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CASE REPORT

CLINICAL CASE

4-Year Follow-Up After Transcatheter Tricuspid Valve Replacement Using the EVOQUE System

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ABSTRACT

Transcatheter tricuspid valve replacement (TTVR) is an increasingly used treatment technique for patients with severe tricuspid regurgitation (TR). Currently, available data from international registries and randomized controlled trials provide outcome data until a maximum follow-up of 2 years after the procedure. This case report presents 4-year follow-up data for an 84-year-old woman who underwent TTVR for torrential TR in 2019. The patient experienced durable TR reduction, symptomatic improvement, right ventricular reverse remodeling, and substantial improvement in liver and kidney function. (J Am Coll Cardiol Case Rep 2024;29:102393) © 2024 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

An 84-year-old woman with known tricuspid regurgitation (TR) was referred to our hospital for further diagnostic workup and treatment planning. She presented with dyspnea and dizziness, and a history of recurrent hospitalizations for right heart failure. Auscultation revealed a 3/6 systolic murmur in position of the tricuspid valve (TV). Physical examination was indicative of mild peripheral edema and jugular vein distension. Laboratory workup showed elevated N-terminal pro-B-type natriuretic peptide levels (3,271 pg/mL), chronic kidney disease (estimated glomerular filtration rate 35 mL/min), and cardiohepatic syndrome (bilirubin 1.3 mg/dL, gamma glutamyl transferase 185 U/L, alkaline phosphatase 214 U/L). Electrocardiogram at admission revealed a ventricular paced rhythm. Device interrogation of the one-chamber pacemaker indicated 100% right ventricular (RV) pacing. Diuretic medication included torasemide (60 mg/d), hydrochlorothiazide (12.5 mg/d), and spironolactone (50 mg/d).

LEARNING OBJECTIVES

- To summarize the impact of TTVR on symptomatic, echocardiographic, and laboratory outcomes.
- To give an overview of challenges in the management of patients with TTVR over the course of follow-up.

PAST MEDICAL HISTORY

The patient had previously undergone pacemaker implantation for bradycardic atrial fibrillation. In the same year, the patient experienced an ischemic

