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Postoperative care in patients with DeBakey type I aortic dissection: criteria of aortic remodeling and risk factors of disease progression

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ABSTRACT

Aim — to present current treatment modes for DeBakey type I aortic dissection, to compare their early and mid-term postoperative results, to evaluate predictors of negative aortic remodeling after surgery.

Material and methods. Retrospective cohort analysis included 78 patients with DeBakey type I aortic dissection who underwent surgical treatment in 2009—2017. Patients were divided into 3 groups depending on type of intervention: group I (n=22) — Elephant Trunk procedure, group II (n=29) - hybrid interventions, group III (n=27) — proximal aortic replacement alone. Early postoperative results and aortic remodeling in mid-term postoperative period were compared.

Results. There were no significant differences in postoperative morbidity, in-hospital mortality and freedom from aortic death. However, 7 patients were lost for follow-up in group III. Analysis of false lumen patency showed results in favor of more aggressive approach (groups I and II) with significantly higher rate of false lumen thrombosis in segments 1 and 2 ($p<0,001$ and $p=0,004$ respectively). Freedom from negative aortic remodeling was also significantly higher in groups I and II. Risk factors of patent false lumen were residual fenestration, large volume of false lumen in segment 2, dissection of supra-aortic vessels and connective tissue disorders. Risk factors of negative aortic remodeling were connective tissue disorders, patent false lumen and dissection of supra-aortic vessels.

Conclusion. Advanced surgical approach (Elephant Trunk procedure or hybrid interventions) should be preferred for DeBakey type I aortic dissection.

Keywords: aortic dissection, remodeling, hybrid interventions.

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Introduction

Aortic dissection is currently one of the most serious pathologies in cardiovascular surgery with annual incidence near 2-3.5 cases per 100,000 [1]. Over the past decades, treatment of these patients has undergone significant changes. However, only proximal aortic replacement is still performed for aortic dissection in some clinics despite available modern procedures including Elephant Trunk surgery and hybrid interventions [2]. It is known that this approach is associated with need for redo surgery in 20—30% of cases within 4.7±2.8 years after the first operation [3].

In this report, we have compared three surgical approaches in patients with aortic dissection: proximal aortic replacement alone (early years), elephant trunk procedure (blood flow direction into the true aortic lumen), and hybrid interventions. Fundamental surgical differences, features of postoperative course and important aspects of management of patients in mid- and long-term period are considered.

Material and methods

Retrospective cohort analysis included 78 patients with true DeBakey type I aortic dissection (up to the level of bifurcation) who were operated in 2009—2017 **(Fig. 1)**. All patients were divided into 3 groups depending on surgical technique: group I (n=22; 2013—2017) — ascending aorta and aortic arch replacement (Elephant Trunk procedure with blood flow direction into the true lumen); group II (n=29; 2013—2017) — hybrid approach — Frozen Elephant Trunk procedure and total debranching of supra-aortic vessels; group III (n=27, 2009—2013) — proximal aortic replacement alone (ascending aorta with (n=17) or without hemiarch surgery) **(Table 1)**. Groups were comparable regarding type of proximal aorta reconstruction and concomitant cardiac surgery: supracoronary ascending aortic replacement was performed in 56.3% (including 34.5% of aortic valve or aortic root repair), Bentall-DeBono procedure or aortic valve replacement followed by ascending aortic replacement were performed in 33.4% of patients, valve-sparing surgery (David procedure) was performed in 14.8% of cases. Concomitant myocardial revascularization was performed in 11.5% of patients, mitral or tricuspid valve surgery — in 3.9% of patients.

In-hospital, mid- and long-term outcomes were compared. Mean follow-up was 2.4±1.7 years (range 0.5—6.9).

