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КАЛЬЦИНИРОВАННЫЙ КЛАПАННЫЙ АОРТАЛЬНЫЙ СТЕНОЗ: ВОЗМОЖНОСТИ И ОСЛОЖНЕНИЯ ХИРУРГИЧЕСКОГО ЛЕЧЕНИЯ

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Цель. Обсуждение различных подходов к выбору метода хирургической коррекции выраженного аортального стеноза (АС). Рассматриваются показания, противопоказания, преимущества и возможные осложнения транскатетерной имплантации аортального клапана (ТИАК). Приводится описание клинического случая, обсуждаются возможные причины неблагоприятного исхода.

АС является наиболее распространенным клапанным пороком, частота которого существенно увеличивается с возрастом и занимает одно из первых мест среди показаний к операции на сердце. Особенностью клинической картины АС является длительный бессимптомный период, продолжительность которого варьирует у различных пациентов. С момента возникновения первых клинических проявлений прогноз заболевания резко ухудшается. Хирургическое протезирование аортального клапана длительное время являлось «золотым стандартом» лечения пациентов с симптомным АС. Увеличивающееся число пациентов пожилого и старческого возраста с большим количеством сопутствующих заболеваний, у которых применение вмешательства с искусственным кровообращением сопряжено с повышенным риском развития послеоперационных осложнений, стало решающим фактором для разработки альтернативных методов хирургической коррекции патологии АК.

Заключение. ТИАК в настоящее время обладает существенными преимуществами перед хирургическим протезированием и является методом выбора у больных пожилого возраста, применяется для лечения неоперабельных больных, а также пациентов с высоким, промежуточным и низким хирургическим риском и требует мультидисциплинарного подхода.

Ключевые слова*: аортальный стеноз; транскатетерное протезирование аортального клапана; преимущества ТИАК; осложнения ТИАК.*

CALCIFIC AORTIC VALVE STENOSIS: POTENTIALS AND COMPLICATIONS OF SURGICAL TREATMENT

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Aim. The study aim is to discuss different approaches to the selection of a method of surgical correction of pronounced aortic stenosis (AS). Indications, contraindications, advantages and probable complications of transcatheter aortic valve implantation (TAVI) are considered. A description of a clinical case is given, and probable causes of unfavorable outcomes are discussed.

AS is the most common valvular disease, and its frequency increases significantly with age. It is one of the leading indications for heart surgery. A peculiarity of the clinical presentation of AS is a long asymptomatic period that varies from patient to patient. With the appearance of the

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first clinical manifestations, the prognosis of the disease sharply worsens. For a long time, surgical replacement of the aortic valve remained «the gold standard» of treatment of patients with symptomatic AS. An increase in the number of elderly patients and those in old age with many comorbid diseases who have received cardiopulmonary bypass is linked with an increased risk of postoperative complications, which are became a determining factor for the development of alternative methods of surgical correction of aortic valve pathology.

Conclusion. At present, TAVI has considerable advantages over surgical replacement; is a method of choice for elderly and inoperable patients as well as patients at high, intermediate, and low risk from surgery; and requires a multidisciplinary approach.

Keywords: *aortic stenosis; transcatheter replacement aortic valve; advantages; complications.*

Aortic stenosis (AS) is the most common acquired heart disease (41.2%) and is present in 2-7% of the population above 65 years of age [1]. In most cases, it results from calcification of the aortic valve (AV), which can be congenitally bicuspid (50% of cases), initially normal (30-40% of cases), or unicuspidal (10%). Calcinosis usually spreads from the base of leaflets to their free edge, limiting mobility and reducing the surface area of the aortic ostium without fusion along commissures. A less common cause of AS is rheumatic lesion with fusion of the AV along commissures with subsequent destruction and calcification of the edges of leaflets. Here, AS is often accompanied by lesions of the mitral valve (MV). Congenital disease of the AV is a more common cause of AS at young age, with infectious endocarditis, systemic lupus erythematosus, and others being less common causes [2,3].

