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CASE REPORT

ADVANCED

CLINICAL CASE: TCT 2021 CASE

Heterotopic Transcatheter Tricuspid Valve Replacement in Severe Tricuspid Regurgitation and Refractory Right Heart Failure

Giulia Costa, MD, Marco De Carlo, MD, PhD, Paolo Spontoni, MD, Cristina Giannini, MD, PhD, Marco Angelillis, MD, PhD, Laura Stazzoni, MD, Daniele Bozzoli, RT, Roberto Del Sorbo, RT, Anna Sonia Petronio, MD

ABSTRACT

Torrential tricuspid regurgitation may lead to heart failure and poor survival and quality of life. Heterotopic transcatheter tricuspid replacement is increasingly offered to patients unsuitable for direct valve repair or replacement. We describe 1 patient treated by transcatheter implantation of 2 self-expanding valves in the venae cavae with a multimodality imaging approach. (**Level of Difficulty: Advanced.**) (J Am Coll Cardiol Case Rep 2022;4:1005–1011) © 2022 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/).

A 71-year-old woman was admitted to our institution because of worsening dyspnea at rest (New York Heart Association [NYHA] functional class IV), swollen legs, abdominal discomfort, and profound asthenia. The result of physical examination was notable for jugular vein distension, mild jaundice, lower limb edema, and a swollen abdomen. Auscultation showed irregular rhythm, metallic S1, a pansystolic murmur at the lower left sternal border, and S3 gallop. Decreased breath sounds and dull percussion in the lower chest were also noted. Her vital signs were normal excepted for oxygen saturation of 92% while breathing air. Laboratory tests showed markedly elevated N-terminal pro-brain natriuretic peptide (Table 1).

LEARNING OBJECTIVES

- To understand the role of careful preprocedural planning and of intraprocedural fusion imaging for transcatheter tricuspid valve interventions.
- To understand the pathophysiology of right-sided heart failure.
- To understand the role of multidisciplinary and multimodality assessment of patients referred for transcatheter tricuspid valve interventions to guarantee optimal patient selection.

MEDICAL HISTORY

The patient reported a history of rheumatic heart disease at a young age with severe mitral valve stenosis treated by mitral commissurotomy and subsequent mitral valve replacement with a mechanical prosthesis 25 years earlier. Her clinical history was also relevant for permanent atrial fibrillation, diabetes mellitus, previous hepatitis B virus infection, and chronic renal failure.

From the Cardiac Thoracic and Vascular Department, Azienda Ospedaliero-Universitaria Pisana, Pisa, Italy.
The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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ABBREVIATIONS AND ACRONYMS

CAVI = caval valve implantation

IVC = inferior vena cava

MSCT = multislice computed tomography

RA = right atrium

RV = right ventricle

SVC = superior vena cava

TR = tricuspid regurgitation

TTV = transcatheter tricuspid valve

In the previous year her dyspnea had worsened, and a diagnosis of severe aortic stenosis and severe tricuspid regurgitation (TR) had been made. After multidisciplinary evaluation, the patient was deemed at high risk for surgery (EuroSCORE II, 13.4%) and suitable for transcatheter intervention on the aortic and tricuspid valve. A self-expandable transcatheter aortic valve was then implanted via the transfemoral route without complications. After 4 months, the patient was readmitted because of cardiac decompensation with torrential TR. Therefore, edge-to-edge transcatheter tricuspid valve (TTV) repair with three TriClip XT (Abbott) was performed, which was unsuccessful because of intraoperative partial detachment of the septal clip, despite a non-prohibitive anatomy (preoperative coaptation gap size 7 mm), leading to recurrence of torrential TR. Medical therapy was optimized with furosemide (200 mg/day), β-blockers, angiotensin receptor blockers, and aldosterone receptor antagonists at the maximum tolerated dose.

DIFFERENTIAL DIAGNOSIS

Given the patient's history of rheumatic heart disease, a primary disease of the tricuspid valve had to be excluded. However, the typical echocardiographic features of tricuspid rheumatic disease (restricted leaflet motion/leaflet shortening) were absent, whereas annular dilatation with leaflet tethering and lack of coaptation were prominent. Therefore, a diagnosis of a secondary TR due to primary mitral valve disease was most likely (however, a primary involvement of the tricuspid valve might have been present and could have contributed to the failure of TTV repair).

