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CASE REPORT

ADVANCED

CLINICAL CASE

First-in-Human Implantation of a New Transcatheter Tricuspid Valve Replacement System

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ABSTRACT

Therapeutic options for patients with isolated severe to torrential tricuspid regurgitation have been limited. Because a surgical option is often not attractive, new catheter-based therapies are emerging. We report the first-in-human percutaneous transcatheter tricuspid valve replacement with the MonarQ system in a 75-year-old female patient with severely symptomatic torrential tricuspid regurgitation. (**Level of Difficulty: Advanced.**) (J Am Coll Cardiol Case Rep 2023;14:101841) © 2023 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

The patient was a 75-year-old woman with chronic atrial fibrillation who presented with torrential tricuspid regurgitation (TR) that was secondary to tricuspid annulus dilatation. Despite maximal medical treatment, the patient experienced poor quality of life with fatigue, shortness of breath with activity (NYHA functional class III), and swelling in the abdomen and legs. The patient wished for a more definite treatment but was not a candidate for transcatheter edge-to-edge repair (TEER) and did not want to undergo cardiac surgery (European System for Cardiac Operative Risk Evaluation II value 2.97%).

LEARNING OBJECTIVES

- To understand the required investigations and selection criteria in the preprocedural planning of a TTVR procedure.
- To understand the mechanism of action of this new TTVR system.
- To determine the possible future role of TTVR in the treatment of patients with severe TR.

PAST MEDICAL HISTORY

The patient was known to have arterial hypertension and chronic atrial fibrillation, for which she was treated with losartan, a low-dose beta-blocker, furosemide, spironolactone, and rivaroxaban. A minor non-disabling ischemic stroke was also noted in the medical history. Two years ago, the patient was hospitalized with Takotsubo cardiomyopathy with a left ventricular ejection fraction of 25% to 30% and concomitant moderate to severe mitral and tricuspid regurgitation. The left ventricular and mitral valvular function normalized within a few weeks. However, a moderate to severe TR and a mildly reduced right

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ABBREVIATIONS AND ACRONYMS

CT = computed tomography

TEE = transesophageal echocardiography

TEER = transcatheter edge-to-edge repair

TR = tricuspid regurgitation

TTVR = transcatheter tricuspid valve replacement

ventricular function persisted. Subsequently, the patient's condition further deteriorated, and she developed an invalidating torrential TR.

DIFFERENTIAL DIAGNOSIS

The patient underwent several cardiopulmonary tests. On computed tomography (CT) imaging of the lungs, only a few limited areas with ground-glass opacity were detected, and the patient had a forced expiration volume of 1.7 L (85% of the expected value). Pulmonary hypertension was ruled out by means of a right heart catheterization revealing a mean pulmonary artery pressure of 20 mm Hg and a normal pulmonary vascular resistance of 1.1 WU. A left heart catheterization excluded significant coronary artery disease. Consequently, the torrential TR was considered responsible for the patient's symptoms.

INVESTIGATIONS

Echocardiography showed enlargement of both atria and a severely dilated tricuspid annulus with a central coaptation defect exceeding 10 mm (**Figure 1**). On color Doppler, there was torrential TR (Video 1) with a regurgitant velocity of 1.8 m/s, a dagger-shaped continuous wave Doppler profile, and systolic flow reversal in the hepatic veins. The right ventricular systolic function was judged to be mildly to moderately reduced (tricuspid annular plane systolic function 14-15 mm) with right ventricular free wall hypokinesis.[1] Left ventricular ejection fraction was normal with mild mitral regurgitation.

Cardiac CT imaging confirmed severely dilated atria, and the tricuspid annulus was measured to be 47.2 × 50.5 mm (area-derived mean diameter 48.9 mm) in the diastolic phase (90% of the cardiac cycle). An electrocardiogram showed atrial fibrillation with a ventricular rate of 64 beats/min and a QRS width of 106 milliseconds. Results of blood tests showed a hemoglobin level of 12.1 g/dL, moderate nephropathy, and mild hepatic impairment/congestion (alanine aminotransferase 90 U/L, bilirubin 50 μmol/L).