Aim. The aim of this review is to discuss different approaches to the choice of a method of surgical correction of a pronounced AS and to conduct an analysis of the indications, contraindications, advantages, and probable complications of transcatheter AV implantation (TAVI). As an illustration of the problem, a description of a clinical case is given with discussion of probable causes of unfavorable outcomes.

There exists a hypothesis of calcific AS being in many aspects similar to atherosclerosis. However, the mechanisms of development of AS are more complicated: chronic inflammation, deposition of lipoproteins, activation of the renin-angiotensin system, accelerated fibrosis, and, that which is especially important, *osteoblastic transformation of interstitial cells of the valve and calcification with activation of specific cellular signal pathways controlling calcification of the valve, which is probably genetically determined* [4].

Obstruction in AS develops gradually over decades. The left ventricle (LV) adapts to systolic overload by pressure through thickening of the wall and hypertrophy with normal volume of the chamber. With time, parietal tension increases and a high post load on the one hand, in combination with reduction of the contractile function of the myocardium on the other hand, lead to reduction of the ejection fraction (EF) of the LV. This *predicts the appearance of symptoms, lesser effectiveness of surgical intervention, and a poor prognosis.* The development of atrial fibrillation (AF) leads to a serious impairment of the clinical condition due to loss of the contribution of atrial systole to the filling of the LV. Concentric hypertrophy of the LV, which at the first stage is an important adaptation mechanism compensating for a high intracavitary pressure, later leads to a relative reduction of the coronary blood flow and to limitation of the coronary vasodilatation reserve, even in the absence of IHD. Hemodynamic stress in physical activity or in tachycardia leads to redistribution of the

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coronary blood flow and development of subendocardial ischemia, which in turn aggravates systolic or diastolic dysfunction of the LV [4].

A peculiarity of the clinical portrait of AS is a long asymptomatic period with a significantly varying duration. After the appearance of the first clinical manifestations of the disease (shortness of breath on exercise, angina pectoris, fainting) the risk of sudden death rises sharply, and the average life expectancy is 2-3 years [5,6].

A key method of AS diagnosis is a complex echocardiological examination (EchoCG) that provides essential information on the peculiarities of the surgical anatomy of the valve. Assessment of the severity of AS is based on measurement of the effective area of the aortic ostium in combination with dynamic characteristics of the transaortic flow, such as maximal flow velocity and maximal and average pressure gradients on the AV (Table 1) [2,7].

Table 1

Classification of Severity of AS by EchoCG Data [2,7]

Parameter	Degree		
	Mild	**Moderate**	**Severe**
Blood flow velocity, m/s	< 3.0	3.0-4.0	> 4.0
Average gradient, mmHg	< 25	25-40	> 40
Surface area of the ostium, cm^2	> 1.5	1.0-1.5	< 1.0
Index of opening area, cm^2/m^2	> 0.85	0.6-0.85	< 0.6

AS is considered severe when the ostium area is <1 cm^2 and the blood flow velocity though the AV is >4 m/s; an ostium area <0.8 cm^2 is considered critical AS. Annually, the ostium area of the AV decreases by approximately 0.1 cm^2, maximal flow velocity increases by 0.3 m/s, and the average pressure gradient by 7 mm Hg. In making clinical decisions, besides the parameters of echocardiogram (EchoCG) (size of the valve, flow velocity, average pressure gradient, contractile function, size and thickness of the wall of the LV, degree of calcification of the valve), of importance are arterial pressure (AP) and the overall condition of the patient [7].

There are four variants of AS:

1. AS with a high gradient (valve area <1 cm^2, average gradient >40 mmHg) is considered severe irrespective of the blood flow and EF LV;

2. *Low-flow, low-gradient AS with reduced EF LV* (valve area <1 cm^2, average gradient < 40 mmHg, EF LV <50%, stroke index [SI] ≤35 ml/m^2). Stress-EchoCG with a low dose of dobutamine distinguishes a true severe AS from pseudo severe AS characterized by an increase in the area of the AV >1.0 cm^2 with normalization of the blood flow. The existence of the coronary reserve (syn.: contractile reserve – increase in the stroke volume to >20%) has a positive prognostic significance;

