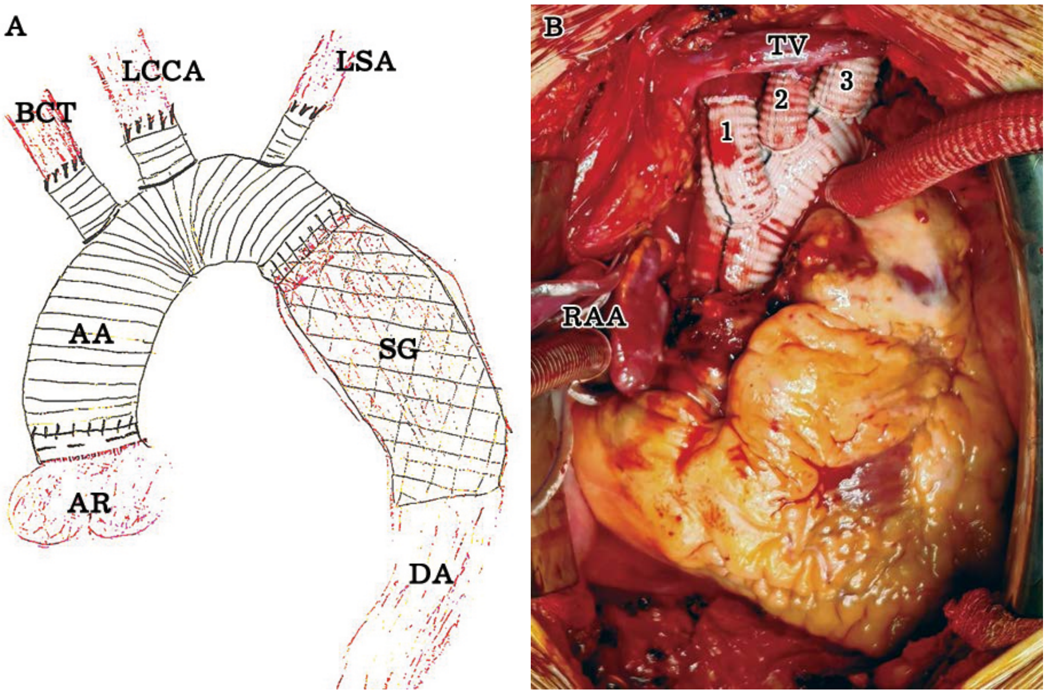

Fig. 3. A. The diagram of the Frozen Elephant Trunk surgery: AR, aortic root; AA, ascending aorta; BCT, brachiocephalic trunk; LCCA, left common carotid artery; LSA, left subclavian artery; SG, stent graft; DA, descending aorta. B. Intraoperative photograph. Surgery using the Frozen Elephant Trunk technique in a patient with acute Stanford type A aortic dissection , distal anastomosis in LZ 3 (↑ patient's head from above): RV, right ventricle; RAA, right atrial appendage; TV, transverse vein; PB, perfusion branch of the vascular prosthesis; 1, anastomosis of the vascular prosthesis branch with the brachiocephalic trunk; 2, anastomosis of the vascular prosthesis branch with the left common carotid artery; 3, anastomosis of the vascular prosthesis branch of the with the left subclavian artery

After completing the proximal reconstruction, the aortic clamp was removed, hemostasis was achieved, and cardiopulmonary bypass was completed. The sternum was sutured with wire and the wound was closed layer by layer.

Results

In half of the patients in the study group (n=9; 50%), the right axillary artery (AA) was chosen as the priority for arterial cannulation (Table 6). This allows for antegrade systemic perfusion and simplifies the technique of antegrade cerebral perfusion (ACP) during circulatory arrest (CA).

Table 6. Arterial cannulation

Arterial cannulation	Value, abs. (%)
Right axillary artery	9 (50)
Left common femoral artery	3 (16.7)
Aortic arch	1 (5.6)
Left axillary artery	5 (27.8)

In 83.3% of operations, bilateral ACP was performed. Intraoperative assessment of the ACP effectiveness during CA was performed using cerebral oximetry (Fig. 4). No critical decrease in cerebral oxygenation in either hemisphere was observed during the entire CA.