MANAGEMENT

Despite optimal medical treatment, the patient remained severely symptomatic and expressed a strong wish for a more definitive treatment. The tricuspid valve was technically not suitable for TEER because of an excessive coaptation gap (>10 mm). Cardiac surgery was proposed but refused by the patient. After Heart Team discussion, compassionate use of the MonarQ Transcatheter Tricuspid Valve Replacement (TTVR) System (InQB8 Medical Technologies) (**Figure 2**) was requested and approval obtained from the Danish National Board of Health. Informed written consent was obtained from the patient.

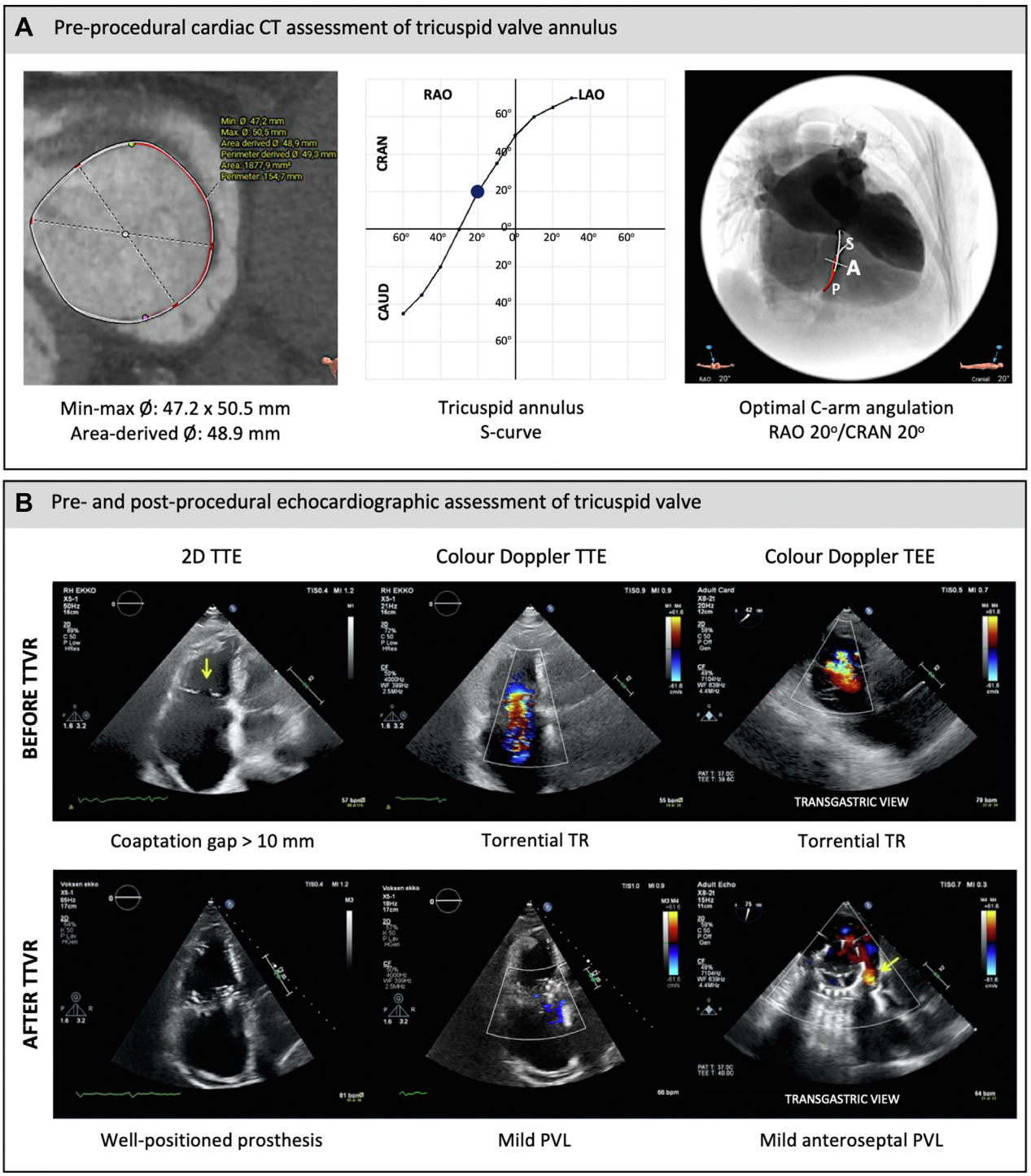
Considering the large tricuspid annulus dimensions measured at CT imaging, the patient was maximally diuresed preprocedurally using high-dose intravenous loop diuretics. The procedure was performed in general anesthesia and by making use of a transjugular venous access to deliver the 30-F delivery system. An additional 6-F femoral arterial access for rapid pacing on a left ventricular stiff Safari guidewire as well as a 10-F venous femoral access for an occlusive balloon in the inferior vena cava were used for facilitating leaflet grasping during TTVR. **Figure 3** provides a step-by-step overview of the different procedural steps with the introduction, positioning, valve expansion, leaflet grasping, and final lowering of the atrial arms of the TTVR system.