3. *Low-flow, low-gradient AS with preserved EF* (valve area <1 cm^2, average gradient <40 mmHg, EF LV ≥50%, SI ≤35 ml/m^2) is characteristic of elderly individuals with essential hypertension and is associated with a small cavity and pronounced hypertrophy of the LV. Multislice helical computed tomography (MHCT) with evaluation of the degree of calcification of the valve permits assessment of the severity of AS and determination of prognosis;

4. *Normal-flow, low-gradient AS with preserved EF* (the valve area <1 cm^2, average gradient <40 mmHg, EF LV ≥50%, SI >35 ml/m^2). Usually, in these patients, AS is of moderate severity [6].

It is recommended that physically active patients with AS also perform a test with a physical load for identification of

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latent symptoms and for risk stratification. Transesophageal EchoCG permits additional evaluation of coexisting disorders of the MV and at the same time is an important method of monitoring the TAVI procedure and of evaluating the results, especially in the case of the development of complications. MHCT and magnetic resonance tomography (MRT) of the heart provide additional information about the size and geometry of the aortic root, of the ascending aorta, and of the degree of calcification. A quantitative evaluation of calcification of the valve is especially important in the evaluation of the severity of AS with a low gradient. MRT permits identification and quantitative evaluation of myocardial fibrosis. Determination of the level of natriuretic peptide permits determination of the optimal time of intervention in asymptomatic patients, since it correlates with the duration of the asymptomatic course and outcome in patients with normal and low-flow severe AS. MHCT is a preferable imaging technique for evaluating the anatomy and dimensions of the aortic root, form and size of the AV ring, distance from it to the orifices of the coronary arteries, distribution of calcificates, and number of leaflets of the AV before the TAVI procedure. In terms of the choice of access points, MHCT provides a more precise determination of the internal dimensions of the vessels and the extent of calcification than MRT [6].

All patients with clinical manifestations of severe AS need early surgical intervention because of the poor prognosis if the disease is allowed to run its natural course; drug therapy is conducted as the stage of preparation for surgery or for alleviation of symptoms of chronic heart failure (CHF) and for relief of the condition in cases where surgery is contraindicated [6]. Exclusions are patients with a supposed life expectancy <1 year and patients with serious comorbid diseases or elderly patients whose health condition and quality and duration of life are unlikely to be improved as a result of the operation. Indications for surgical treatment of AS are given in Table 2.

Table 2

Indications for Surgical Treatment of AS [6]

Recommendation Class	Recommendations
I	Severe AS + symptoms; Severe AS + no symptoms + EF LV <50%; Severe AS + another cardiac surgery
IIa	Very severe AS (blood flow velocity >5 m/s) + no symptoms; Severe AS + no symptoms + low tolerance to physical activity; Severe AS + symptoms+ low-flow/low-gradient AS; Moderate AS + other cardiac surgeries
IIb	Severe AS + no symptoms + rapid progression

Surgical AV replacement (SAVR) has a more than 50-year history, which started in 1960 when D. Harken made the first successful installation of a ball-valve prosthesis in cardiopulmonary bypass (CPB) conditions [8]. *A «standard» surgery* suggested sternotomy, the use of CPB, excision of a pathologically modified AV, and fixation of a prosthesis to the fibrous ring of the AV by sutures. Before the introduction of TAVI, it was the only effective method of treatment for AS that permitted immediate recovery of normal function of the AV with a low frequency of paravalvular leakage, of atrioventricular (AV) block, non-correspondence of the size of the prosthesis, and perioperative lethality from 4-8% [9]. The level of in-hospital lethality in the older age group with different comorbid pathology exceeded the respective parameter in young and middle-aged patients (16% vs

3-5%, respectively), and every third patient with critical AS was considered inoperable due to a pronounced reduction of the contractility of the LV and severe comorbid diseases. In connection with this, *TAVI became the procedure of choice for inoperable patients with AS and for patients at a high surgical risk.* The outcomes of AV replacement have been steadily improved through use of *minimally invasive accesses through the upper sternotomy or right-sided thoracotomy*. Preservation of the integrity of the chest has permitted reduction of manifestations of respiratory failure in the postoperative period and provided activization of patients at an earlier time [10,11].

