

Valve-in-valve methodologies in transcatheter atrioventricular re-replacement using balloon-expandable prostheses: a series of clinical cases

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Conflict of interest

The authors declare no conflict of interest.

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Abstract

Introduction: Given the annual increase in the need for repeated heart valve replacement, which is a high-risk surgical procedure due to repeated surgical access against the background of severe adhesions, trauma and comorbidity of patients, the technique of transcatheter heart valve replacement is becoming increasingly relevant and preferable.

Objective: To present in detail modern methodologies for transcatheter mitral and tricuspid valve replacement using clinical examples.

Methods: The presented patients had dysfunction of a previously openly implanted mitral/tricuspid bioprosthesis according to clinical data and echocardiography. Taking into account the high risk of surgical intervention, re-sternotomy and comorbid condition, after analyzing multispiral computed tomography within the framework of the cardiac team (cardiologist, endovascular surgeon, cardiovascular surgeon) it was decided to perform endovascular transcatheter repeat replacement using the "valve-in-valve" method. In both cases, puncture vascular access through the common femoral vein was used.

Results: Balloon-expandable heart valve prostheses were effectively implanted in patients in the atrioventricular positions, achieving satisfactory hemodynamic parameters. Local anesthesia and transthoracic echocardiography were used for transcatheter tricuspid valve replacement. Mitral valve replacement was performed under total intravenous anesthesia, artificial ventilation, using transesophageal echocardiography, ultra-frequent cardiac pacing, and puncture of the interatrial septum. No complications were detected in the intra- and postoperative periods. The patients were discharged on the seventh day after the intervention.

Conclusion: The methodology of transcatheter atrioventricular heart valve replacement is presented using clinical cases as an example, the effectiveness and safety of endovascular mitral and tricuspid valve replacement using balloon-expandable prostheses are shown. Further studies are needed that can provide a comparative assessment of the technologies of transcatheter and surgical atrioventricular heart valve replacement based on the analysis of long-term surgical results.

Keywords: balloon-expandable prosthesis; bioprosthesis dysfunction; mitral valve; transcatheter valve replacement using the "valve-in-valve" method; tricuspid valve



Методологии «клапан-в-клапан» при транскатетерном атриовентрикулярном репротезировании с использованием баллон-расширяемых протезов: серия клинических случаев

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Аннотация

Актуальность. С учетом ежегодного роста потребности в операциях репротезирования клапанов сердца, относящихся к операциям высокого хирургического риска вследствие повторного хирургического доступа на фоне выраженного спаечного процесса, травматичности и коморбидности пациентов, методика транскатетерного репротезирования клапана сердца становится все более актуальной и предпочтительной.

Цель. Детально представить современные методологии транскатетерного репротезирования митрального и трикуспидального клапанов на клинических примерах.

Методы. Представленные пациенты имели дисфункцию ранее открыто имплантированного митрального/трикуспидального биопротеза по клиническим данным и эхокардиографии. С учетом высокого риска хирургического вмешательства, рестернотомии и коморбидного состояния после анализа мультиспиральной компьютерной томографии в рамках кардиокоманды (кардиолог, рентгенэндоваскулярный хирург, сердечно-сосудистый хирург) принято решение выполнить эндоваскулярное транскатетерное репротезирование по методу «клапан-в-клапан». В обоих случаях использован пункционный сосудистый доступ через общую бедренную вену.

Результаты. Пациентам в атриовентрикулярные позиции эффективно имплантированы баллон-расширяемые протезы клапана сердца с достижением удовлетворительных гемодинамических показателей. При транскатетерном репротезировании трикуспидального клапана применялись местная анестезия и трансторакальная эхокардиография. Репротезирование митрального клапана выполнялось в условиях тотальной внутривенной анестезии, искусственной вентиляции легких, с использованием чреспищеводной эхокардиографии, сверхчастой кардиостимуляции, осуществлялась пункция межпредсердной перегородки. В интра- и постоперационном периоде осложнений не выявлено. Пациенты выписаны на седьмые сутки после вмешательства.