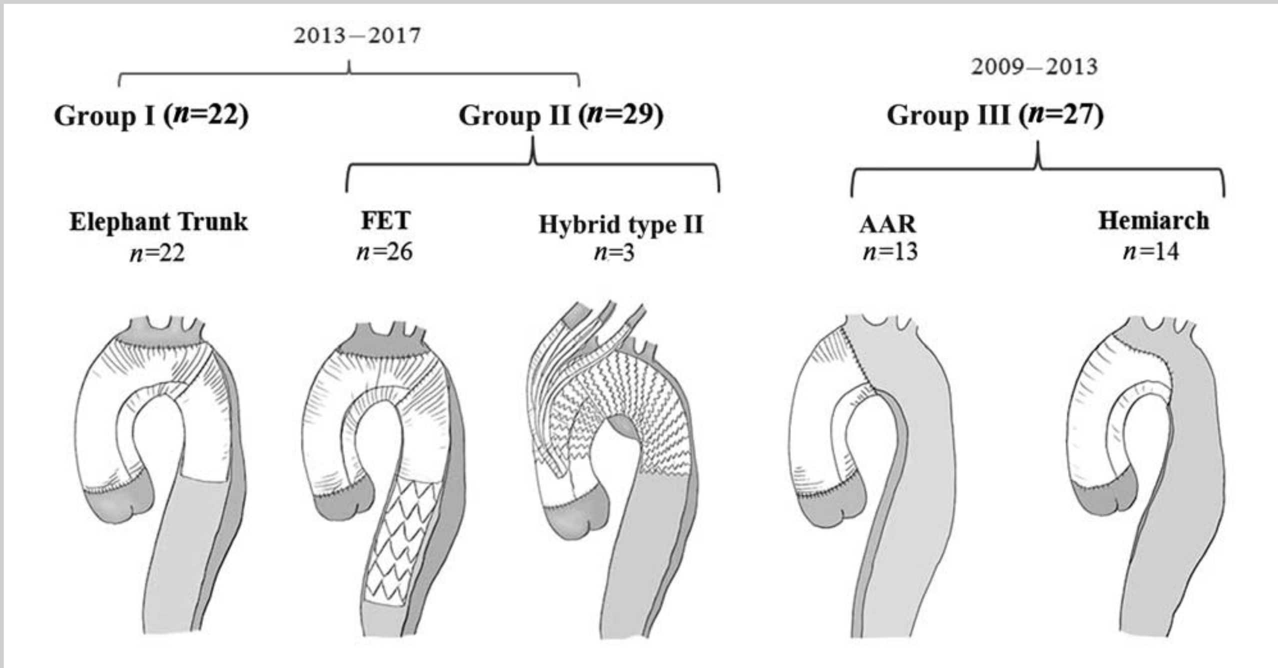

Fig. 1. **Schemes of interventions. FET — Frozen Elephant Trunk; hybrids type II — debranching of supra-aortic vessels into the prosthesis of the ascending aorta followed by thoracic aortic stenting; ПВА — ascending aortic replacement.**

Table 1. Characteristics of patients

Variable, n (%)	Group I (n=22)	Group II (n=29)	Group III (n=27)	In all (n=78)	p
Age (M±σ, years)	51,4± 9,3	53,8 ± 9,8	50,3 ± 10,9	51,9 ± 10,1	0,426
Male, n (%)	14 (63,6)	23 (79,3)	21 (77,8)	58 (74,4)	0,394
Connective tissue dysplasia, n (%)	10 (45,4)	4 (13,8)	12 (44,4)	26 (33,3)	**0,028***
Arterial hypertension, n (%)	20 (90,9)	26 (89,7)	23 (85,2)	69 (88,5)	0,797
Coronary artery disease, n (%)	3 (13,6)	4 (13,8)	3 (11,1)	10 (12,8)	0,936
Diabetes mellitus, n (%)	1 (4,5)	4 (13,8)	0	5 (6,4)	0,100
Chronic kidney disease, n (%)	5 (22,7)	3 (10,3)	1 (3,7)	9 (11,5)	0,069
Chronic obstructive pulmonary disease, n (%)	2 (9,1)	4 (13,8)	2 (7,4)	8 (10,3)	0,728
Previous stroke or TIA, n (%)	2 (9,1)	1 (3,4)	3 (11,1)	6 (7,7)	0,513
Previous cardiac/aortic surgery, n (%)	2 (9,1)	3 (10,3)	1 (3,7)	6 (7,7)	0,613
Acute dissection, n (%)	5 (22,7)	6 (20,7)	4 (14,8)	15 (19,2)	0,759
Subacute dissection, n (%)	5 (22,7)	10 (34,5)	8 (29,6)	23 (29,5)	0,660
Chronic dissection, n (%)	12 (54,5)	13 (44,8)	15 (55,6)	40 (51,3)	0,679
Visceral malperfusion, n (%)	1 (4,5)	2 (6,9)	1 (3,7)	3 (3,8)	0,107
Cerebral malperfusion, n (%)	2 (9,1)	2 (6,9)	0	4 (5,1)	0,308
Malperfusion of lower extremities, n (%)	0	4 (13,8)	1 (3,7)	5 (6,4)	0,855
Multiple malperfusion, n (%)	0	2 (6,9)	1 (3,7)	3 (3,8)	0,447

Note. Data are presented as n (%). p — values for 3 groups. There was significant difference in χ^2-test for connective tissue dysplasia, p=0.0078 (Bonferroni correction was taken into account: statistical significance for p<0.0083) between groups I and II and groups II and III. TIA — transient ischemic attack.