In 2007, a method of *sutureless AV replacement* by open surgery was proposed, which permitted reduction of the period of use of cardiopulmonary bypass and the duration of ischemia [12]. *Replacement of AV today remains the only method of implantation of mechanical prostheses in younger patients due to the short longevity of biological prostheses in TAVI.*

In 1986, the French scientist A. Cribier first performed balloon valvuloplasty in critical AS in a patient at high surgical risk [13]. To prevent restenosis, which develops as early as 6–8 months after the procedure, the decision was made to install a sort of stent in position of the AV ring, which simultaneously functioned as a valve. In 1989, H. Andersen implanted a prototype of such a prosthesis in an experiment on pigs [14]. In 1993-1994, A. Cribier, in experiments on autopsied material, implanted a balloon-expandable stent and proved the possibility of its adequate fixation in the position of the aortic root; moreover, he made a series of pencil drawings of that stent valve and made a serious step forward in development of this trend. The world's first successful lifetime transcutaneous transcatheter implantation of the first-generation stent valve through transvenous transseptal access was performed by French surgeons under the guidance of A. Cribier in 2002 [15]. In 2003, D. Paniagua performed the first retrograde transcatheter implantation of a novel balloon-expandable AV prosthesis [16]. A year later, retrograde transfemoral and transapical accesses were successfully introduced with the use of improved delivery systems. Simultaneously, another conceptually different model of the valve based on the self-expandable nitinol stent was implanted in 2004. This success permitted the development of more perfect second-generation transcatheter valves. In 2006, a prosthesis was first implanted that was fixed with two inflatable rings with a polymer inside and in 2007, a self-expandable *Lotus* valve, a peculiar feature of which was a complete repositioning in the case of unsuccessful implantation. In 2009, the stent-valve *Accurate* opened up the era of the second-generation expandable valve with a minimal risk of disorders in patency due to its minimal protrusion into the exit pathway of the LV. The first TAVI procedure in the Russian Federation was performed in 2009 [17].

Of the *four main accesses in TAVI (transfemoral, transapical, transclavicular, and transaortic), the most common are the transfemoral and transapical ones*. An advantage of transfemoral access is a possibility for implementation of the procedure under local anesthesia. The transapical method is used in pronounced atherosclerosis of the vessels of the lower extremities, in calcification and tortuosity of the aorta, when implantation of the valve through transfemoral access is linked with the risk of development of vascular and neurological complications [18].

TAVI possesses such advantages as lower lethality in comparison with SAVR, especially with transfemoral access, a lower rate of acute cardiac and acute renal insufficiency in the postoperative period, a reduced risk of stroke, reduction in the duration of in-hospital stay, in particular, in the cardiac intensive care unit, absence of blood loss, minimal invasiveness, shorter duration of the operation, no need for cardiopulmonary

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bypass, the possibility of implementation of the TAVI procedure on patients with a severe comorbid pathology, in repeated interventions, reduction of costs of hospitalization and of rehabilitation of patients, and improvement of the quality of life within a year after the operation.

TAVI is indicated for patients with critical AS and pronounced clinical symptoms who have contraindications to SAVR due to a high risk and life expectancy of more than one year, the existence of severe comorbid diseases, age ≥75 years, a history of cardiac surgeries, limited mobility, and conditions that impede rehabilitation after the intervention. TAVI is contraindicated in patients with acute myocardial infarction within a month before the suggested treatment, cardiac or respiratory insufficiency requiring inotropic support and mechanical lung ventilation, active endocarditis, mechanical support of the circulatory system within the previous 30 days, hypertrophic cardiomyopathy with or without obstruction of the LV, EF LV less than 20%, severe pulmonary hypertension and right ventricular dysfunction, an AV ring size less than 18 mm or more than 29 mm according to EchoCG, existence of contraindications and/or intolerance to anticoagulants, in case of intracardiac thrombus or myxoma, unfavorable anatomy of the aortic root, pronounced asymmetric calcinosis with a high risk for occlusion of the orifices of coronary arteries, pronounced atheromatosis of the ascending aorta with unstable plaques and a high risk of systemic embolism, pathological tortuosity or severe stenosis of femoral, iliac arteries or the abdominal aorta (for transfemoral access), a history of stroke verified by MRT or transient ischemic attack within 6 months before the procedure, severe loss of cognitive ability (dementia, etc.), and life expectancy less than 12 months due to comorbid pathology [18].