Transesophageal echocardiography (TEE) guidance was used throughout the entire procedure. It was first used to verify that the TTVR delivery system was positioned perpendicular to the tricuspid annulus plane, and second, to check whether the ventricular arms of the valve implant were below the tricuspid leaflets and grasped the leaflets when retracting the valve toward the atrium. Finally, TEE was used to confirm leaflet grasping between the ventricular and atrial arms (**Figures 2 and 3**). If needed, the atrial arms can be raised to allow repositioning of the implant, then lowered again. The proximal handle on the TTVR delivery system controls the final release of the implant, which includes release of the rigid connection between the delivery system and implant as well as release of some absorbable sutures at the atrial side of the implant. Once released, the delivery system was retracted and removed from the body.

Hemodynamics remained stable during the entire procedure, and the valvular function could be assessed with the implant in its final position. TEE showed proper capture of all tricuspid leaflets by the valve implant with only a mild paravalvular leak at the antero-septal commissure and a mean transprosthetic gradient of 2 mm Hg (**Figure 1**, Videos 2 and 3). The patient was extubated in the hybrid room and already mobilized the day after the procedure. The patient was discharged in good clinical status and on direct oral anticoagulation.

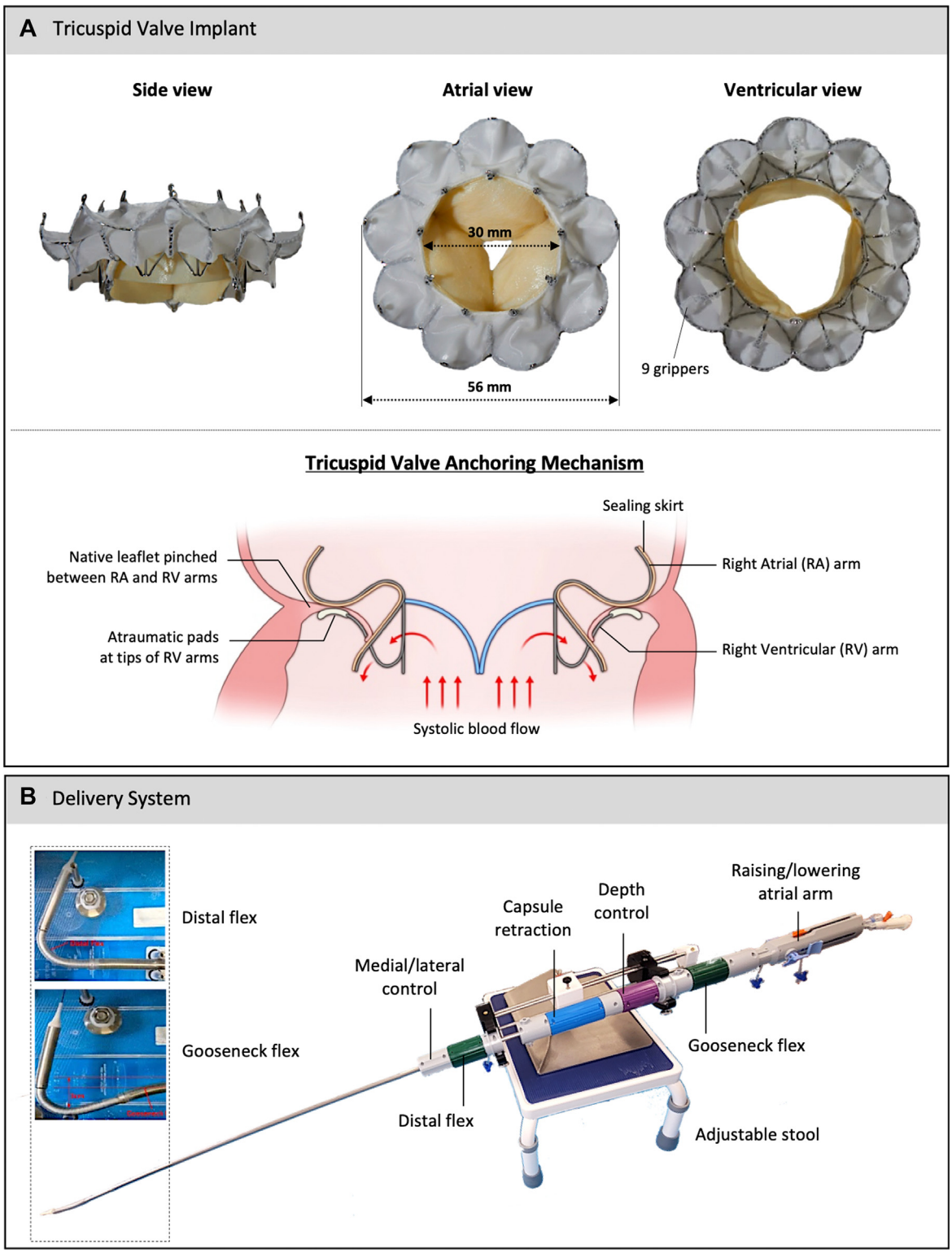
At 30-day follow-up, the patient displayed favorable tricuspid bioprosthetic valve hemodynamics, an