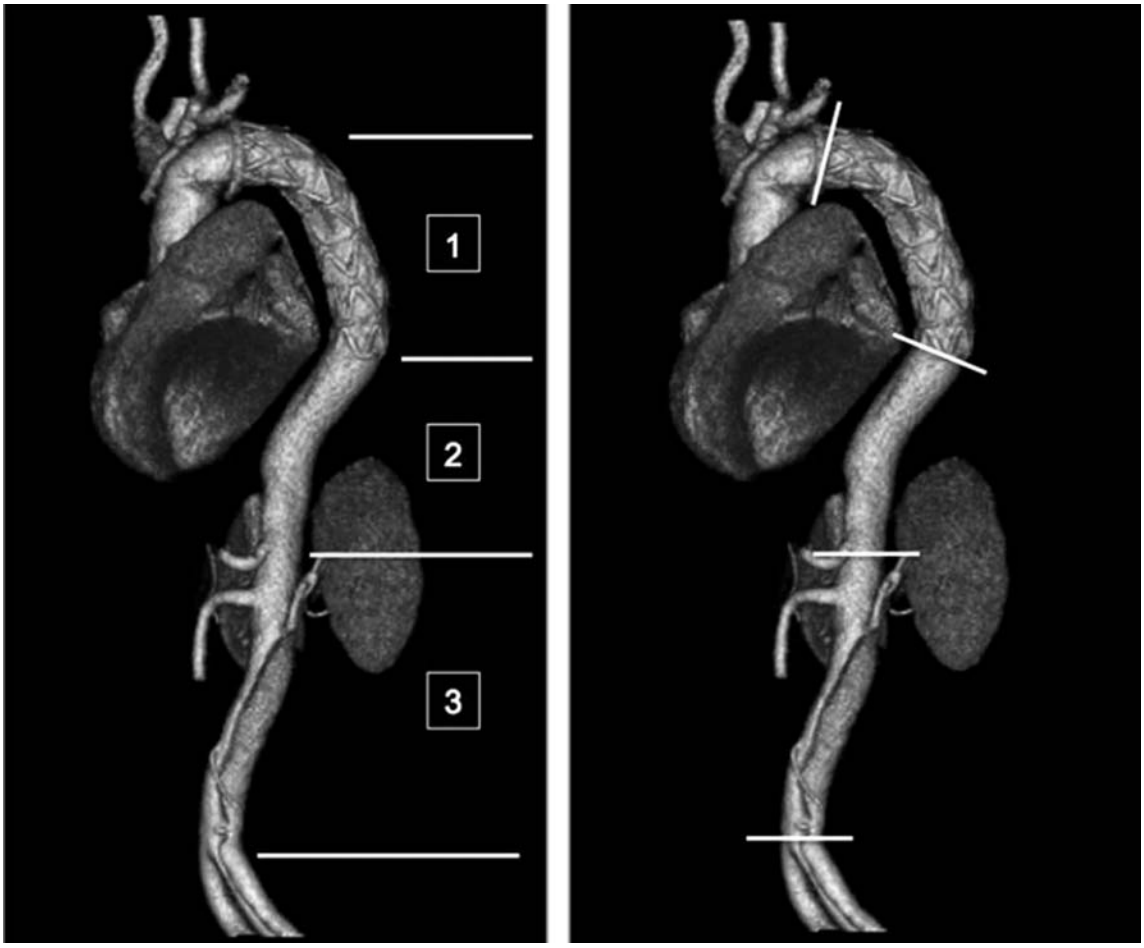

***Fig. 2.* Postoperative 3D CT-scan of the aorta.**

A – segments for assessment of aortic remodeling: segment 1 — from the isthmus to the level of LA; segment 2 — from the level of LA to the level of celiac trunk orifice, segment 3 — from the level of celiac trunk orifice to aortic bifurcation. B — levels of planimetric analysis of true lumen and overall dimension of the aorta (mean diameter, circumference and area).

In group I 100% of discharged patients were examined, in group II — 96%, in group III — 70%. CT of the aorta was performed in all patients prior to surgery and at discharge. According to international guidelines, patients with acute dissection were surveyed after 3, 6 and 12 months after surgery and thereafter annually if negative dynamics was absent; those with subacute and chronic dissection were examined after 6 months, 1 year and thereafter annually [1, 4]. In total, 272 contrast-enhanced CT-scans of the aorta were analyzed. CT-control was completed in 95, 92 and 61% of patients in groups I, II and III, respectively. Analysis of CT-data was carried out by using of OsiriX software package, version 5.5.2. (PixmcoSàrl, «Bernex», Switzerland). Aortic remodeling in mid- and long-term period was performed in accordance with previously described standards [5, 6]: thoracoabdominal aorta was divided into 3 segments: from the isthmus to the level of the left atrium (segment 1), from the level of the left atrium to the level of the celiac trunk ostium (segment 2) and from the celiac trunk ostium to the level of the aortic bifurcation (segment 3) **(Fig. 2)**.

We analyzed the state of false lumen (total thrombosis, partial thrombosis or persistent blood flow) and aortic remodeling by using of volumetric analysis. Remodeling was assessed considering the standards approved in endovascular surgery [7]: change by 10% was considered significant, true lumen enlargement by >10% with stable false lumen or overall decrease of aortic volume by >10% with stable true lumen were considered as positive remodeling, any changes less than 10% were interpreted as stable remodeling, any other changes - as negative remodeling. Logistic regression was used to determine the main risk factors of patent false lumen and negative aortic remodeling.

Statistical analysis was performed by using of SPSS 17.0 software package (SPSS, Inc., Chicago, USA). Paired Student's t-test was used to compare two groups and ANOVA univariate analysis was applied for 3 groups with

Table 2. **Early postoperative results**

Variable, n (%)	Group I (n=22)	Group II (n=29)	Group III (n=27)	p-test
Multiple organ failure [a], n (%)	1 (4,5)	3 (10,3)	8 (29,6)	0,046 [a]
Stroke, n (%)	1 (4,5)	1 (3,4)	2 (7,4)	0,831
Subdural hematoma, n (%)	0 (0)	1 (3,4)	0 (0)	1,000
Paraplegia, n (%)	0 (0)	0 (0)	0 (0)	1,000
Re-sternotomy (bleeding), n (%)	2 (9,1)	3 (10,3)	6 (22,2)	0,396
Renal failure (hemodialysis), n (%)	2 (9,1)	2 (6,9)	5 (19,2)	0,364
Intraoperative myocardial infarction, n (%)	1 (4,5)	0 (0)	1 (3,7)	0,527
Ventilation >3 days, n (%)	7 (31,8)	6 (20,7)	7 (25,6)	0,684
Tracheostomy, n (%)	5 (22,7)	3 (10,3)	3 (11,1)	0,465
Wound complications, n (%)	3 (13,6)	3 (10,3)	4 (14,8)	0,915
In-hospital mortality, n (%)	1 (4,5)	3 (10,3)	4 (14,8)	0,515
Multiple organ failure	1	1	3	-
Meningitis and sepsis	-	1	-	-
Stroke	-	1	-	-
Abdominal bleeding after cholecystostomy	-	-	1	-