Finally, primary liver disease caused by hepatitis B virus infection was excluded by the hepatologist on the basis of virologic assays and liver function test results (**Table 1**) along with the absence of cirrhosis at abdominal ultrasonography. Therefore, cardiohepatic syndrome with hepatic congestion secondary to right-sided heart failure fulfilled the clinical picture.

INVESTIGATIONS

The 12-lead electrocardiogram showed atrial fibrillation with average heart rate of 80 to 90 beasts/min and no intraventricular disturbances; a chest x-ray film showed cardiomegaly and bilateral pleural effusion.

Transthoracic echocardiography revealed a dilated right atrium (RA) and right ventricle (RV) with preserved systolic function, partial detachment of the septal clip with torrential regurgitation, and an estimated systolic pulmonary pressure of 55 mm Hg (**Figure 1,** Video 1). The left ventricle showed a normal ejection fraction. The aortic and mitral prostheses were functioning normally.

A complete right heart catheterization was performed before the percutaneous aortic valve replacement procedure, showing severe combined pulmonary hypertension. **Table 2** shows the results of preoperative examinations.

TABLE 1 Preoperative Laboratory Test Results

Test	Result
Hemoglobin (g/dL)	9.3 (11.5-16)
WBC ($10^{+}3/\mu L$)	3.27 (4.0-11.0)
PLT ($10^{+}6/\mu L$)	156 (140-450)
aPTT (s)	39.3 (28.0-39.0)[a]
INR	2.5 (0.86-1.20)[a]
AST (U/L)	21 (<40)
ALT (U/L)	9 (<40)
gGT (U/L)	125 (<36)
Cholinesterase (U/L)	3,127 (5,300-12,900)
Total bilirubin (mg/dL)	0.75 (<1.2)
ALP (U/L)	255 (35-105)
Serum amylase (U/L)	136 (28-100)
Serum lipase (U/L)	37 (13-60)
Serum total protein (g/dL)	7.1 (6.0-8.2)
Serum albumin (g/dL)	3.8 (3.5-5.2)
Creatinine (mg/dL)	1.70 (0.50-1.10)
Sodium (mEq/L)	140 (135-145)
Potassium (mEq/L)	3.5 (3.4-4-5)
NT-proBNP (ng/L)	21,047 (<125)
HBV (DNA)	Negative
HBsAg	Positive (0.20 KUI/L)
HBeAg	Negative
Anti-HBs	Negative
Anti-HBe	Positive
Anti-HBc	Positive
Anti-HCV	Negative
Anti-HDV	Negative

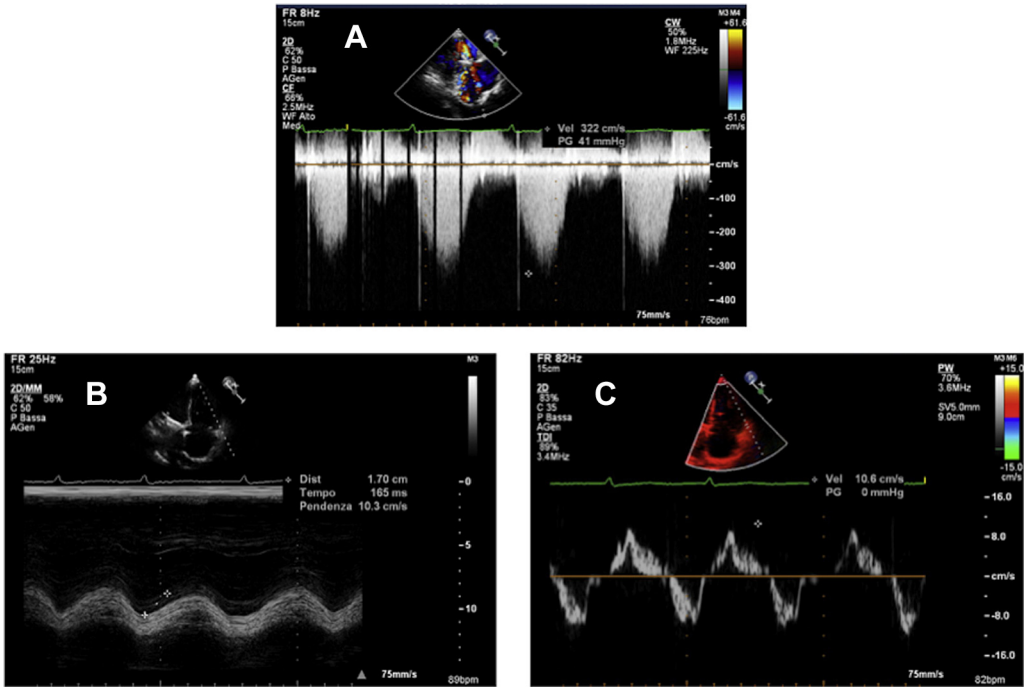
The results are expressed as values along with the local laboratory reference ranges. [a]Patient using oral anticoagulation (warfarin).