In recent years, much information has been acquired on the use of TAVI in patients with an intermediate surgical risk, and the range of indications for the use of transcatheter valves has been expanded. A decision on the choice between SAVR and TAVI in clinically manifested AS is made by a multidisciplinary (valvular) team including cardiac surgeons, interventional cardiologists, and anesthesiologists (Table 3).

Both types of interventions should be performed *in specialized centers that have both cardiac surgery and cardiology departments, an immediately available cardiopulmonary bypass apparatus, the possibility of interventional angiology* in case of development of vascular complications, *and the ability to conduct the necessary examinations* (echocardiography, coronary angiography [CAG], and computed tomography [CT]) [19,20]. Age, comorbid diseases, anatomy, and the statistics on cardiac surgery and transcatheter interventions in a particular center must be taken into account. When choosing an intervention in relatively young patients, it should be borne in mind that *the totality of the evidence was obtained on patients with an average age of 80 years; therefore, the available recommendations are not applicable to persons younger than 70-75 years*. In younger patients, bicuspid AV are more common, which worsens the results of TAVI. In connection with the higher life expectancy of patients in young age groups, the lack of information about the longevity of valves for TAVI, the higher frequency of complications such as perivalvular leakage, and the need for implantation of an electrocardiostimulator (EC), *a relatively young patient must have a huge risk associated with open surgery for the choice to fall on TAVI.*

No less important and contradictory is the question of the timing of surgical treatment of asymptomatic patients with AS. The existence of pulmonary hypertension (PH) is one of the criteria for the selection of such patients for an operation, since it is a predictor of a poor outcome, and stress-EchoCG is excluded from the criteria for selection of asymptomatic patients [6,20].

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Table 3

Aspects for Consideration by Valvular Group in Selecting between SAVR and TAVI in Patients with AS and Increased Surgical Risk [6]

	In favor of TAVI	In favor of SAVR
Clinical Characteristics		
STS/EuroScore I < 4% (logistic EuroScore I < 10%)		+
STS/EuroScore I ≥ 4% (logistic EuroScore I ≥ 10%)	+	
Existence of severe comorbid diseases	+	
Age < 75 years		+
Age ≥ 75 years	+	
Cardiac surgeries in history	+	
«Fragility»	+	
Limitation of mobility and difficulty of rehabilitation	+	
Probable endocarditis		+
Anatomical and Technical Aspects		
Transfemoral access convenient for TAVI	+	
Access (any) inconvenient for TAVI		+
Consequences of irradiation of the chest	+	
Calcification of the aorta	+	
Risk for existing intact coronary stents in sternotomy	+	
Expected mismatch between a patient and prosthesis	+	
Evident deformation of the chest or scoliosis	+	
Small distance between the orifice of coronary arteries and fibrous ring of AV		+
Size of AV fibrous ring not suitable for TAVI		+
Anatomy of the aortic arch not favorable for TAVI		+
Structure of the valve (bicuspid, degree of calcification, location of calcificates) unfavorable for TAVI		+
Presence of thrombi in the aorta or LV		+
Cardiac Diseases Coexisting with AS that should be Taken into Account in Concurrent Interventions		
Severe IHD requiring revascularization using bypass surgery		+
Severe primary disease of the MV amenable to surgery		+
Severe disease of the tricuspid valve		+
Aneurysm of the ascending aorta		+
Hypertrophy of the interventricular septum requiring myectomy		+

Notes: EuroSCORE – risk on European System for Cardiac Operative Risk Evaluation, STS – Society of Thoracic Surgeons