Заключение. На примере клинических случаев представлена методология транскатетерного репротезирования атриовентрикулярных клапанов сердца, показана эффективность и безопасность эндоваскулярного репротезирования митрального и трикуспидального клапанов с использованием баллон-расширяемых протезов. Необходимы дальнейшие исследования, способные дать сравнительную оценку технологий транскатетерного и хирургического репротезирования атриовентрикулярных клапанов сердца на основании анализа отдаленных результатов операций.

Ключевые слова: баллон-расширяемый протез; дисфункция биопротеза; митральный клапан; транскатетерное репротезирование клапанов сердца по методу «клапан-в-клапан»; трикуспидальный клапан



Introduction

The principal limitation of the use of bioprosthetic heart valves is their structural deterioration in the long-term follow-up period. During the functioning of bioprosthetic valves, degeneration and calcification of the leaflet apparatus occur, leading to prosthetic dysfunction in the form of stenosis or regurgitation. It is well known that the degenerative processes affecting the leaflet apparatus of bioprosthetic valves and those of the native valve are generally identical. Thus, calcium deposits identified in the tissue of epoxy-treated bioprosthetic heart valves and in the human native valve appear to be formed through dystrophic mineralization. The morphology of calcific deposits in bioprostheses depends on the type of biological tissue in which they are formed. No relationship has been identified between the morphological structure of calcific deposits detected in bioprosthetic leaflets and the implantation site of the devices [1; 2].

The main factors leading to dysfunction of bioprosthetic heart valves include immune mechanisms, aging of the leaflet apparatus, leaflet calcification, and infection. According to the literature, dysfunction of bioprosthetic heart valve leaflets most commonly develops within 10–15 years, with an incidence of up to 49%. Freedom from reoperation 5 years after valve replacement is 86%, whereas at 10 years it is 81% [3; 4]. It is known that the durability of atrioventricular bioprostheses may be shorter than that of prostheses in the aortic position, with reoperation rates reaching 22% within 9 years and freedom from repeat intervention being <60% at 15 years [1]. For the mitral position, published data indicate a high incidence of dysfunction in younger patients. For example, freedom from bioprosthetic dysfunction 18 years after implantation of the Carpentier-Edwards PERIMOUNT valve (Sotramed, Belarus) in the mitral position is only 39% in patients younger than 60 years compared with 66% in patients older than 60 years [5]. It is believed that in the mitral position, commissural stress on the leaflet apparatus is higher because of the marked pressure difference between the left atrium and the left ventricle during systole, which is reflected in the more frequent development of dysfunction [2].

Approximately 300,000 repeat heart valve replacement procedures are performed worldwide each year. These operations are considered high-risk surgical interventions because of repeat surgical access in the

setting of extensive adhesions, procedural trauma, and patient comorbidity [6]. In each individual case, the strategy for repeat valve replacement is selected by the heart team based on risk stratification, including assessment of the patient's clinical status, comorbidities, and degree of surgical risk.

Two approaches are currently used for repeat replacement of dysfunctional bioprosthetic heart valves: open redo valve replacement via re sternotomy under cardiopulmonary bypass, and transcatheter valve-in-valve implantation performed in the catheterization laboratory under echocardiographic and fluoroscopic guidance. By definition, the transcatheter redo approach is fundamentally less invasive; however, the evidence base regarding its efficacy and safety remains rather limited. Therefore, clinical studies aimed at establishing a contemporary evidence base for minimally invasive transcatheter redo heart valve replacement techniques are needed [7].

Objective – to present and substantiate methodologies for transcatheter redo replacement of atrioventricular heart valves using the valve-in-valve technique and balloon-expandable prostheses, illustrated by clinical cases.

Methods

Methodology of Transcatheter Mitral Valve-in-Valve Replacement

The technique of transcatheter transseptal mitral valve-in-valve replacement is considered for patients with a previously surgically implanted bioprosthesis in the mitral position who subsequently developed prosthetic dysfunction. Certain prerequisites must be met to perform transcatheter transseptal mitral valve replacement. The procedure is carried out under general anesthesia with mechanical ventilation, placement of venous and arterial catheters for invasive hemodynamic monitoring, and insertion of a transesophageal echocardiography probe to ensure more accurate puncture of the interatrial septum. The main stages of the procedure are discussed below using a clinical case as an example. The key requirements and procedural aspects of transcatheter transseptal mitral valve-in-valve replacement are presented below.