FIGURE 1 **Multimodality Imaging of Tricuspid Valve**



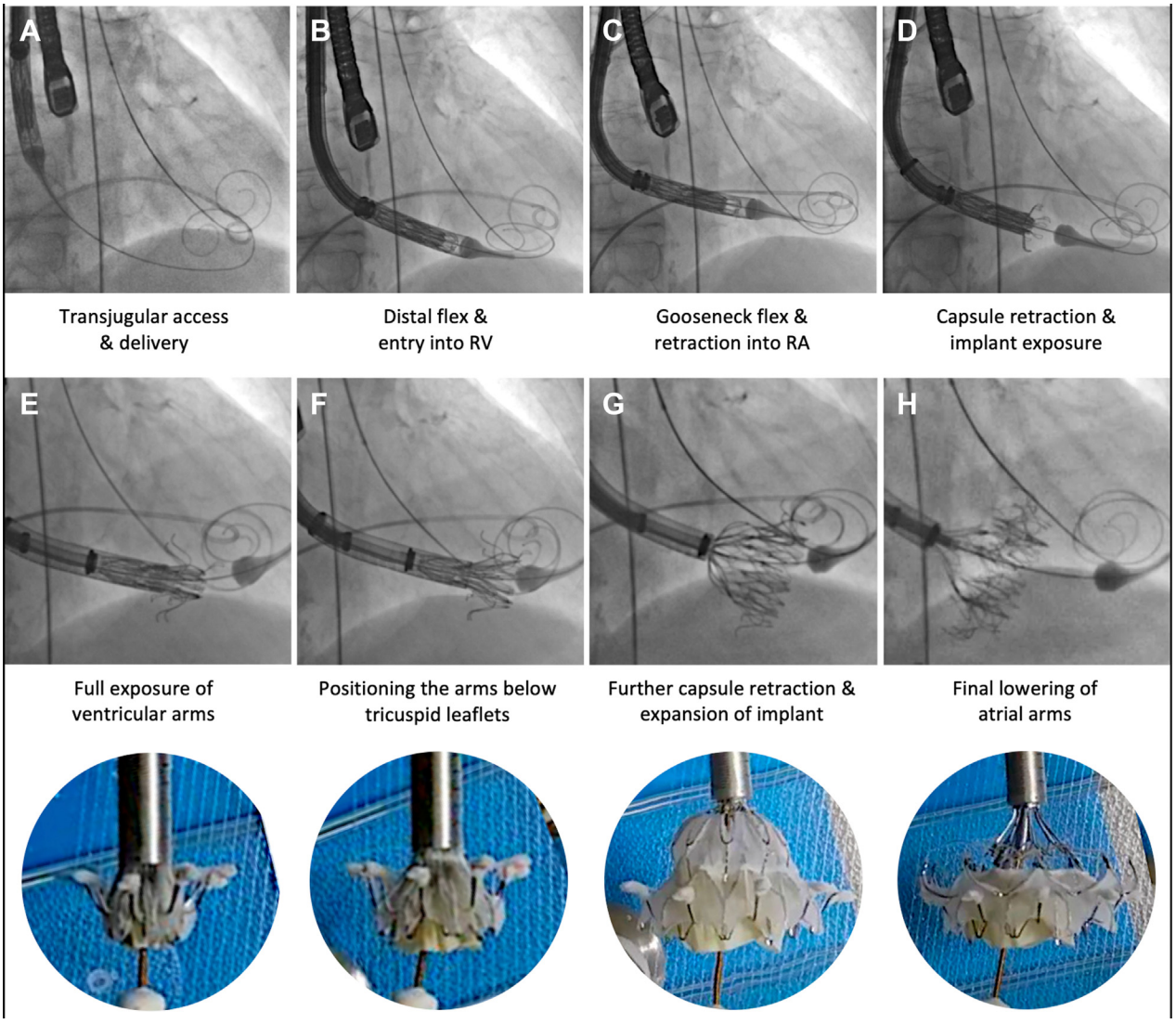
(A) Preprocedural cardiac computed tomography (CT) assessment of the tricuspid valve annulus. **(B)** Preprocedural and postprocedural echocardiographic assessment of the tricuspid valve, showing torrential tricuspid regurgitation (TR) with an effective regurgitant orifice area ≥80 mm^2 and its abolishment after transcatheter tricuspid valve replacement (TTVR). PVL = paravalvular leakage; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