With the accumulation of clinical experience and the use of modern transcatheter heart valves, outcomes of TAVI have continuously improved. Early randomized controlled trials have shown that TAVI is more effective than drug therapy and is a treatment option for inoperable patients [21]. TAVI was later shown to be an effective treatment for patients at high surgical risk [22]. *Then, no differences were demonstrated in one-year mortality between TAVI and SAVR in intermediate-risk patients with the lowest mortality with transfemoral access* [23]. TAVI is less often complicated with bleeding when there is a mismatch between the size of the prosthesis and the size of the AV but has a higher frequency of complications with vascular access in the form of paravalvular leakage and AV block, compared with SAVR. In addition, TAVI has shown excellent results in elderly patients who need repeated SAVR due to failure of the biological AV prosthesis [24]. Currently, data have been obtained on the safety of TAVI in patients with severe symptomatic AS and low surgical risk, as well as on a low

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complication rate, short stay in hospital, zero mortality, and zero disabling stroke within 30 days after the intervention [25]. When discussing the benefits of TAVI, it should be borne in mind that the patients included in the clinical trials were carefully selected. The exclusion criteria were severe mitral and tricuspid valve disease, severe IHD, as well as relative anatomical contraindications (bicuspid AV, insufficient diameter of the aortic ring, increased risk of coronary obstruction, hypertrophic cardiomyopathy with outflow tract obstruction in the LV), and severe PH. We believe that the existence of a large number of different transcatheter valves with additional functions, such as the possibility of extraction, smaller delivery device diameters, or the possibility of an anatomical opening, will expand the indications for TAVI in future.

At present, more than 350,000 TAVI have been conducted worldwide in 1400 centers of 65 countries, and the results evidence the advantages of the method irrespective of the initial surgical risk and type of transcatheter valve; however, this method is not devoid of complications [26]. The most common complications of TAVI are blood loss not requiring additional surgical hemostasis (17.2%), hemopericardium (6%), heart rhythm disorders requiring implantation of a permanent ECS (15.1%), acute renal failure (8%), acute cerebrovascular event (7.1%), ventricular fibrillation (5.1%), and myocardial infarction (2%). Rather common complications of TAVI are cardiogenic shock or acute heart failure (low cardiac output syndrome) myocardial ischemia, damage to the fibrous ring of the AV (0.4-0.6%), blockages of the conducting system of the heart (6-65%), including those requiring a permanent ECS (6-27%), and paraprosthetic fistulae with moderate (7%) and severe insufficiency (0.3%). With transfemoral access, the rate of injury to peripheral vessels (rupture, perforation, dissection, or occlusion of the arteries of the femoral or iliac segment of the aorta) may reach 15.9% and is largely determined by the diameter of the system of valve delivery [17,26].

Patients with severe AS often have a small myocardial reserve, especially in the presence of dysfunction and hypertrophy of the LV or of coronary artery obstruction. The causes of cardiogenic shock can be hypovolemia, super-high-rate cardiac stimulation, aortic insufficiency caused by balloon valvuloplasty, and impaired coronary perfusion. Regardless of the cause, hypotension or tachycardia lead to ischemia, dysfunction of the myocardium, and then to shock. Occlusion of orifices of the coronary arteries is a quite rare (0.3-0.4%) but threatening complication that more commonly occurs in women without previous coronary artery bypass grafting (CABG) with the use of balloon-expandable valves and can lead to critical myocardial ischemia and cardiogenic shock as a result of predominant damage (88%) to the trunk of the left coronary artery (LCA). The occurrence of persistent severe hypotension, regardless of the presence or absence of ST segment alterations, immediately after valve implantation requires exclusion of this complication. Emergency stenting of the affected arteries or CABG surgery is an effective treatment method [27]. The causes of moderate and severe paraprosthetic leakage are pronounced calcification of the valve, which does not allow the stent-prosthesis to spread adequately, non-optimal position of the stent-prosthesis (too high or too low), and mismatch between the size of the prosthesis and the diameter of the valve ring. The initial sign is usually an unexpectedly low diastolic pressure in the aorta. An increase in the pressure of ventricular filling can lead to myocardial infarction, ventricular dysfunction, and eventually to shock. The diagnosis is confirmed by aortography or echocardiography [9,17]. The frequency of disorders of cerebral circulation varies from 1.7% to 8.4%, but according to MRT data, subclinical brain lesions occur in 84% of patients who have undergone TAVI. The most common cause of a procedural stroke is atheroembolism from the ascending part of the aorta or aortic arch, less often embolism with calcified fragments of the AV,