Requirements and Main Procedural Steps:

- general anesthesia;
- mechanical ventilation;

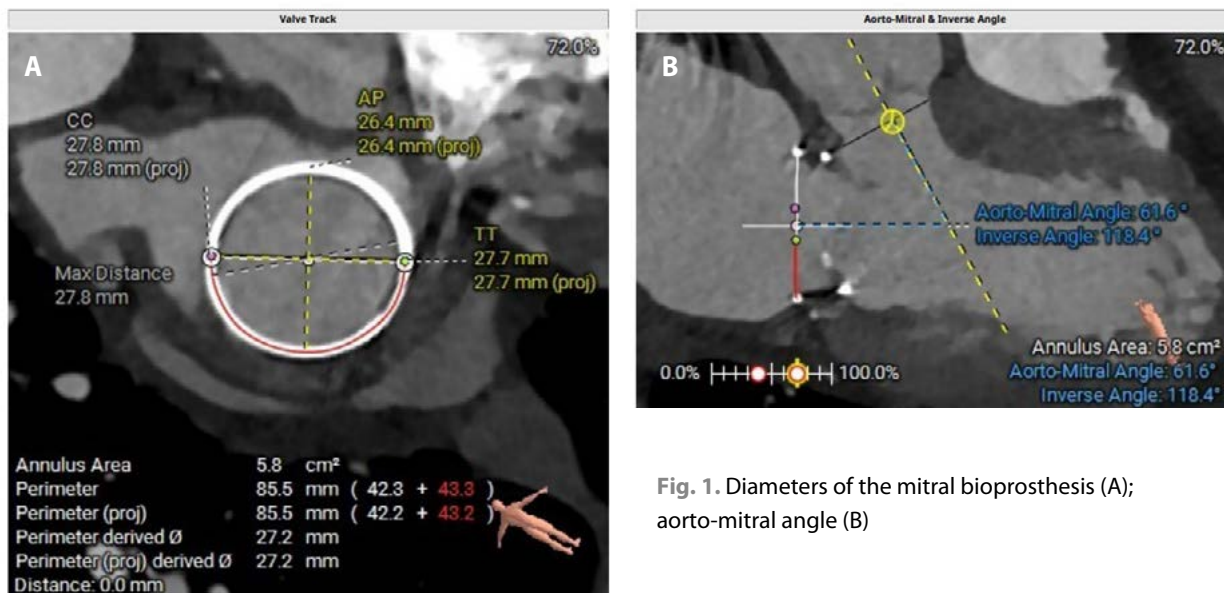


Fig. 1. Diameters of the mitral bioprosthesis (A); aorto-mitral angle (B)

- central venous catheter;
- arterial catheter for invasive hemodynamic monitoring;
- transesophageal echocardiography probe;
- rapid ventricular pacing at the time of balloon-expandable prosthesis implantation via either a right ventricular pacing lead or an extra-stiff guidewire positioned in the left ventricle;
- puncture and catheterization of the common femoral vein;
- puncture of the interatrial septum in a posterior and inferior direction;
- predilation of the interatrial septum with a 14–16 mm balloon;
- placement of an extra-stiff guidewire in the left ventricle;
- advancement of the transcatheter balloon-expandable prosthesis into the previously implanted prosthesis or annuloplasty ring;
- implantation of the balloon-expandable prosthesis during rapid pacing with a decrease in systolic arterial pressure to less than 50 mmHg;
- removal of the delivery system balloon and introducer sheath;
- hemostasis with placement of a Z-shaped skin suture at the common femoral vein puncture site and application of a pressure dressing.

Clinical Case of Transcatheter Transseptal Mitral Valve-in-Valve Replacement

A 73-year-old female patient was admitted to the clinic with a diagnosis of connective tissue dysplasia and a history of mitral valve replacement with a xenobioprosthesis, KemKor-28 (KemKor LLC, Russia), in 2003. Due to bioprosthetic dysfunction, she subsequently underwent redo mitral valve replacement with a UniLine-28 biological prosthesis (NeoCor CJSC, Russia) and tricuspid annuloplasty with a NeoCor-32 annuloplasty ring (NeoCor CJSC, Russia) in 2015. She presented with obstructive dysfunction of the mitral valve prosthesis and moderate-to-severe (grade 2–3) functional tricuspid regurgitation. Her medical history was also significant for coronary artery disease and percutaneous coronary intervention of the right coronary artery (10/2025). She had chronic heart failure (CHF) stage I, New York Heart Association (NYHA) functional class II.