ALP = alkaline phosphatase; ALT = alanine aminotransferase; AST = aspartate aminotransferase; aTT = activated partial thromboplastin time; gGT = γ-glutamyl-transferase; HBeAg = hepatitis B e antigen; HBsAg = hepatitis B surface antigen; HBV = hepatitis B virus; HCV = hepatitis C virus; HDV = hepatitis D virus; INR = international normalized ratio; NT-proBNP = N-terminal pro-brain natriuretic peptide; PLT = platelets; WBC = white blood cells.

MANAGEMENT

Initially, a trial of medical therapy was attempted with high-dose intravenous loop diuretics (up to 500 mg/day), levosimendan, and low-dose inotropic agents. Inasmuch as the clinical conditions did not improve, after careful multidisciplinary team discussion and careful counseling with the patient and the

FIGURE 1 Preoperative Echocardiography



(A) Continuous wave Doppler over the tricuspid valve. **(B)** Tricuspid annular plane systolic excursion. **(C)** Pulsed Doppler peak velocity at tricuspid annulus.

relatives, heterotopic TTV replacement with the TricValve system (P+F Products + Features) was proposed. Multislice computed tomography (MSCT) was performed and revealed patent and normally located superior vena cava (SVC) and inferior vena cava (IVC) throughout the femoral veins (**Figure 2**). The MSCT measurements for SVC and IVC prostheses sizing are shown in **Table 3**.

The procedure was performed with the guidance of fusion imaging of MSCT and fluoroscopy. Three venous accesses were obtained: 1 in the right common femoral vein for stent deployment, and 2 in the left common femoral vein for multipurpose and pigtail catheter positioning. A 6-F multipurpose catheter was placed in the right pulmonary artery as a marker for the positioning of the SVC stent. A stiff wire was advanced in the right internal jugular vein, and 2 self-expanding valves loaded into 27-F catheters were deployed in the SVC and IVC (29-mm and 31-mm, respectively) via the right femoral vein with a sheathless approach (Videos 2 to 8). MSCT fusion imaging was key for the correct deployment of both devices and allowed for the use of a small amount (35 mL) of iodinated contrast medium (**Figure 3**). The clinical course was uneventful, and the patient was safely discharged home 1 week after the procedure.

DISCUSSION

Torrential TR with right-sided heart failure represents a challenge both for the complex and heterogeneous anatomy of the tricuspid valve and for the clinical profile of the patients. Several transcatheter options may be offered to these patients, ranging from direct annuloplasty and edge-to-edge repair to orthotopic valve replacement.[1-4] As illustrated in our case, the complexity of TR patients precludes the majority of transcatheter options, mostly owing to the broad anatomic variability.