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thromboembolism from catheters, and prolonged hypotension [17,19]. The frequency of cardiac arrhythmias and conduction disorders requiring permanent ECS implantation depends on the type of prosthesis (20-43% and 4-6% after implantation of the CoreValve prosthesis and Edwards Sapien, respectively). The mechanical impact of the stent-prosthesis frame on the area of the conducting pathways located subendocardially in the outflow tract of the LV and in the interventricular septum can lead to high-degree block or complete atrioventricular block and block of the left branch of the bundle of His. Potential risk factors for high-degree conduction disorders include pre-existing conduction defects, including block of the right branch of the bundle of His (RBBH), male gender, and age. Since heart block usually manifests immediately after valvuloplasty or valve implantation, temporary ECS placement is performed during the TAVI procedure. Prolonged and repeated episodes of high-frequency ECS may provoke life-threatening arrhythmias. Risk factors for rupture of the AV fibrous ring include a small size of the AV fibrous ring or of the sinotubular junction, pronounced local calcinosis, balloon-expandable TAVI, and aggressive predilatation. This complication requires immediate conversion and continuation of the operation on the open heart. The frequency of serious vascular complications in TAVI (rupture, perforation, dissection or occlusion of the arteries of the femoral or iliac segment and of the aorta) has decreased to 5.2% in recent years with a decrease in the diameter of the valve delivery catheter [17,19].

We give a description of a ***clinical case*** of N., a female patient 79 years of age admitted to Ryazan Regional Clinical Cardiologic Dispensary with complaints of compressing pain in the heart while walking, frequent intermissions in the work of the heart, dyspnea in usual physical activity, weakness, and lightheadedness.

Case history: the patient had been noting elevation of AP for 10 years to a maximal value 160/90 mm Hg, decreasing on treatment to 110/70 mm Hg. In 2005, intermissions in the work of the heart appeared and stenosis of the aortic orifice was identified. AF was first recorded in 2013. In 2017, the patient started to feel dyspnea on mild exertion and angina attacks. EchoCG showed an increase in the degree of AS to a severe level; the patient was consulted by a cardiac surgeon, and TAVI was recommended.

Past diseases: urolithiasis, stones in the left kidney. Chronic kidney disease (CDK), C2 stage. Varix dilatation of veins of the lower extremities.

History of allergies without peculiarities.

Heredity: mother had essential hypertension; father had heart disease.

Data of physical examination. On admission, the condition was satisfactory. Height was 162 cm, weight 85 kg, and body mass index 32.4 kg/m^2. In the lungs, vesicular breathing was present with no rales. Heart sounds were attenuated, with *rasping systolic murmurs in all points, the epicenter on the aorta and at the Botkin point*, irregular rhythm, heart rate (HR) 92 beat/min, and AP 140/60 mm Hg. The abdomen was soft and painless; the liver boundary was along the coastal margin. No edema was present.

Data of laboratory and instrumental examinations. General blood and urine tests were withing normal ranges. In biochemical blood tests, the levels of total bilirubin and glucose were increased (40.5 μmol/l and 7.4 mmol/l, respectively), and the remaining parameters were within normal limits.

EchoCG showed AF and complete block of the RBBH with alterations in the myocardium of the subendocardial ischemia type.

EchoCG: critical valvular AS (systolic pressure gradient LV-aorta 115 mmHg), aortic insufficiency (regurgitation, reg.) of II-III degree (deg), MV (reg. III deg). Hypertrophy of the walls of the LV (thickness of the interventricular septum 1.7 cm, of the posterior wall of the LV 1.33 cm), dilatation of the left (5.1 cm) and right atrium (4.4×5.5 cm), PH (systolic pressure gradient on tricuspid valve

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29 mm Hg). EF LV was 62%.