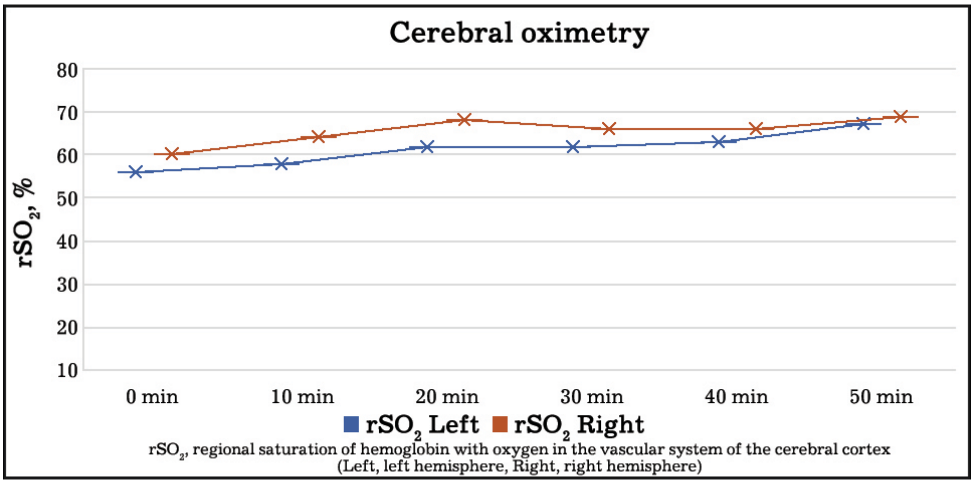

Fig. 4. Cerebral oximetry values during circulatory arrest

Intraoperative data are presented in Table 7.

Table 7. Intraoperative data

Parameters	Meaning
Time of assisted circulation, Me (Q_1;Q_3), min	241 (178;285)
Aortic clamping time, Me (Q_1;Q_3), min	135.5 (123;176)
Circulatory arrest time, Me (Q_1;Q_3), min	51 (33;63)
Body temperature, ^{o}C	25 (24;26)

Primary fenestration was localized in the ascending aorta in 61.1% of cases, and in the aortic arch in 6 patients (Table 8). In 9 patients, a distal aortic intimal defect could be visualized intraoperatively.

Table 8. Localization of fenestration

Parameters	Value, abs. (%)
Primary fenestration	
Ascending aorta	11 (61.1)
Sino-tubular junction	1 (5.6)
Orifice of the brachycephalic trunk	1 (5.6)
Orifice of the left common carotid artery	1 (5.6)
The orifice of the left subclavian artery	1 (5.6)
Lesser curvature of the aortic arch	3 (16.7)
Secondary fenestration	
Orifice of the brachycephalic trunk	4 (22.2)
Lesser curvature of the aortic arch	1 (5.6)
Descending aorta, below the isthmus	4 (22.2)

Given the extensive aortic lesion and dissection-associated complications, the large volume of thoracic aortic reconstruction, the use of deep hypothermia, and cerebral angioplasty are associated with a high risk of complications in the early postoperative period. Multiple organ failure syndrome developed in 5 patients (27.8%) (Table 9).

Table 9. Early postoperative results

Parameters	Value, abs. (%)
Hydropericardium	1 (5.6)
Pneumonia	7 (38.9)
Sepsis	3 (16.7)
Bleeding, resternotomy	4 (22.2)
Inflammation of the postoperative wound	1 (5.6)
Acute gastric bleeding	1 (5.6)
Tracheostomy	4 (22.2)
Cerebral complications	6 (33.3)
Renal failure	4 (22.2)
Multiple organ failure syndrome	5 (27.8)
30-day hospital mortality	4 (22.2)

Four patients (22.2%) required renal replacement therapy due to developing renal failure. In 38.9% of study subjects, a prolonged mechanical ventilation was complicated by pneumonia. A tracheostomy was performed in 22.2% of patients. Cerebral complications were observed in six patients (33.3%). The postoperative period was complicated by the sepsis development in 16.7% of cases.

In the study group, a 30-day mortality was 22.2% despite the fact that the preoperative risk was somewhat higher: GERAADA Score $Me(Q_1;Q_3)$ = 33.2 (28.95;35.8).

Three months after surgery, MSCT of the aorta with CE and ECG synchronization was performed to assess aortic remodeling (Fig. 5).