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ABBREVIATIONS AND ACRONYMS

6MWD = 6-minute walking test distance

CT = computed tomography

HALT = hypoattenuated leaflet thickening

MLHFQ = Minnesota Living with Heart Failure Questionnaire

RV = right ventricular

TR = tricuspid regurgitation

TTVR = transcatheter tricuspid valve replacement

TV = tricuspid valve

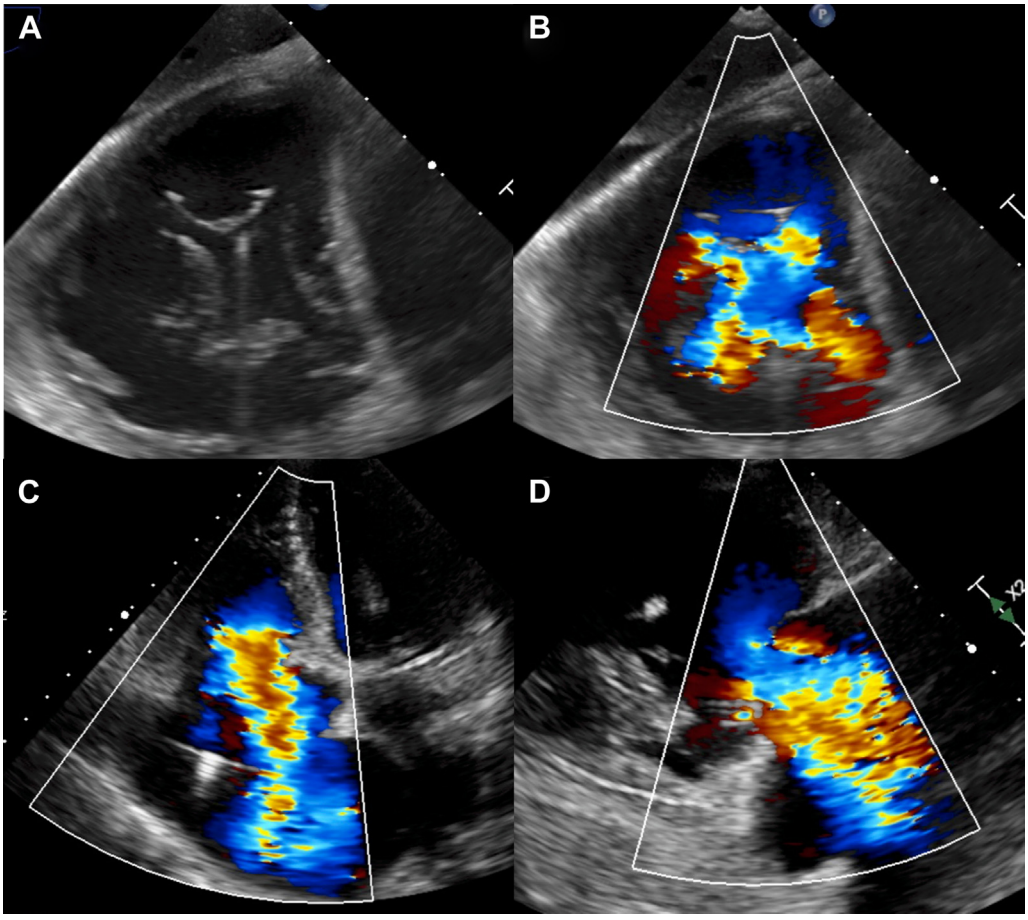
stroke without relevant neurologic sequelae. Beyond that, past medical history included pancreatitis (2021), *Clostridium difficile*-induced diarrhea, chronic venous insufficiency of the lower limb, hypothyroidism (under substitution), and chronic kidney disease.

During the patient's last hospitalization for right heart failure in an external hospital (August 2019), coronary angiography ruled out relevant coronary artery disease. Right heart catheterization was indicative of mild postcapillary pulmonary hypertension (mean pulmonary artery pressure 29 mm Hg, postcapillary wedge pressure 21 mm Hg).

INVESTIGATIONS

Transthoracic and transesophageal echocardiographic evaluation confirmed the diagnosis of torrential secondary ventricular TR (effective regurgitant orifice area 1.4 cm^2, regurgitant volume 57 mL, coaptation gap 10 mm, coaptation gap area 2.8 cm^2, triangular continuous wave Doppler signal) (**Figure 1**, **Table 1**, Videos 1 and 2) with reflux into the hepatic veins and dilation of the inferior vena cava. The TV showed a type IIB anatomy with 2 posterior leaflets. RV function was significantly reduced (tricuspid annular plane systolic excursion 13 mm, RV fractional area change 37.0%, 3-dimensional RV ejection fraction 40%). There was no evidence of relevant contribution of the

FIGURE 1 Torrential Tricuspid Regurgitation Prior to Transcatheter Tricuspid Valve Replacement



Transesophageal echocardiography: (A and B) Transgastric view of the tricuspid valve with and without color Doppler; Transthoracic echocardiography: (C) Tricuspid regurgitation in an apical 4-chamber view. (D) Right ventricle-focused parasternal long axis view.

TABLE 1 4-Year Follow-Up After Transcatheter Tricuspid Valve Replacement Using the EVOQUE System