Note. Data are presented as n (%). p-values for three groups. a — threshold p-value <0.008 was not reached after Bonferroni correction (p=0.011).

normal distribution. In case of abnormal distribution of continuous data, we used Wilcoxon (for dependent samples) and Mann—Whitney (for independent samples) tests were used to compare two groups, Kruskal—Wallis test — to compare three groups. Categorical variables were compared by using of Fisher's exact test or χ^2-test. Kaplan—Meier method was used to analyze survival, freedom from redo aortic surgery, aorta-associated mortality, negative remodeling and rate of false lumen thrombosis. Binary logistic regression and Wald statistics were used to determine significant risk factors (threshold p-value <0.05).

Results

Early postoperative results

There were similar early postoperative morbidity and mortality despite significantly less time of cardiopulmonary bypass (CPB), aortic cross-clamping and circulatory arrest in group III compared with groups I and II (p<0.001) **(Table 2)**. Moreover, large intraoperative blood loss was noted in group III (p=0.013) that was reflected in a tendency to less incidence of multiple organ failure in groups I and II compared with group III (4.5, 10.3 and 29.6%, respectively). However, significant alpha-threshold (p<0.008) was not reached (p=0.011) considering Bonferroni correction. These data confirm that advanced interventions are not associated with higher perioperative risks compared to more «simple» surgery of proximal aortic replacement alone despite their technical complexity (prolonged CPB, aortic arch repair under circulatory arrest with cerebral and visceral protection). It should also be noted that advanced blood loss in group III was primarily due to widely used in those years deep hypothermia followed by severe coagulopathy and limited possibilities of pharmacological hemostasis.

Mid- and long-term outcomes

Completeness of the analysis of mid- and long-term outcomes was 100% in group I, 95% in group II (one patient is lost) and 70% in group III (7 patients are lost). Mean follow-up was 32±21 months. Overall 1- and 3-year freedom from aorta-related mortality was 98% and 94%, respectively. Annual freedom from aorta-related mortality was 100, 100 and 94% groups I, II and III, respectively; 3-year freedom — 94, 100 and 88%, respectively. Aortic complication followed by death occurred in 1 patient of group I (with mega-aorta, connective tissue dysplasia and negative aortic remodeling; patient died at home despite call for additional surgical treatment). There was no aorta-related mortality in group II. In group III, 2 patients died due to aortic rupture. Overall survival and freedom from aorta-related mortality were similar in all groups **(Fig. 3)**. However, it should be emphasized that postoperative follow-up was small and 7 patients were unavailable for the contact in group III (and, as a result, censored).

Freedom from additional distal aortic surgery was also similar **(Fig. 4)**. However, it should be noted that 7 patients were not available for assessment and lost in group of proximal reconstructions (group III) while additional surgery was elective in groups I and II. Five out of 8 patients in all groups who required or are awaiting for additional interventions due to negative aortic remodeling have connective tissue dysplasia.

False lumen in previously described segments of the thoracoabdominal aorta was the main criterion of aortic stabilization **(Fig. 5)**. Hybrid interventions were followed by thrombosis of false lumen in the first segment at discharge regardless stage of dissection. Elephant trunk procedure was accompanied by thrombosis of false lumen in the first segment in 76% of cases at discharge, after 2 years — in 88% of patients.