Her comorbidities included impaired glucose tolerance, autoimmune thyroiditis, mild anemia, non-allergic bronchial asthma, and grade 3 arterial hypertension, risk category 4.

According to echocardiography, left ventricular myocardial contractility was satisfactory; sclerotic changes of the aorta and aortic valve were noted, as well as dysfunction of the mitral bioprosthesis (effective orifice area 1.5 cm², peak gradient 26 mmHg, mean gradient 12 mmHg).

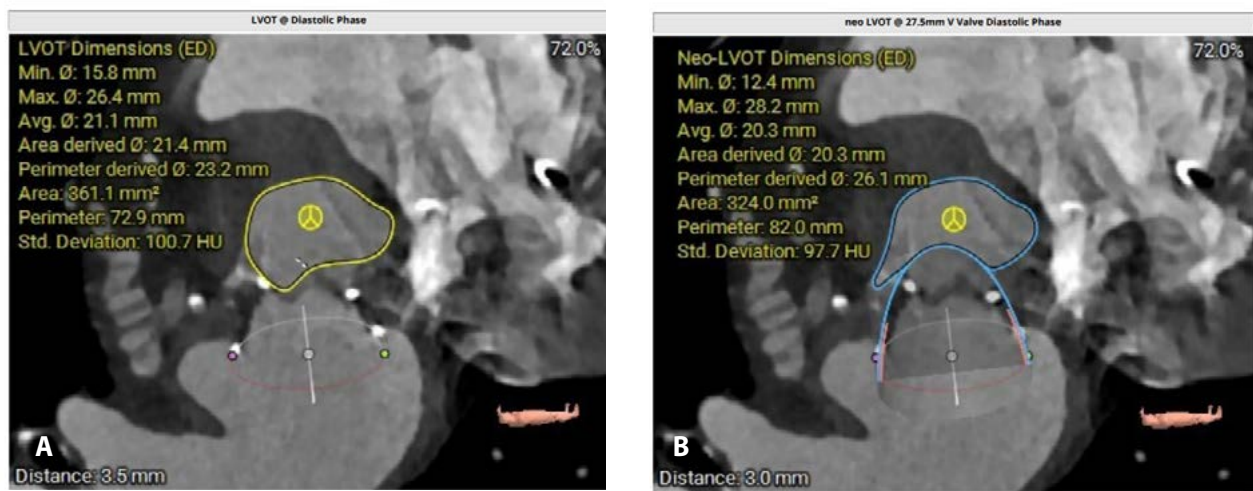


Fig. 2. Left ventricular outflow tract (A); neo-LVOT (B)

Note: LVOT – left ventricular outflow tract.

The patient underwent additional evaluation, including coronary angiography and contrast-enhanced computed tomography of the aorta (CT panaortography). Coronary angiography revealed significant stenosis of the right coronary artery; therefore, as the first stage of treatment, stenting was performed in October 2025. On CT panaortography, a number of mitral valve measurements were obtained: valve diameters 26.4 and 27.7 mm, aorto-mitral angle 61.6°, and left ventricular outflow tract area 361.1 mm² (Figs. 1 and 2). Considering the patient's history of prior open mitral valve surgery and the high

risk of repeat open surgery, transcatheter transseptal mitral valve-in-valve replacement with implantation of a 27.5 mm balloon-expandable prosthesis was selected.