Caval valve implantation (CAVI) has emerged as a viable option for patients unsuitable for direct interventions on the tricuspid valve at high or prohibitive surgical risk. The rationale is that preventing venous backflow within the venae cavae reduces the symptoms of congestion and ameliorates liver and renal perfusion, possibly leading to positive RV

TABLE 2 Preoperative Examination Results

Procedure	Result
Echocardiography	
Aortic valve (Corevalve Evolut R 29)	
Mean PG (mm Hg)	5
EOA (cm^2)	1.2
Regurgitation	+
Mitral valve (Carbomedics 29)	
Mean PG (mm Hg)	5
Regurgitation	None
Left atrium	
LAD (mm)	50
Volume (mL)	78
Left ventricle	
EDD (mm)	47
ESD (mm)	34
EDV (mL)	78
EF (%)	55
Right ventricle	
Tricuspid annulus diameter (mm)	47
TAPSE (mm)	17
S′ (cm/s)	11
FAC (%)	45
Right atrium	
Area (cm^2)	26
Tricuspid valve	
Tricuspid regurgitation	+++++
Vena contracta (mm)	9.5
PASP (mm Hg)	55
Right heart catheterization[a,b]	
RA (mm Hg)	18/30/16
RV (mm Hg)	74/16
PA (mm Hg)	74/35/48
Ao (mm Hg)	115/80/92
PAWP (mm Hg)	20/45/26
DPG (mm Hg)	9
PVR (WU)	3.96

[a]Right heart catheterization was performed before transcatheter aortic valve replacement for severe aortic stenosis. [b]Pressures are expressed as systolic/end-diastolic or a-wave/v-wave/mean or systolic/diastolic/mean, when appropriate.

Ao = aorta; DPG = diastolic pressure gradient; EDD = end-diastolic diameter; EDV = end-diastolic volume; EF = ejection fraction; EOA = effective orifice area; ESD = end-systolic diameter; ESV = end-systolic volume; FAC = fractional area change; LAD = left atrial diameter; PA = pulmonary artery; PASP = pulmonary artery systolic pressure; PAWP = pulmonary arterial wedge pressure; PG = pressure gradient; PVR = pulmonary vascular resistance; RA = right atrium; RV = right ventricle; TAPSE = tricuspid annular plane excursion; WU = Woods units.

TABLE 3 MSCT Sizing

Prosthesis	Millimeters
SVC prosthesis sizing	
Confluence innominate	22.9
SVC to PA	23.9
SVC to middle PA	27.9
Length of middle PA	42.9
Length of SVC to confluence	53.5
IVC prosthesis sizing	
IVC to RA junction	27.2
IVC to top of SHVs confluence	24.8
Length IVC/RA junction to SHVs	11.2
IVC below SHVs confluence	29.3
IVC 5 cm below RA junction	27.5

IVC = inferior vena cava; MSCT = multislice computed tomography; PA = diameter of the superior vena cava at the level of right pulmonary artery crossing; RA = right atrium; SHVs = suprahepatic veins; SVC = superior vena cava.

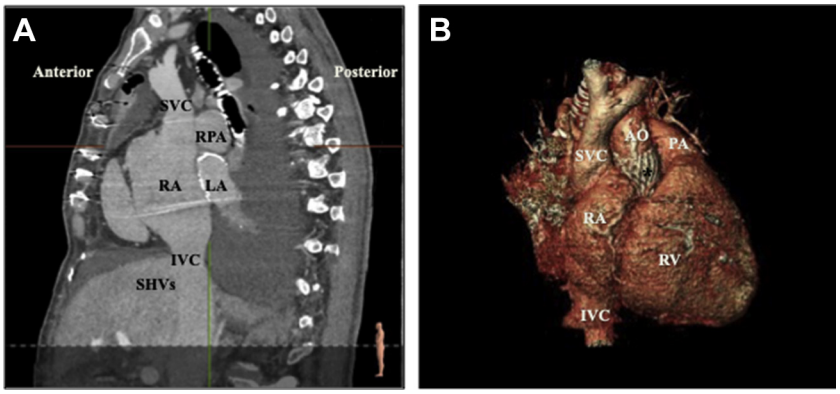
remodeling and reduction of the severity of TR. CAVI may be performed either with nondedicated devices or with specifically designed devices. Currently, the system presented in this case at the moment is the only device with European Commission Mark approval. It consists of 2 self-expanding nitinol frames with bovine pericardium leaflets designed for the SVC and IVC. Compared with other TTV replacement options, CAVI needs a shorter learning curve and has high rates of procedural success.[5] However, unimpressive midterm clinical outcomes may reflect the intrinsic high-risk features of these patients. From the pathophysiological point of view, after CAVI the RA becomes part of the RV, leading to an initial rise in the RA pressures. Although this event may be well tolerated by an RV with a preserved function, it may lead to severe decompensation if an "occult" dysfunction is present, especially in patients with stiff and noncompliant right chambers. Moreover, the increased preload may trigger a vicious circle of further annular dilatation. Finally, the mitigation of TR may hamper the "venting" function of the tricuspid valve on a dysfunctional RV, leading to further dysfunction. This may be comparable to the reduction of left ventricular function sometimes observed after correction of severe mitral regurgitation.[6] In our patient, the evidence of increased pulmonary vascular resistance at right heart catheterization had raised the suspicion of a lack of compensatory mechanisms and a possible detrimental effect of any type of tricuspid intervention, even before TTV repair. However, the young age and severe symptoms refractory to maximal medical therapy led to the decision to attempt the correction of TR.