FIGURE 2 **MonarQ Transcatheter Tricuspid Valve Replacement System**



(A) The valve implant comprises 2 nitinol frames (an atrial frame and a ventricular frame with 9 ventricular arms), polyester sealing skirts, and a central 30 mm diameter trileaflet bioprosthetic valve. **(B)** The delivery system comprises a main handle assembly, a catheter shaft, and a distal capsule that houses the valve implant.

FIGURE 3 **Transcatheter Tricuspid Valve Replacement by Transjugular Approach**



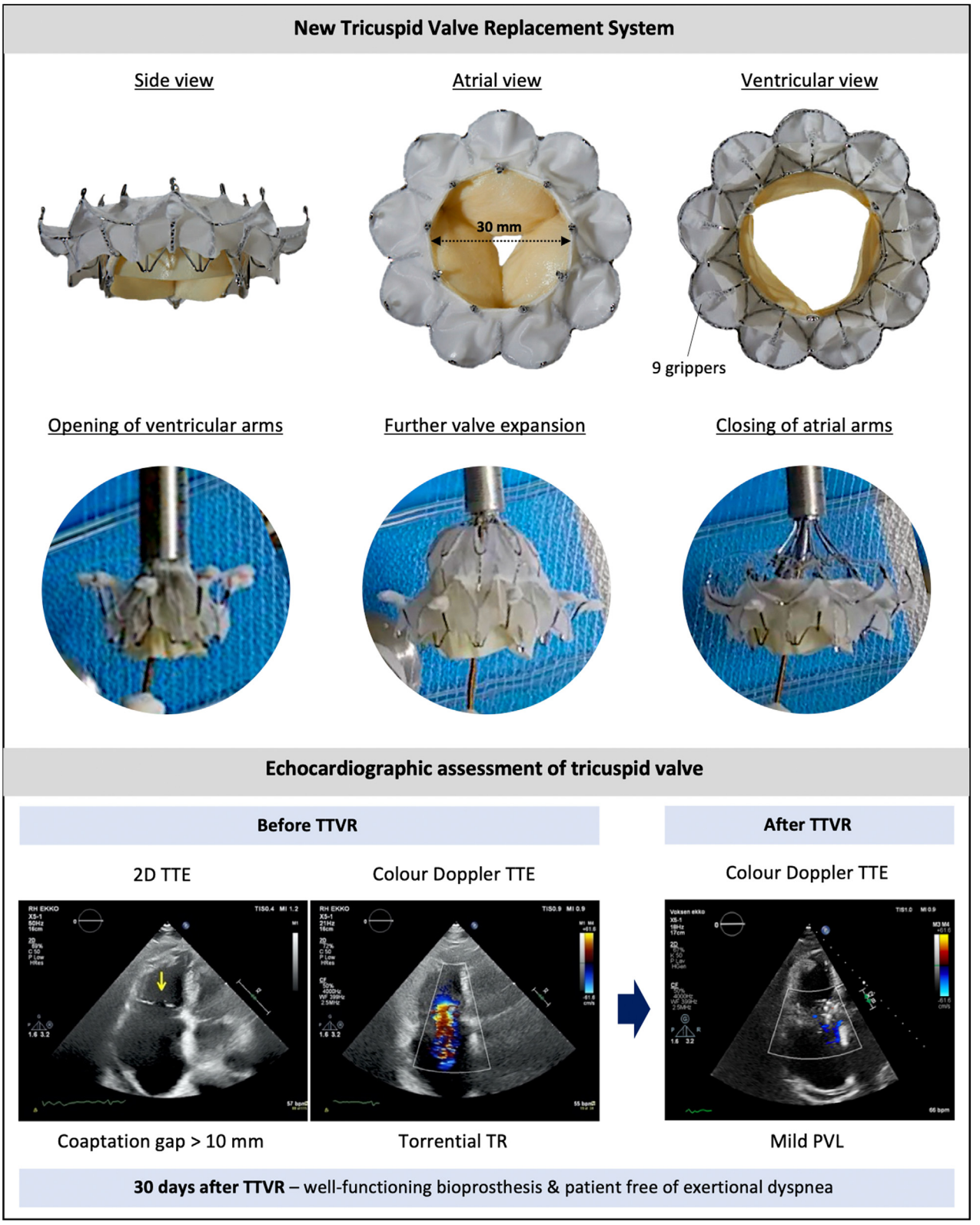
An overview of the procedural steps to position and deploy this particular transcatheter tricuspid valve. RA = right atrium; RV = right ventricle.