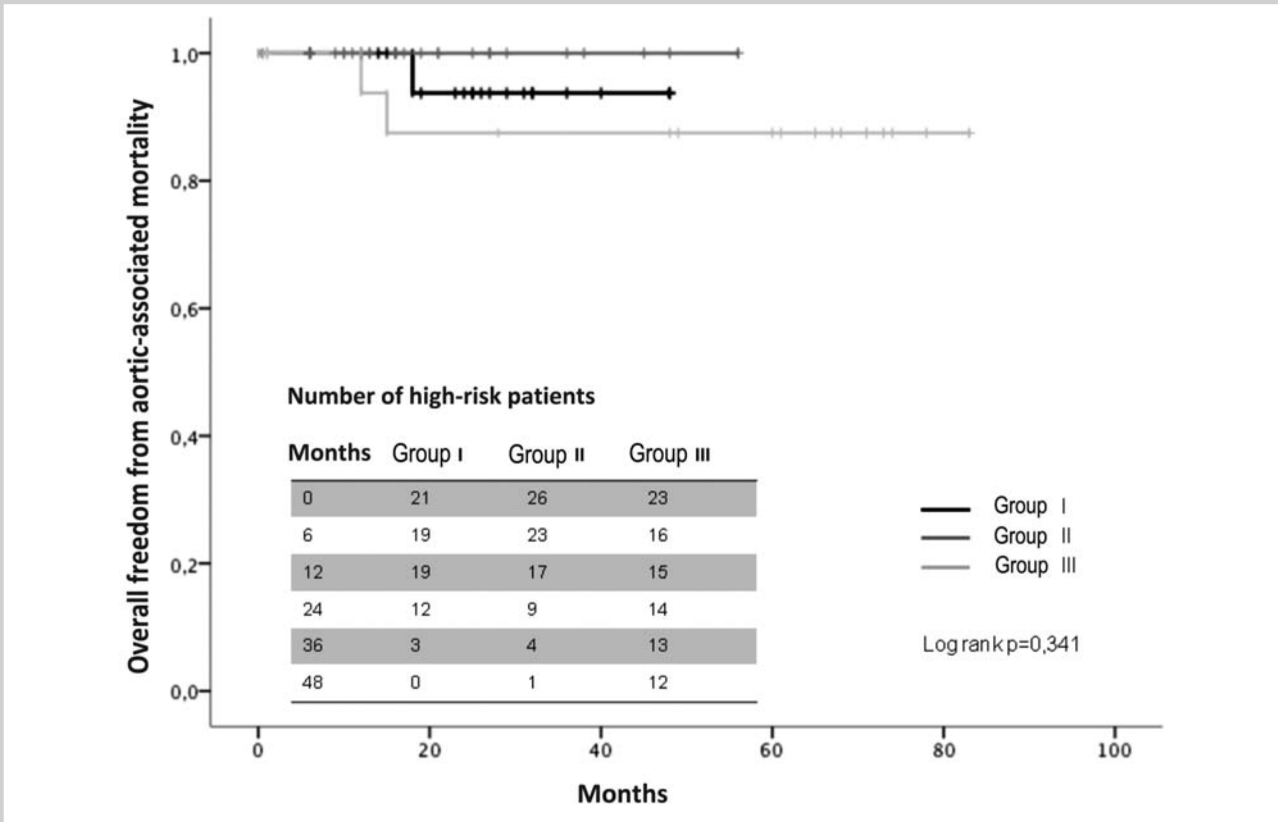

Fig. 3. **Kaplan—Meier curves of cumulative freedom from aorta-associated mortality in all groups.**

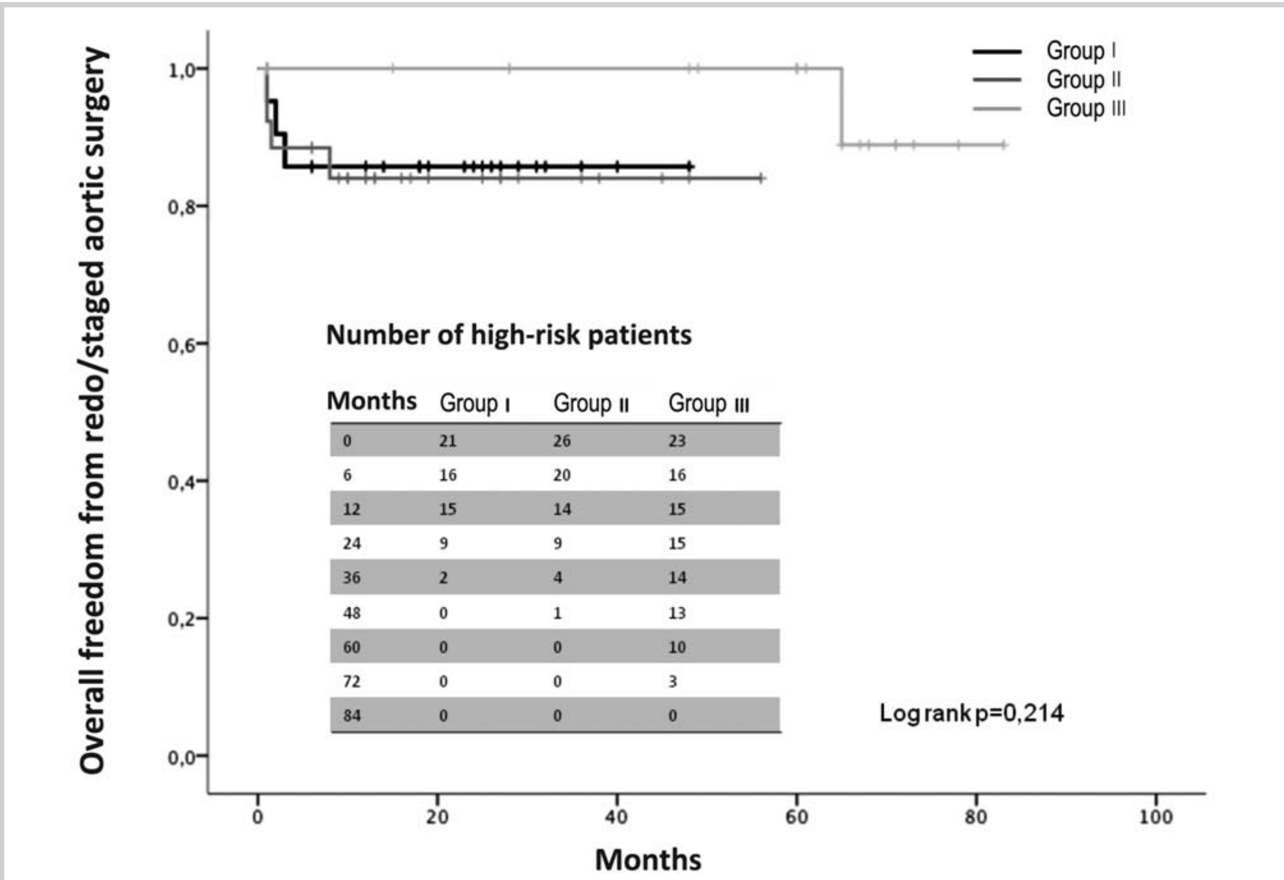

Fig. 4. **Kaplan—Meier curves of freedom from staged or additional aortic interventions.**