	Baseline	1-Month Follow-Up	6-Month Follow-Up	1-Year Follow-Up	2-Year Follow-Up	3-Year Follow-Up	4-Year Follow-Up
Heart failure symptoms							
NYHA functional class	III	II	III	II	II	I-II	I-II
6MWD, m	87	184	187	218	272	211	265
MLHFQ, points	51	67	46	35	10	27	30
Peripheral edema	++	+	+	+	None	None	None
Jugular vein distension	++	None	+	None	None	None	None
Pleural effusion	+	Na	+	Na	Na	Na	None
Ascites	None	None	None	None	None	None	None
Laboratory data							
NT-proBNP, pg/mL	3,271	6,469	4,739	4,968	1,651	2,512	2,967
eGFR, mL/min	35	45	26	32	34	34	40
Bilirubin, mg/dL	1.3	0.9	Na	0.4	0.4	0.6	0.5
GGT, U/L	185	140	Na	155	35	33	30
AP, U/L	214	242	Na	251	205	127	139
Echocardiography							
TR severity	Torrential	Trace	Trace	Trace	Trace	Trace	Trace
3D RVEF, % (echocardiogram)	40	36	33	39	37	37	40
3D RVEDV, mL (echocardiogram)	203	167	133	135	131	126	128
3D RVESV, mL (echocardiogram)	121	106	88	82	83	80	77
IVC diameter, mm	29	24	18	19	18	19	18
LV forward stroke volume, mL	47	58	50	51	49	Na	Na
TV mean PG, mm Hg	1.1	2.5	2.3	2.2	2.5	2.5	2.5
LVEF, %	51	45	45	52	50	48	50
Medication							
Anticoagulation	Marcumar	Marcumar	Edoxaban	Edoxaban	Edoxaban	Edoxaban	Edoxaban
Torasemide dosage, mg/d	60	20	50	60	70	70	70
RAS-I, mg/d	None	5[a]	12/13[b]	12/13[b]	12/13[b]	12/13[b]	12/13[b]
Beta blocker (bisoprolol), mg/d	None	10	10	10	10	10	5
MRA	None	None	None	None	None	None	None
SGLT2 inhibitor	None	None	None	None	None	None	None

[a]Losartan. [b]Sacubitril/valsartan.

3D = 3-dimensional; 6MWD = 6-minute walking test distance; AP = alkaline phosphatase; eGFR = estimated glomerular filtration rate; GGT = gamma glutamyltransferase; IVC = inferior vena cava; LV = left ventricle; LVEF = left ventricular ejection fraction; MLHFQ = Minnesota Living with Heart Failure Questionnaire; MRA = mineralocorticoid receptor antagonist; Na = not applicable; NT-proBNP = N-terminal pro-B-type natriuretic peptide; PG = pressure gradient; RAS-I = renin angiotensin aldosteron system inhibitor; RVEDV = right ventricular end-diastolic volume; RVEF = right ventricular ejection fraction; RVESV = right ventricular end-systolic volume; SGLT2i = sodium-glucose cotransporter-2 (SGLT2) inhibitors; TR = tricuspid regurgitation; TV = tricuspid valve.

cardiac implantable electronic device lead to TR. Left ventricular function and dimensions were normal, and no other relevant valve pathologies were observed. Further echocardiographic baseline characteristics are presented in Table 2.

MANAGEMENT

Considering her advanced age and several comorbidities (TRI-SCORE 8 of 12 points, Child-Pugh class A), the interdisciplinary heart team opted for an interventional treatment approach. Due to the large coaptation gap, the patient was ineligible for transcatheter edge-to-edge repair. After addition of a cardiac computed tomography (CT) scan, the patient was confirmed to be anatomically suitable for transcatheter tricuspid valve replacement (TTVR) using the EVOQUE device (Edwards Lifesciences) in a compassionate use setting.

The patient underwent transfemoral TTVR using an EVOQUE 48-mm device (Figure 2). TR was successfully eliminated after the procedure. The mean postprocedural TV inflow gradient was 2 to 3 mm Hg. The cardiac implantable electronic device lead was jailed in position of the posterior leaflet of the native valve. Postprocedural device interrogation remained unremarkable. At discharge, echocardiography revealed trace central TR without relevant paravalvular leakage. The patient was discharged with a reduced dosage of diuretic medication (20 mg/d torasemide). Oral anticoagulation was continued with a vitamin K antagonist.