improved right ventricular function, and marked clinical improvement; she can take long walks again.

DISCUSSION

Medical and interventional therapies for the management of severe functional TR are limited. Diuretic agents can be used to decrease volume overload. In the 2020 American College of Cardiology/American Heart Association Guideline for the Management of Valvular Heart Disease,[2] it is specified that in patients with signs of right-sided heart failure and severe isolated secondary TR attributable to annular dilation (in the absence of pulmonary hypertension or left-sided disease), isolated tricuspid valve surgery can be beneficial to reduce symptoms and recurrent hospitalizations. However, isolated tricuspid valve surgery for severe TR historically has been performed relatively late in the natural history of the disease, when patients have become symptomatic with signs of right-sided heart failure.

FIGURE 4 First-in-Human Transcatheter Tricuspid Valve Replacement With the New Transcatheter Tricuspid Valve Replacement System



PVL = paravalvular leakage; TR = tricuspid regurgitation; TTE = transthoracic echocardiography; TTVR = transcatheter tricuspid valve replacement.

Transcatheter therapies for the treatment of severe TR have only recently been developed, with TEER being the most used technique until today. However, TTVR may be a more attractive strategy, as TEER to treat severe TR is not always an option, as it is often complex and with mixed TR reduction outcomes. Although catheter-based therapies to treat severe TR are not mentioned in the 2020 guidelines, this may be expected to change in a next version of the guidelines.

As the aforementioned TTVR system anchors itself by "pinching" both the atrial and ventricular side of the native leaflets, this valve avoids potentially harmful interaction with the annulus and atrioventricular node, thereby mitigating the risk of conduction abnormalities. Moreover, the biodynamic attachment system utilizes and preserves the heart's natural motion to secure the implant to the native leaflets, distribute systolic loads, and minimize the risk of paravalvular leakage over a wide range of annulus sizes (**Figure 4**). The single limitation thus far is the availability of one valve size only; however, other valve sizes will become available in the future.

CONCLUSIONS

This first-in-human TTVR with the MonarQ system confirms the feasibility and safety of this new system, thereby abolishing torrential TR. A CE and U.S. Food and Drug Administration approval study is planned to start in 2023 to 2024.

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Dr Quadri is a shareholder in InQB8 Medical Technologies. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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KEY WORDS percutaneous, transcatheter valve therapy, tricuspid regurgitation, valve replacement

APPENDIX For supplemental videos, please see the online version of this paper.