As highlighted by the present case, CAVI is technically feasible and safe even in very complex anatomies and after failed edge-to-edge TTV repair. MSCT plays a pivotal role in patient selection, prosthesis sizing, and procedural guidance, particularly with the use of fusion imaging.

FOLLOW-UP

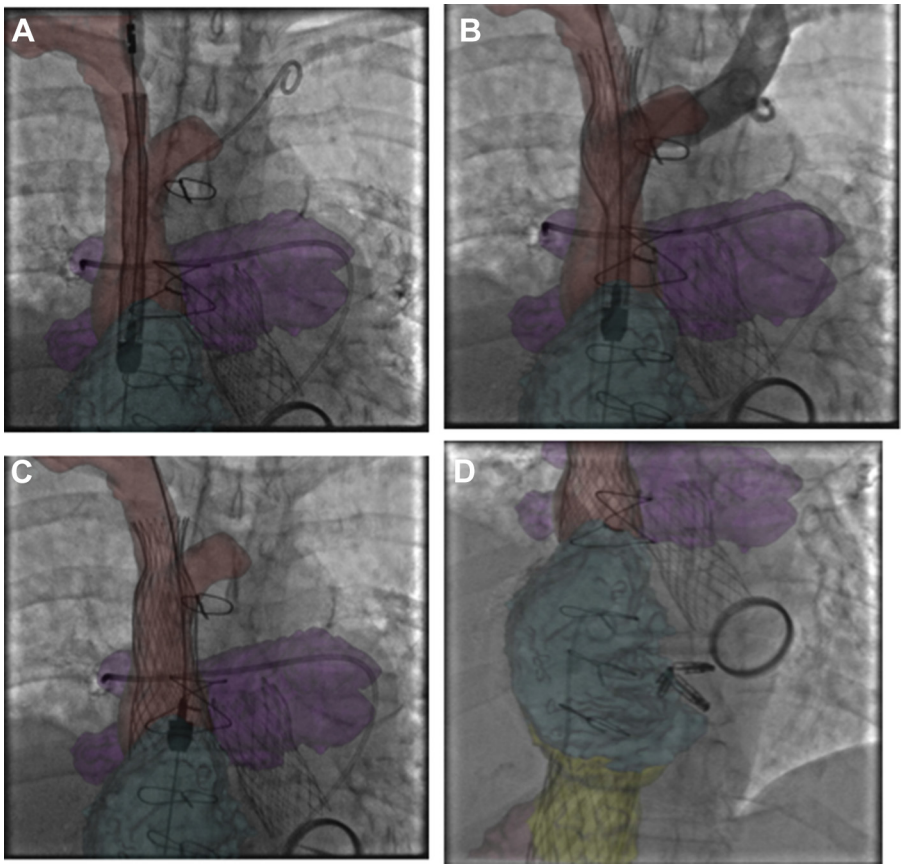
Unfortunately, the patient experienced a progressive deterioration of RV function (**Figure 4,** Video 9) and worsening of the symptoms of right-sided heart