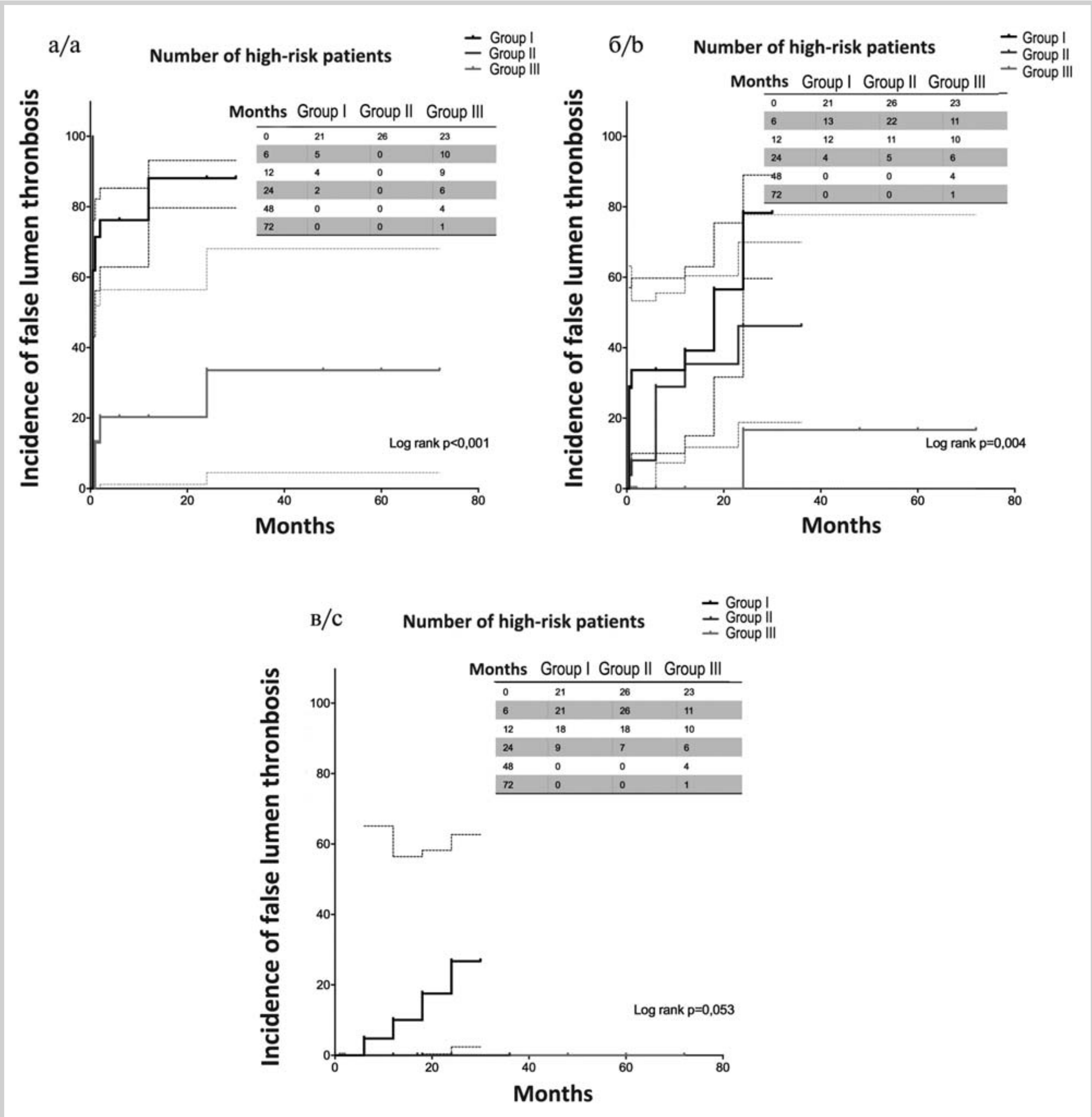

Fig. 5. **Kaplan—Meier curves of false lumen thrombosis in segments I, II and III (curves A, B and C, respectively).**

As was to be expected, proximal reconstructions led to thrombosis in early postoperative period in 13% of patients, after 2 years — in 34% (in segment 1, log-rank $p<0.001$). Significant difference was obtained for the second segment (log-rank $p=0.004$), while false lumen thrombosis at discharge occurred in 30% of patients of group I, in 8% of group II and was absent in group III.

According to the analysis of aortic remodeling, radical interventions had advantages over the proximal reconstructions particularly in the second and third segments **(Fig. 6)**. Annual postoperative freedom from negative remodeling in segment I was 91, 96 and 93% in groups I, II and III, respectively; after 2 years — 91, 96 and 74%, respectively. Freedom from negative remodeling in segment II was similar in groups I and II (88 and 92% after 2 years, respectively). In the third group, this value was 50% after 2 years ($p=0.026$ for Elephant trunk procedure, $p=0.047$ for Frozen Elephant Trunk procedure). Significant difference regarding segment III was also revealed between groups I and III ($p=0.035$). Annual freedom from negative remodeling was 100, 92 and 49%, after 2 years — 93, 86 and 42% in groups I, II and III, respectively.