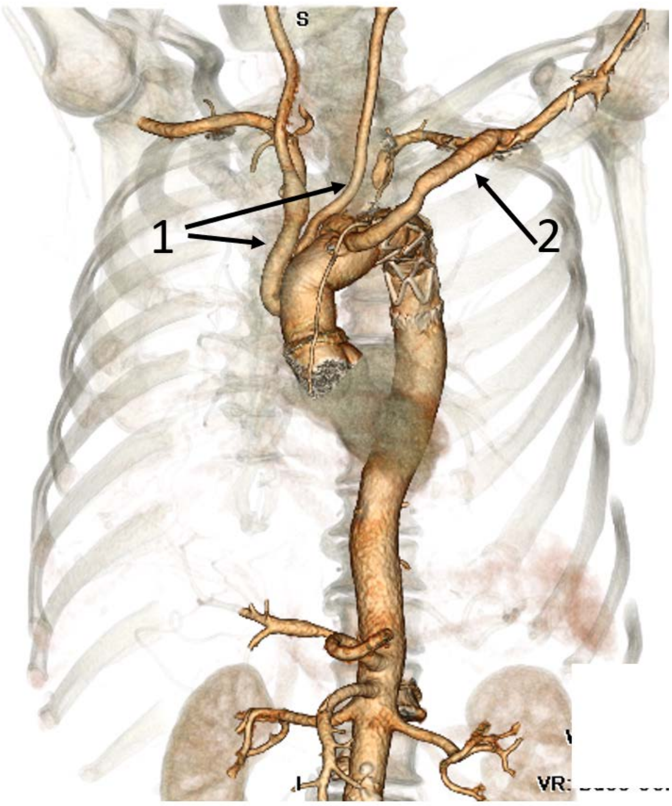

Fig. 5. Three-dimensional reconstruction of computed tomography data after surgery: vascular branches to the brachiocephalic trunk and left common carotid artery (1), extra-anatomical bypass to the left axillary artery (2) are identified. A stent-graft of a hybrid prosthesis is identified in the lumen of the descending aorta

Discussion

Currently, the problem of choosing the optimal extent of surgical reconstruction for acute type A aortic dissection remains relevant in the community of aortic surgeons. A significant portion of surgeons adhere to a conservative approach, which consists of the resection of the most vulnerable ascending aorta, the elimination of the proximal fenestration, redirection of blood flow into the true lumen and creation of conditions for obliteration of the false lumen [15, 17, 19]. Considering the frequency of the primary intimal defect location in the ascending aorta, in most cases the above approach will consist of linear prosthetics of the ascending aorta with or without forming an open distal anastomosis, or use of the "hemi-arch" technique for resection of the lesser curvature of the arch. The forced expansion of the reconstruction volume to the aortic arch (total arthroplasty) when fenestration is localized on the greater curvature or an aneurysm of the arch is present significantly worsens immediate results due to prolongation of the CPB and CA time in patients who already have a systemic inflammatory response before surgery [22]. Making a direct distal anastomosis in the LZ 3 zone is technically complex and is associated with an increased risk of developing difficult-to-control bleeding at this level. Also, the technical complexity of the anastomosis carries an increased risk of forming an artificial fenestration, which does not contribute to the resolution of malperfusion present in some patients or to a reduction in the risk of aortic-associated complications in the future. The use of the hybrid FET technique in the most acute phase of the aortic dissection allows for an expansion of the scope of proximal reconstruction during the primary surgery due to the technological mitigation of the negative aspects of the "standard" aortic arch replacement. First, there is a relative technical "ease" in forming the distal anastomosis, which significantly reduces the CA time and the risk of bleeding. Second, it becomes possible to proximalize the anastomosis (including LZ 0) without reducing the effect of the intervention at the level of the proximal descending aorta. Third, the absence of artificial fenestration, type 1 A and type II endoleaks and a predicted restoration of blood flow through the true lumen at the level of the descending aorta will be of decisive importance in relieving malperfusion syndrome.

FET technique in the long term allows achieving thrombosis of the false lumen up to 95.5% [19], which will significantly reduce the risk of negative aortic remodeling at the level of the proximal descending aorta.

Despite the numerous advantages of this method, its use in patients with acute aortic dissection should be considered based on the clinical condition and perioperative risk. FET is a technically challenging procedure requiring prolonged periods of on-pump time, aortic cross-clamping time, and CA. The patient's clinical status, which is quite clearly defined in emergency situations by the University of Pennsylvania classification (Penn), is crucial in choosing this method.

In patients with Penn A (uncomplicated), it makes sense to consider expanding the scope of proximal reconstruction using the FET technique if their perioperative risk is low or moderate, which will significantly reduce the risk of negative aortic remodeling and the development of late aortic-associated complications in the future.

For patients with Penn B (malperfusion), the use of this technique is advisable during primary proximal aortic reconstruction, when there is a short time interval from the moment of disease manifestation and there is no irreversible ischemic damage to the organs.

Patients with Penn C (systemic ischemia) often have significant metabolic changes due to a low cardiac output, and the extensive aortic reconstructions with prolonged periods of on-pump maintenance may contribute to the development or progression of multiple organ failure in the early postoperative period. In this group of patients, the extent of reconstruction should be minimized.

Penn B+C patient category is the most severe and requires further research to determine the optimal treatment strategy, possibly using hybrid technologies.

In this report, we present our initial experience using the FET technology in a multi-functional emergency hospital. The results obtained in a limited number of patients do not allow for a comprehensive statistical analysis. However, the observed trend toward a reduction in early mortality and postoperative complications suggests a positive outlook for expanding the indications for this technology in patients with early acute aortic dissection.

Conclusion

In our study, the use of hybrid prostheses with proximalization of the distal anastomosis zone in LZ 2 (77.7% of cases) allowed us to obtain relatively satisfactory early results in the treatment of acute aortic dissection (30-day mortality making 22.2%), comparable with the estimated risk of perioperative mortality according to GERAADA Score (23.7% in the overall group and 33.2% in the fatal outcome group), despite the fact that only 16.7% of patients had an "uncomplicated" course of the disease (Penn A) according to the Pennsylvania classification.

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