CAG showed 50% narrowing of the orifice of the trunk of the LCA, irregularity of the contours of the anterior interventricular artery and of the circumflex artery, and 90% stenosis of the right coronary artery (RCA) in the upper segment. In CT of the thoracic and abdominal aorta with bolus contrast injection, calcific AS and a mild dilatation of the ascending aorta were verified.

On the basis of complaints, history, data of an objective examination and of additional methods, the following *clinical diagnosis* was established: Calcific critical AS, AV insufficiency (reg. II-III degree) and of MV (reg. III deg). Hypertrophy of the LV. IHD: exertional angina of III functional class (FC). 50% Stenosis of the LCA, 90% stenosis of RCA. Essential hypertension III degree, risk 4. Dyslipidemia. Permanent AF. Ventricular extrasystole. Complete block of RBBH. CHF IIA stage, III FC. PH. Varix dilatation of the veins of the lower limbs. Urolithiasis: chronic pyelonephritis outside exacerbation. CKD C2. Obesity stage I. Glycemic disorder in the fasted condition.

Drug therapy included carvedilol, torsemide, eplerenone, atorvastatin, rivaroxaban, and trimetazidine. TAVI was planned.

Surgical treatment started with transcutaneous transluminal coronary angioplasty (TTCA) and endoprosthetics of the RCA. On the control CAG, the lumen of the artery completely recovered, and blood flow was level III according to the *Thrombolysis in Myocardial Infarction* classification, without distal embolization. Stable hemodynamics: AP 125/70 mm Hg, HR 76 per minute, saturation (SpO_2) 96%.

During TAVI, a tendency toward hypotension began to build up: AP 105/70 mm Hg, HR 64/min. At the moment of opening of the AV, bradyarrhythmia developed with HR 38-40/min, ECS was conducted at 70 beats/minute. Despite the introduction of vasopressors, AP dropped to 70/40 mm Hg and SpO_2 to 70% on an ECG monitor; ECS rhythm was recorded with non-effective heart contractions. Resuscitation measures were undertaken. On ECG monitoring, fibrillation of the ventricles appeared; after defibrillation with 200 J discharge, no autonomous contractions appeared. Further resuscitation measures gave no effect. Biological death was stated.

On *postmortem examination*, calcific AV stenosis was verified, insufficiency of the aortic valves, enlargement of the heart (439 g) due to hypertrophy of the myocardium of the LV. Surgery: TAVI was accurate. Complications: hypotonic dilatation of the cavity of the LV. Dystrophic alterations of parenchymatous organs. Lung edema. Diffuse small-focal cardiosclerosis, obliterating atherosclerosis of the coronary arteries (III degree, III stage, stenosis to 71%). Operation: CAG, TTCA, and endoprosthetics of the RCA. Essential hypertension. Chronic pyelonephritis outside exacerbation. Obesity. *The cause of death was calcific AS* in a patient with essential hypertension and obliterating atherosclerosis of the coronary arteries complicated with acute cardiovascular insufficiency in the early period of implantation of a bioprosthetic AV.

Thus, in the process of TAVI, a cardiogenic shock developed in the patient that could have been caused by aortic insufficiency induced by balloon valvuloplasty, derangement of coronary perfusion with the underlying hemodynamically significant stenosis of the trunk of LCA and pronounced insufficiency of MV, and also acute dilatation of the LV due to increase in its filling pressure with decrease in the post load. A forecastable disorder in the atrioventricular conduction during opening of the stent-prosthesis of AV could also have made a negative contribution to the unfavorable outcome.

Conclusion

Due to the increase in the life expectancy of the population of economically developed countries, a significant increase in the number of patients with calcified AS is predicted in the coming decades; the only means of correction is replacement of the AV. Transcatheter implantation of the AV

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possesses significant advantages over surgical replacement and is a method of choice for elderly patients irrespective of risk level; however, it does not always guarantee 100% survival and requires thorough patient selection. While planning transcatheter implantation of the AV in a cardiologic hospital, it is reasonable to choose patents without significant narrowing of the coronary arteries or significant lesions of other heart valves.

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