TABLE 2 Detailed Echocardiographic Baseline Characteristics

LVEF, %	51
LVEDV, mL	74
LVESV, mL	36
LA volume, mL	107
MR severity	1
sPAP, mm Hg	23
TRmaxPG, mm Hg	8
TAPSE, mm	13
RV FAC, %	37
RVEDA, cm^2	36
RVESA, cm^2	23
RVEF, %	40
RVEDV, mL	203
RVESV, mL	121
RV basal diameter, mm	58
RV midventricular diameter, mm	47
TV annular diameter, mm	49
RV length, mm	77
TV tenting area, cm^2	3.8
TV tenting height, mm	8.9
TR EROA, cm^2	1.4
TR regurgitant volume, mL	57
TR vena contracta, mm	18
Coaptation gap size, mm	10
Coaptation gap area, cm^2	2.8

EROA = effective regurgitant orifice area; FAC = fractional area change; LA = left atrium; LVEDV = left ventricular end-diastolic volume; LVEF = left ventricular ejection fraction; LVESV = left ventricular end-systolic volume; MR = mitral regurgitation; RV = right ventricle; RVEDA = right ventricular end-diastolic area; RVESA = right ventricular end-systolic area; sPAP = systolic pulmonary artery pressure; TAPSE = tricuspid annular plane systolic excursion; TrMaxPG = maximum systolic tricuspid regurgitation pressure gradient; other abbreviations as in Table 1.

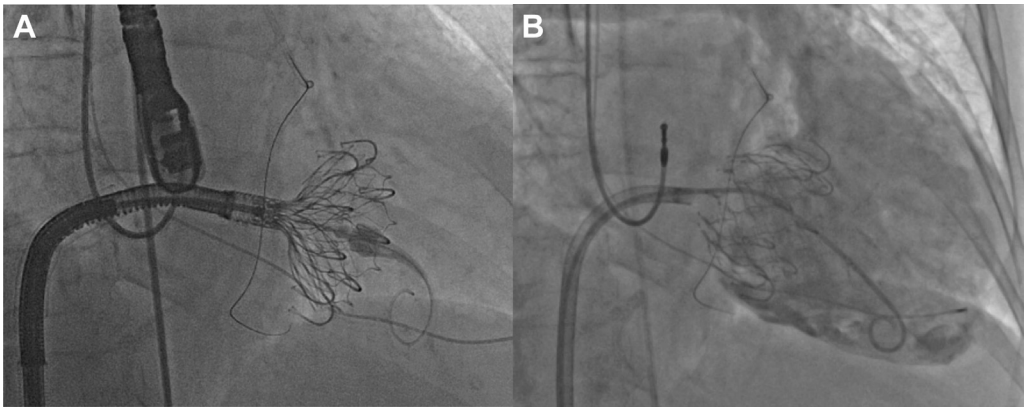
FOLLOW-UP

The patient regularly attended the clinic's outpatient department for follow-up visits (Table 1). At 1-month follow-up, the patient presented with significantly improved functional capacity (NYHA functional class II) and only minimally visible peripheral edema. The 6-minute walking test distance (6MWD) improved from 87 to 184 m. N-terminal pro-B-type natriuretic peptide increased to 6,469 pg/mL, and renal and hepatic function showed significant improvement (Table 1). Procedural results remained stable with trace central TR and adequate TV inflow gradients (2 mm Hg). Cardiac CT scan revealed good positioning and function of the valve with mild hypoattenuated leaflet thickening (HALT), but without restriction of leaflet mobility.

Six months after TTVR, the patient was hospitalized due to worsening dyspnea and pleural effusion, which was drained without any complications. There was evidence of only mild peripheral edema. Echocardiographically, valve function was unremarkable with stable trace central TR. Device interrogation of the pacemaker revealed 100% RV pacing but no significant changes in device function. The patient refused upgrading the pacemaker to a cardiac resynchronization therapy system against the background of a high RV pacing burden. After the pleural effusion was drained and diuretic medication dosage was increased, dyspnea improved, and the patient was discharged home. Before discharge, vitamin K antagonist was switched to edoxaban.