Procedure

Under mechanical ventilation and intravenous anesthesia, percutaneous access to the right common femoral vein was obtained. Under transesophageal echocardiographic guidance, transseptal puncture of the interatrial septum was performed, followed by placement of two extra-stiff guidewires: one primary guidewire

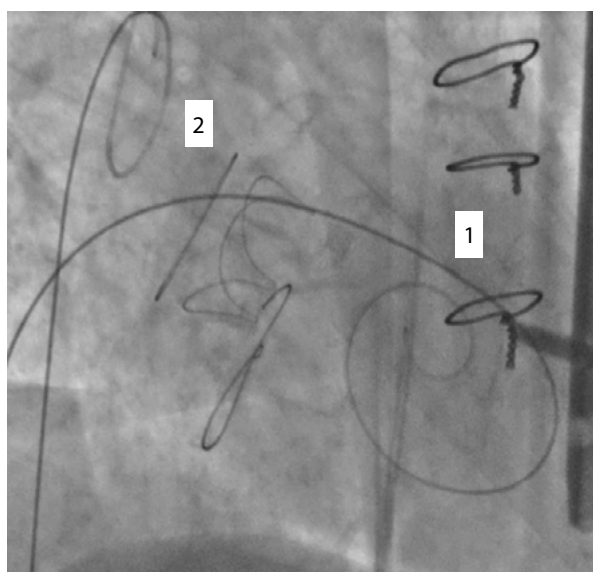


Fig. 3. Position of the guidewires in the left ventricle (1) and left atrium (2)



Fig. 4. Balloon inflation across the interatrial septum

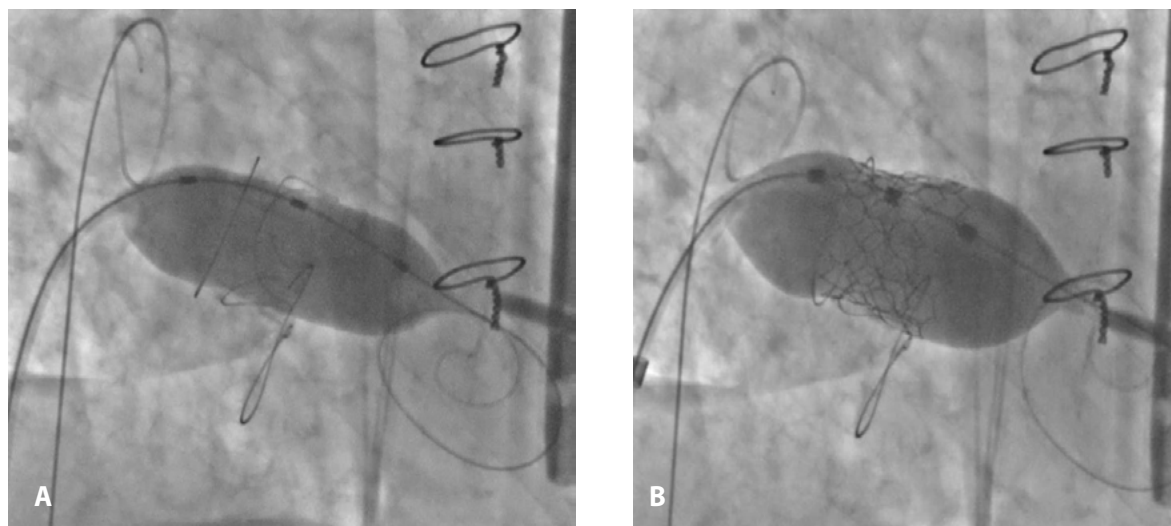


Fig. 5. Balloon predilation of the valve (A); implantation of the transcatheter bioprosthesis in the mitral position (B)

through the mitral bioprosthesis into the left ventricle and one backup guidewire into the left atrium (Fig. 3).

A balloon catheter was advanced over the primary guidewire into the interatrial septum to perform sequential predilation, first with a 12 mm balloon and then with a 16 mm balloon, to facilitate advancement of the valve delivery system (Fig. 4).

An 18 Fr introducer sheath was inserted into the common femoral vein. Predilation was then performed using a 20 mm Mamonth balloon (Meril, India) (Fig. 5A). Subsequently, under rapid left ventricular pacing at 180 beats/min, a 27.5 mm balloon-expandable MyVal transcatheter valve (Meril, India) was positioned and implanted within the mitral bioprosthesis (Fig. 5B).