Planimetric analysis of CT-scans before and after surgical treatment and comparison of these data with volumetric characteristics of the aorta in mid- and long-term postoperative period were also essential. Although volumetric analysis is now recognized as fundamental in assessing aortic remodeling [5, 7], maximum diameter and aortic lumen square at the certain levels are often used to analyze the aorta in postoperative period. So, volumetric data of negative aortic remodeling in 51 cases (in all three segments) were accompanied by similar planimetric data in 84% of measurements of aortic square (p=0.006), 69% of measurements of mean diameter (p<0.001) and only 35% of measurements of aortic circumference (p <0.001). This means augmentation of the diameter within the areas of anatomical aortic deviations in other cases which are not available for measurement in axial plane. Considering

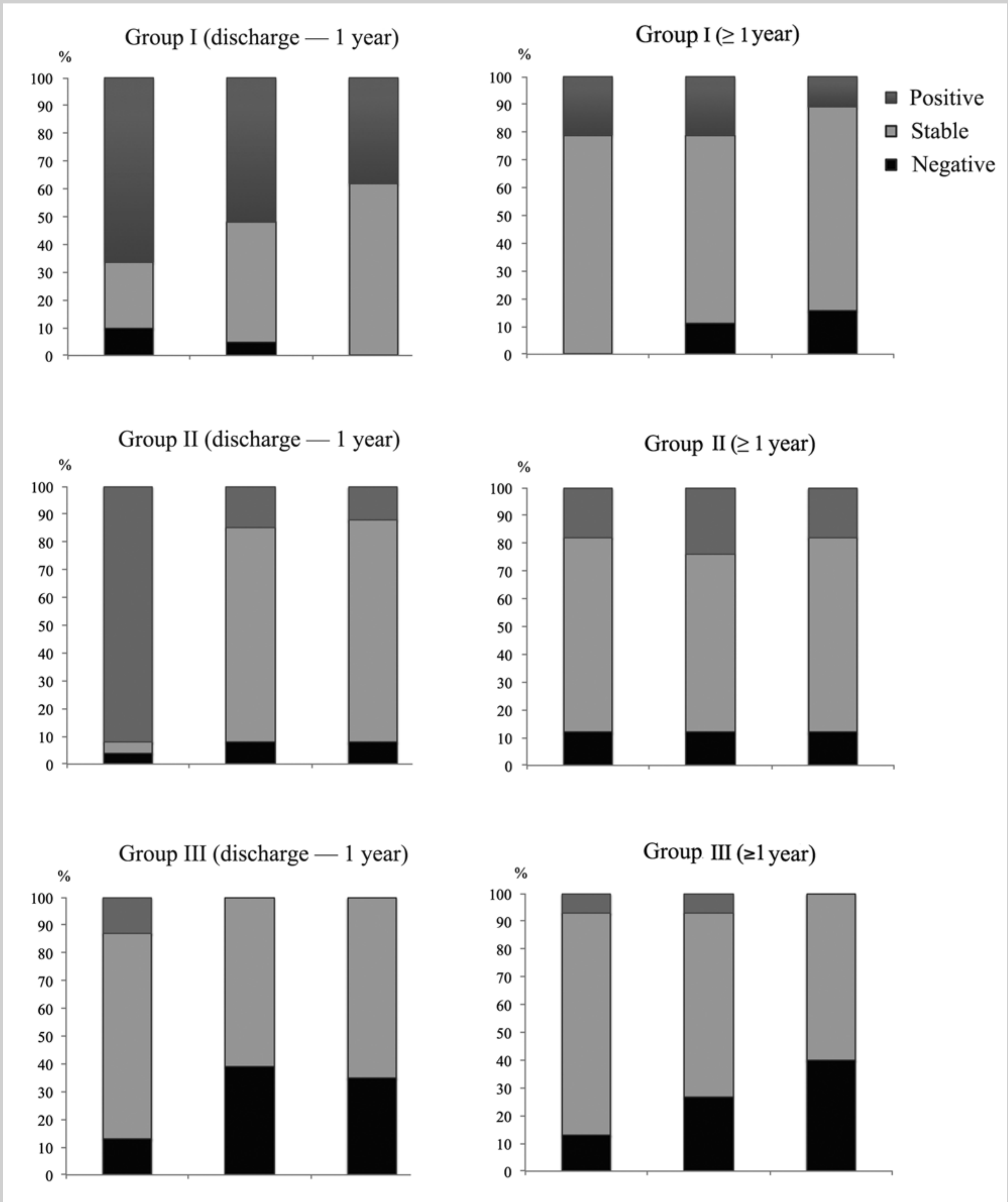

Fig. 6. **Histograms reflecting aortic remodeling by the segments and periods (■ — positive, ■ — stable, ■ — negative remodeling).**

these data, it is obligatory to combine planimetric measurements with thorough volumetric analysis.

Factor analysis

In this trial, binary logistic regression was applied to determine risk factors of patent false lumen (no total thrombosis). Patent false lumen was recognized as both completely patent false lumen and with partial thrombosis. Factors affecting the state of false lumen were enrolled into multivariate analysis by Wald's direct inclusion. Certain risk factors of patent false lumen in descending thoracic aorta were identified. Residual fenestration was associated with 39-fold increase of the likelihood of patent false channel. Another risk factor was false lumen volume in the second segment of the aorta (OR 1.017; p=0.045). Risk of patent false lumen within segment I was associated with dissection of supra-aortic vessels (OR 9.052; p=0.029), connective tissue dysplasia (OR 27.311; p=0.001), and residual fenestration (OR 12,591; p=0.008); for segment II — residual fenestration within or near this segment (OR 2.774; p=0.040); for segment III — false lumen volume within this segment (OR 1.279; p=0.01).