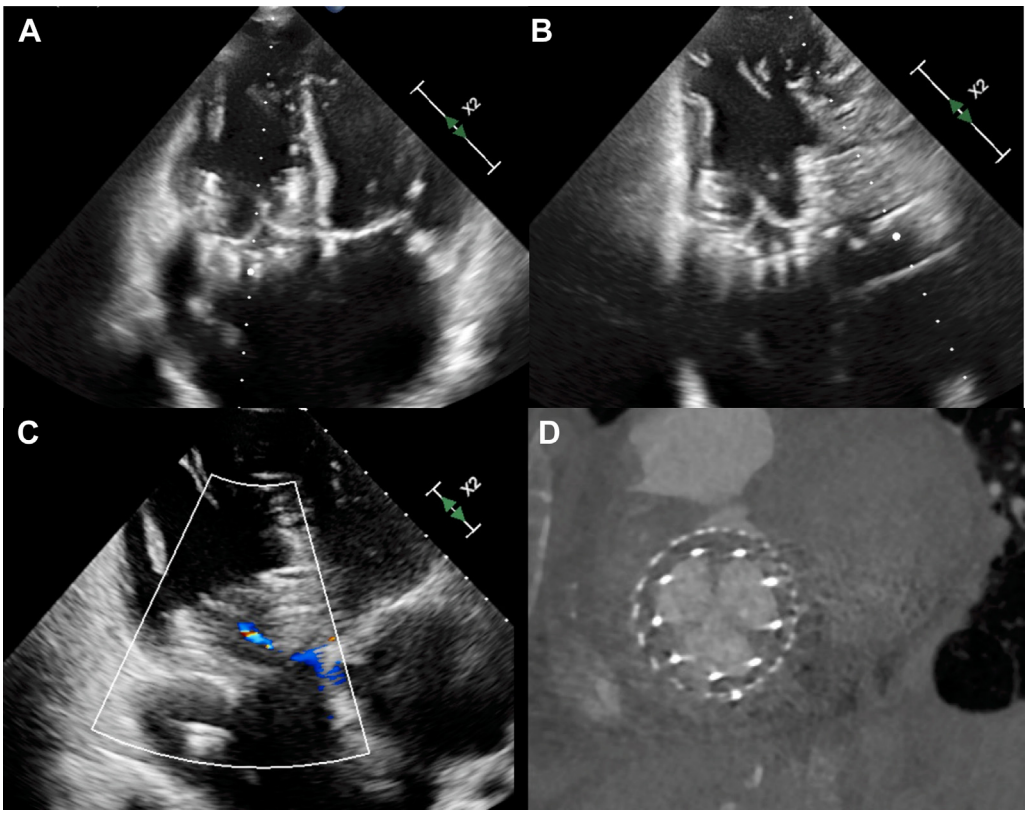
Over the further course of follow-up, the patient gradually improved in terms of 6MWD, Minnesota Living with Heart Failure Questionnaire (MLHFQ), and renal and hepatic function. At 4-year follow-up, 6MWD reached a maximum of 265 m (vs 87 m at baseline). An MLHFQ of 30 points (vs 51 points at baseline) indicated a substantial improvement in

FIGURE 2 Effective Tricuspid Regurgitation Reduction by Transcatheter Tricuspid Valve Replacement



Fluoroscopy during (A) and after (B) EVOQUE implantation.