It is important to note that during positioning and implantation of the balloon-expandable prosthesis, the device is deployed in such a way that approximately 75–80% of its length is located on the left ventricular side and 20–25% on the left atrial side. On control echocardiography, the valve position was correct, with no atrioventricular conduction disturbances and no compromise of the paravalvular structures. No mitral regurgitation was detected. The peak gradient was 6 mmHg and the mean gradient was 3 mmHg. No pericardial leaflet separation was observed. The introducer sheath was removed from the right common femoral vein, and the access site was closed with a subcutaneous Z-suture followed by compression with a sterile pressure dressing. Distal limb perfusion was preserved. The patient was transferred to the intensive care unit.

Postoperative Period

The patient was extubated within 1 hour after surgery. On the following day, the pressure dressing was removed from the common femoral vein puncture site. Hemodynamics remained stable, and the patient's condition was satisfactory. On postoperative day 2, the patient was transferred to the specialty ward. During hospitalization, she reported improved exercise tolerance and reduced dyspnea. Echocardiography revealed no negative changes. The patient was discharged on postoperative day 7 with follow-up recommendations.

Methodology of Transcatheter Tricuspid Valve-in-Valve Replacement

Unlike transcatheter mitral valve-in-valve replacement, this technique is used in patients with tricuspid bioprosthetic dysfunction under local anesthesia and without transesophageal echocardiographic guidance. The procedure is performed under spontaneous breathing with placement of catheters in the jugular vein and an artery for invasive hemodynamic monitoring. In addition to angiography, transthoracic echocardiography is used to assess the quality of bioprosthesis implantation. Rapid pacing is not required during implantation of a balloon-expandable prosthesis in the tricuspid position. The main stages of the procedure are described below using a clinical case as an example. The conditions and key stages of transcatheter tricuspid valve-in-valve replacement are presented below.

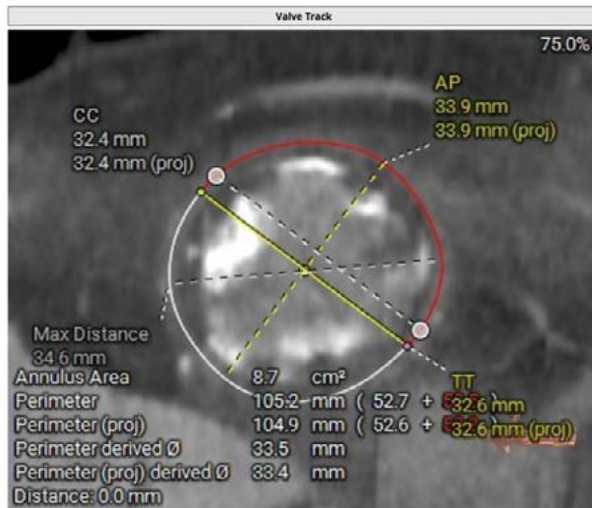


Fig. 6. CT-based measurements of the bioprosthesis in the tricuspid position

Requirements and Main Procedural Steps:

- local anesthesia, intravenous analgesia, and sedation;
- spontaneous breathing;
- central venous catheter;
- arterial catheter for invasive hemodynamic monitoring;
- transthoracic echocardiography;
- puncture and catheterization of the common femoral vein;
- catheterization of the right ventricle or pulmonary artery;
- placement of an extra-stiff guidewire in the right ventricle or pulmonary artery;
- predilation of the previously implanted prosthesis in the tricuspid position in cases of stenotic dysfunction;
- advancement of the transcatheter prosthesis into the previously implanted prosthesis;
- implantation of the transcatheter prosthesis without rapid pacing;
- removal of the prosthesis delivery system and introducer sheath;
- hemostasis with placement of a Z-shaped skin suture at the common femoral vein puncture site and application of a pressure dressing.

Tricuspid Valve-in-Valve Replacement

A 52-year-old male patient was admitted to the clinic with severe tricuspid valve regurgitation resulting from previous infective endocarditis in 1998. He underwent tricuspid valve replacement with a KemKor-32 bioprosthesis (KemKor LLC, Russia) in 2003. He subsequently developed stenosis of the tricuspid bioprosthesis (effective orifice area 0.5 cm²). He also had persistent atrial flutter with normosystolic ventricular response, EHRA (European Heart Rhythm Association) class IIA, and chronic heart failure stage IIA, NYHA functional class II.