Similarly, factor analysis of negative aortic remodeling was performed for each segment. Significant risk factor for the first segment was absence of false lumen thrombosis (OR 10.370; p=0.003); for segment II — connective tissue dysplasia (OR 31,200; p<0.001) and dissection of supra-aortic vessels (OR 14.615; p=0.008); for segment III -connective tissue dysplasia (OR 10.571; p=0.001).

Discussion

Optimal surgical strategy for DeBakey type I aortic dissection is still unclear. «Primary tear oriented» approach involving resection of proximal fenestration, ascending aortic replacement using «open» distal anastomosis technique or hemiarch procedure has been considered as a standard approach for many years [9, 10]. However, according to current data patent false lumen distal to primary reconstruction is observed in 64—90% of patients and aggravates long-term outcomes despite successful proximal aortic repair [10—15]. It is also known that so-called residual fenestrations are significant predictors of incomplete thrombosis of false lumen (including both distal and proximal fenestrations which remained intact after primary surgery) [16]. This means that advanced surgery significantly increases the likelihood of false lumen thrombosis and maximum stabilization of the aorta.

The purpose of surgical treatment is not only saving the life of patient with DeBakey type I aortic dissection, but also maximum stabilization of native aorta distal to reconstruction. Surgical or endovascular closure of proximal fenestration and hemodynamically significant distal fenestration is the only method to induce thrombosis of false lumen. So, hybrid procedures are followed by false lumen thrombosis in 91—95.5% of cases [17]. So, world tendency to apply more radical interventions is justified. Of course, large prospective randomized trial is essential to confirm the advantages of certain technique. However, it is impracticable in clinical practice and advanced procedures are currently preferred considering large evidence base [18, 19].

Surgical techniques of Elephant Trunk and Frozen Elephant Trunk procedures are similar excepting features of hybrid stent-graft deployment. «Trunk» or stent-graft deployment within true lumen of the descending thoracic aorta (hemodynamic correction type I) is essential in both cases (as well as in hybrid interventions type II). Frozen Elephant Trunk technique may be realized by using of hybrid stent-graft systems involving proximal vascular prosthesis and distal stent-graft and intraoperative stenting of the descending thoracic aorta followed by aortic arch replacement incorporating stent-graft into distal anastomosis. E-vita Open and E-vita Open Plus (Jotec GmbH, Hechingen, Germany) and Thoraflex Hybrid Prosthesis (Vascutek, Terumo, Inchinnan, United Kingdom) are currently the most common in Russia.

Debranching of supra-aortic vessels into ascending aortic prosthesis followed by thoracic aortic stenting is another option for hybrid treatment of total aortic dissection. These procedures are preferred in high-risk patients (severe comorbidities, age over 75 years, previous cardiac surgery, stroke, etc.) because they are associated with significantly less duration of cardiopulmonary bypass and do not require circulatory arrest. However, in our center debranching is used according to strict indications and not recommended for patients with moderate surgical risk due to advanced risk of thrombosis of the branches followed by fatal neurological complications.

Hybrid procedures are accompanied by specific early and long-term postoperative complications. These risks are especially high in patients with connective tissue dysplasia [21]. In case of abdominal aortic stenting the structure of the aorta is as close to linear as possible. However, stent-graft and aortic wall within aortic arch and isthmus are under advanced shear stress. This aspect is combined with the rigid structure of the stent-graft, incomplete congruence of its configuration with aortic deviation and pulsatile stress that leads to intimal injury [22]. So-called distal stent-graft-induced new entry occurred. Paraplegia is another stent-associated complication. Incidence of this complication is much less after Elephant Trunk procedure (0.4—2.6%) compared with hybrid interventions (0—22%) [23—25]. We apply generally accepted protocols to prevent paraplegia after hybrid procedures: hemodynamic control (controlled hypertension with mean pressure 80-85 mm Hg) and cerebrospinal fluid (CSF) drainage intraoperatively and for 2 days after surgery (CSF pressure 10—12 mm Hg) [26, 27]. Thus, none of the current methods is a «panacea». Proximal aortic replacement may be only recommended for acute dissection followed by severe hemodynamic disturbances in clinics with no experience in aortic arch surgery (and patient transfer to expert centers is impossible). Advanced reconstructions (Elephant

Trunk procedure with hemodynamic correction type 1, Frozen Elephant Trunk as a gold standard for acute dissection of the entire aorta and hybrid operations) are recommended for clinics with large experience in cerebral and visceral protection during aortic arch repair.

Conclusion

Our data confirmed the effectiveness of Elephant Trunk technique and hybrid operations compared with proximal reconstructions. Elephant Trunk procedure with hemodynamic correction type 1 is followed by similar favorable outcomes as hybrid operations upon condition of correct selection of patients depending on stage of dissection, localization and dimensions of fenestrations, state of visceral organs. Individual approach is essential to determine the most optimal surgical strategy. It is very important to perform contrast-enhanced CT of the entire aorta with careful volumetric analysis in postoperative period.

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