FIGURE 3 4-Year Follow-Up After Transcatheter Tricuspid Valve Replacement



Good positioning and function of the transcatheter tricuspid valve replacement device in an apical 4-chamber (A) and 2-chamber view (B) of the right ventricle. (C) Trace central tricuspid regurgitation. (D) Computed tomography scan-derived image of the transcatheter tricuspid valve replacement device.

quality of life. NYHA functional class remained stable reduced to I to II. There was no longer evidence of peripheral edema, jugular vein distension, or pleura effusion. Transthoracic echocardiography revealed trace central TR with a TV inflow gradient of 2 to 3 mm Hg (Figure 3). Three-dimensional volumetric measurements of the right ventricle indicated substantial RV reverse remodeling (reduction in RV end-systolic volumes) and RV volume unloading (reduction in RV end-diastolic volumes). An additionally performed CT scan at 4-year follow-up confirmed those results and revealed good device positioning and function. The previously reported thickening of the device leaflets (HALT) improved compared with the CT scan at 1-month follow-up under edoxaban (Videos 3A and 3B). CT-based volumetric analyses indicated substantial RV reverse remodeling after TTVR (Table 3). After 4 years, renal function improved to an estimated glomerular filtration rate of 40 mL/min. There was no longer evidence of cardiohepatic syndrome (bilirubin 0.5 mg/dL, gamma glutamyl transferase 30 U/L, alkaline phosphatase 139 U/L).

TABLE 3 Computed Tomography-Derived Right Ventricle Volume and Function Parameter

	Baseline	1-Month Follow-Up	4-Year Follow-Up
RVEDV, mL	338.9	290.0	163.7
RVESV, mL	216.9	200.7	109.5
RVEF, %	36.0	30.8	33.3

Abbreviations as in Table 1.

DISCUSSION

The present case report shows good durability of TTVR using the EVOQUE device over the course of 4-year follow-up. Although compassionate use registries and clinical trials published encouraging results after EVOQUE implantation until a follow-up of up to 2 years, further outcomes have not been reported.[1-5] In line with previous reports, the present patient experienced substantial symptomatic benefit after TTVR (MLHFQ from 51 to 30 points [−41%], 6MWD 87 to 365 m [400%], NYHA functional class III to I to II). One-year outcomes of the TRISCEND (Edwards EVOQUE Transcatheter Tricuspid Valve Replacement: Pivotal Clinical Investigation of Safety and Clinical Efficacy Using a Novel Device) study reported an increase in 6MWD of 56.2 m and Kansas City Cardiomyopathy Questionnaire improvement of 25.7 points.[2]

The patient was hospitalized for heart failure approximately 5 months after the procedure. One might speculate that reduction of diuretic medication at discharge might have caused systemic volume overload with subsequent pleural effusion and worsening dyspnea. Based on our TTVR and transcatheter tricuspid valve edge-to-edge repair experience, we think that continuation of diuretic medication is important especially in the first 3 months after the procedure to allow for RV reverse remodeling. Reduction in diuretic medication should be done with caution and at a later point of time. Nevertheless, controlled data on this topic are lacking today. In line with several studies,[1,6] the present patient experienced substantial RV reverse remodeling, which was well sustained until 4 years after the procedure. Data from the transcatheter tricuspid valve edge-to-edge repair experience have shown that cardiohepatic and cardiorenal syndromes improve after reduction of TR.[7,8] We observed a gradual improvement in both, and kidney and liver function after TTVR. Today, the optimal anticoagulation strategy after TTVR remains unclear. The patient showed HALT of the TTVR device 1 month after the procedure in a cardiac CT scan under oral anticoagulation with a vitamin K antagonist. The finding remained without clinical relevance and was stable until 4-year follow-up even after switching the anticoagulation regimen to edoxaban. Of note, throughout the course of follow-up, TV inflow gradients remained stable, indicating sufficient valve function. Today, anticoagulation after TTVR remains an intensively discussed issue. Further experience, especially data from larger registries and randomized controlled trials, is needed to recommend a standardized anticoagulation regimen based on a solid body of evidence.

CONCLUSIONS

TTVR using the EVOQUE system was associated with significant improvement in quality of life, symptoms of right heart failure, end-organ damage, and RV reverse remodeling 4 years after the procedure.

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KEY WORDS EVOQUE, long-term follow-up, transcatheter tricuspid valve replacement, tricuspid regurgitation, TTVR

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