His comorbidities included 50% stenosis of the left internal carotid artery, moderate chronic obstructive pulmonary disease of mixed type in unstable remission, viral hepatitis C, bilateral hearing loss, and grade 3 arterial hypertension, risk category 4.

According to echocardiography, left ventricular myocardial contractility was satisfactory, with dysfunction of the tricuspid bioprosthesis (effective orifice area 0.5 cm², transprosthetic regurgitation grade 0–I, peak gradient 29 mmHg, mean gradient 19 mmHg).

The patient underwent additional evaluation, including coronary angiography and CT pnaoortography. Coronary angiography showed no occlusive or stenotic lesions in the coronary arteries. CT pnaoortography provided measurements of the tricuspid valve, with diameters of 32.6 and 33.9 mm (Fig. 6). Given the patient's history of previous open tricuspid valve surgery, the high risk of repeat open surgery, and significant comorbidity burden, transcatheter tricuspid valve-in-valve replacement with implantation of a 32 mm balloon-expandable bioprosthesis was selected.

Procedure

Under spontaneous breathing and local anesthesia, percutaneous access to the right common femoral vein was obtained. Given the radiolucency of the frame of the tricuspid bioprosthesis, right atrigraphy was performed to visualize the valve position (Fig. 7).

An extra-stiff Lunderquist guidewire (COOK Medical, USA) was advanced through the tricuspid prosthesis into the left branch of the pulmonary artery (Fig. 8).

In view of tricuspid valve stenosis, balloon valvuloplasty was performed using a 25 mm balloon (Fig. 9).

The valve delivery system was then advanced, and positioning and implantation of a 32 mm balloon-

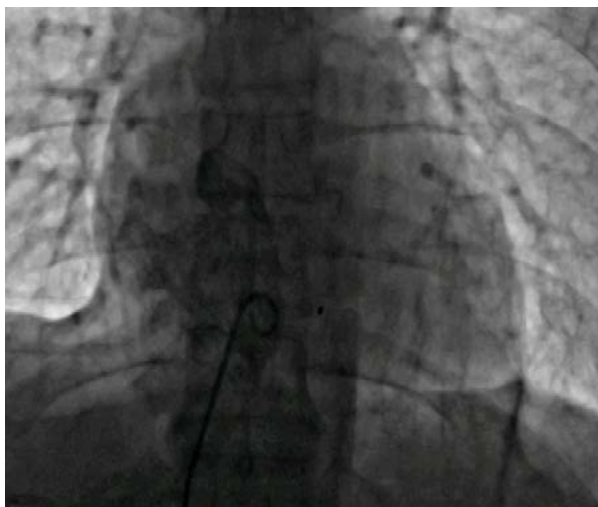


Fig. 7. Radiograph showing visualization of the radiolucent frame of the tricuspid valve



Fig. 8. Extra-stiff guidewire positioned in the left pulmonary artery

expandable MyVal transcatheter valve (Meril, India) within the tricuspid bioprosthesis were performed. Rapid pacing was not used during implantation. During positioning and implantation of the balloon-expandable prosthesis, the device was deployed so that approximately 75–80%

of its length was located on the right ventricular side and 20–25% on the right atrial side (Figs. 10 and 11).

On control echocardiography, the valve position was correct, with no atrioventricular conduction disturbances and no compromise of the paravalvular structures. No

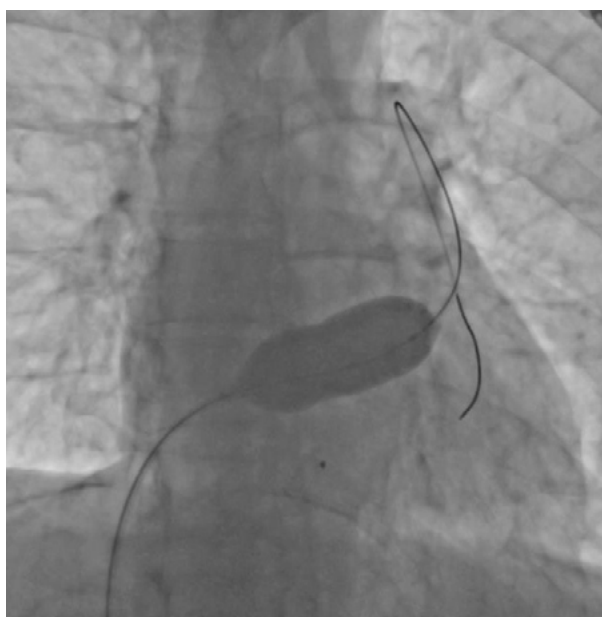


Fig. 9. Balloon valvuloplasty of the tricuspid bioprosthesis



Fig. 10. Implantation of the transcatheter bioprosthesis in the tricuspid position