FIGURE 2 **Preoperative MSCT**



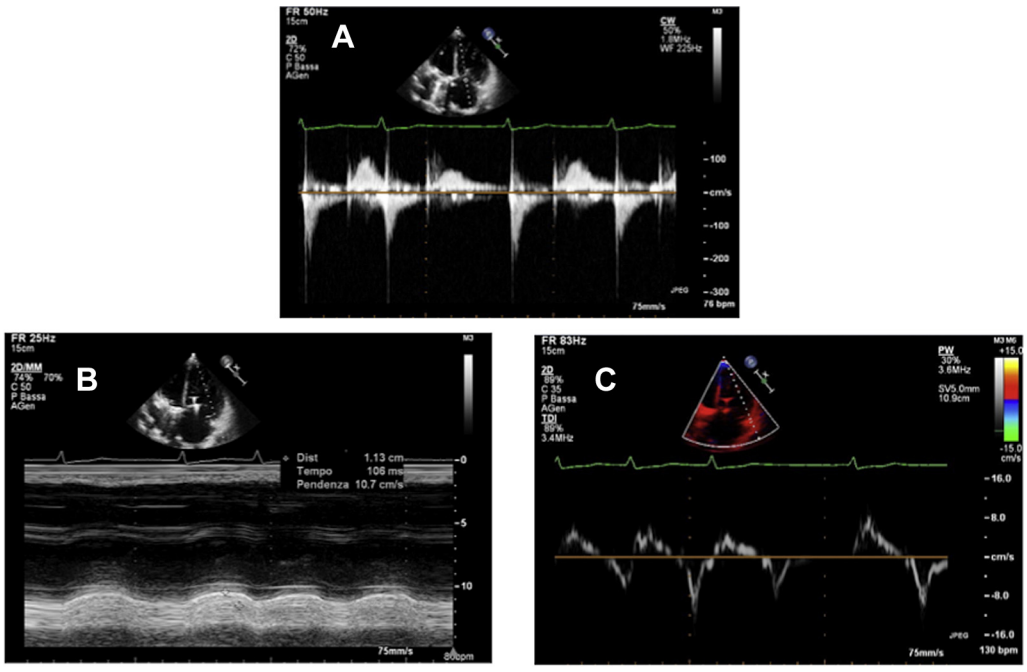
(A) 2-dimensional and **(B)** 3-dimensional anatomic landmarks. *Self-expanding aortic transcatheter prosthesis. AO = aorta; IVC = inferior vena cava; LA = left atrium; MSCT = multislice computed tomography; PA = pulmonary artery; RA = right atrium; RPA = right pulmonary artery; RV = right ventricle; SHV = suprahepatic vein; SVC = superior vena cava.

FIGURE 3 **Intraprocedural Fluoroscopy: Multislice Computed Tomography Fusion Imaging**



(A to C) Prosthesis deployment. **(D)** Final result.

FIGURE 4 **Follow-Up Echocardiography**



(A) Continuous-wave Doppler over the tricuspid valve. **(B)** Tricuspid annular plane systolic excursion. **(C)** Pulsed Doppler peak velocity at tricuspid annulus.

failure. A thoracentesis was needed for the persistence of right pleural effusion, and severe ascites developed. The patient was evaluated for ventricular assistance device implantation, but was refused due to the multiple comorbidities. After five months since CAVI, she is severely ill with NYHA functional class IV heart failure.

CONCLUSIONS

CAVI represents a feasible and safe therapeutic approach for patients with torrential symptomatic TR at high/prohibitive surgical risk and unsuitable for percutaneous direct treatments, even if the intrinsic profile of the patients poses additional challenges. Preprocedural and intraprocedural imaging is of paramount importance for patient selection and procedural guidance, along with a thorough evaluation of the RV function (echocardiography, right heart catheterization) to avoid futility. Longer follow-up data and randomized studies are needed to provide more information about patient selection and mid- and long-term outcomes.

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ADDRESS FOR CORRESPONDENCE: Dr. Anna Sonia Petronio, Cardiac, Thoracic, and Vascular Department, Azienda Ospedaliero-Universitaria Pisana, Via Paradisa 2, 56124 Pisa, Italy. E-mail: as.petronio@gmail.com.

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KEY WORDS computed tomography, imaging, tricuspid valve, valve replacement

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