Fig. 11. Control right ventriculography

tricuspid regurgitation was detected. The peak gradient was 5.6 mmHg and the mean gradient was 3.1 mmHg. No pericardial leaflet separation was observed. The introducer sheath was removed from the right common femoral vein, and the access site was closed subcutaneously with sutures providing compression by interrupted knots. A pressure dressing was applied, and distal limb perfusion was preserved. Hemostasis was achieved. The patient was transferred to the intensive care unit.

Postoperative Period

Twelve hours after surgery, the pressure dressing was removed from the common femoral vein puncture site, and the patient's condition remained stable. After 24 hours, the patient was transferred to the specialty ward. During hospitalization, he reported improvement in overall well-being and increased exercise tolerance. The patient was discharged on postoperative day 7 with follow-up recommendations.

Discussion

The use of bioprosthetic valves implies a limited service life. Dysfunction of bioprosthetic heart valves is among the most frequent indications for repeat valvular intervention [8]. Redo procedures are technically more complex than primary interventions because of adhesions within the pericardial cavity and anterior mediastinum, the presence of advanced heart failure, the high risk of injury to paravalvular structures during prosthesis

explantation, as well as the initially more severe clinical condition of patients, whose age has naturally increased during the period of prosthesis function and who often present with a substantial comorbidity burden [9].

Accordingly, the search for strategies to manage surgical risk is highly relevant and may include the use of minimally invasive transcatheter redo valve replacement techniques. In the presented clinical cases, the feasibility of successful implementation of these approaches in clinical practice was demonstrated, provided that patient selection protocols are strictly followed and these technically demanding procedures are performed appropriately.

With regard to the technical aspects of transcatheter redo replacement of the atrioventricular valves (mitral and tricuspid), it is important to emphasize that, on the one hand, these technologies are in high demand in clinical practice, while on the other hand, they have not yet become routine in the vast majority of centers [1; 5; 6]. The step-by-step methodology for transcatheter redo valve replacement presented in this publication undoubtedly requires implementation in practice with the participation of expert-level specialists who have substantial experience in transcatheter replacement of various heart valves, since interventions on the mitral and tricuspid valves have a number of specific features.

For example, transcatheter tricuspid valve-in-valve replacement generally does not require general anesthesia, transesophageal echocardiography, mechanical ventilation, or rapid pacing during implantation of a balloon-expandable transcatheter prosthesis, given that the right heart is a low-pressure system. In contrast, transcatheter transseptal mitral valve-in-valve replacement must necessarily be accompanied by placement of a transesophageal echocardiography probe, general anesthesia, mechanical ventilation, transseptal puncture, and rapid pacing during implantation of the balloon-expandable prosthesis in order to avoid prosthesis displacement.

Both the experience of our center and the presented clinical cases, as well as published data [1; 5; 6; 8], indicate satisfactory in-hospital clinical and hemodynamic outcomes of transcatheter valve-in-valve implantation, as well as the possibility of rapid patient recovery and early discharge to outpatient follow-up. Nevertheless, a more detailed understanding of the outcomes of transcatheter redo replacement of atrioventricular valves requires clinical studies assessing long-term results in comparison with the outcomes of surgical reoperations.

Conclusion

Using clinical cases as examples, the methodology of transcatheter redo replacement of atrioventricular heart valves is presented, and the efficacy and safety of endovascular redo replacement of the mitral and

tricuspid valves using balloon-expandable prostheses are demonstrated. Further studies are needed to enable comparative evaluation of transcatheter and surgical redo replacement technologies for atrioventricular heart valves based on analysis of long-term postoperative outcomes.

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