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Impact of inferior caval valve implantation on severity of tricuspid regurgitation and right heart function

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Aims: Severe tricuspid regurgitation (TR) is a common finding in heart failure patients and associated with increased mortality. New interventional therapeutic options are needed as many heart failure patients are unfit for surgery. The TRICAVAL study compared valve implantation into the inferior vena cava (CAVI) with optimal medical therapy (OMT) in patients with severe TR. Here, we report details on the impact of CAVI on TR severity as well as right heart function and morphology.

Methods and results: We randomized 28 patients with severe TR to CAVI (n = 14) with transfemoral implantation of an Edwards Sapien XT valve into the inferior vena cava or OMT (n = 14). Inclusion and exclusion criteria were based on anatomical and clinical parameters. Echocardiographic measurements were performed at baseline, at the first postoperative day and one, three, and twelve months after randomization. As proof of concept of an effective sealing of the inferior vena cava, we detected a significant decrease in systolic hepatic vein reflux volume (11.0 [6.2–21.9] mL vs 3.5 [0.6–8.5] mL, P = .016) and hepatic vein diameter (11.5 [10.0–14.8] mm vs 10.0 [9.3–11.8] mm, P = .034) at thirty-day follow-up. However, CAVI had no significant impact on TR, cardiac function, and morphology.

Conclusions: Caval valve implantation significantly reduced systolic reflux into the hepatic veins but was not associated with an improvement in cardiac function, morphology, or TR severity.

KEYWORDS
inferior vena cava, transthoracic echocardiography, tricuspid regurgitation

1 | INTRODUCTION

Tricuspid regurgitation (TR) is a common finding in heart failure patients and associated with increased mortality.[1,2] Current guidelines recommend surgical reconstruction or replacement of the tricuspid valve and medical treatment as the two main therapeutic strategies.[3,4] As surgical repair is not feasible in many elderly patients, new therapeutic options are needed.[5,6] Different transcatheter procedures, including caval valve implantation (CAVI), annuloplasty systems, edge-to-edge techniques, and coaptation devices, were developed for TR.[7–10] Davidson et al proposed the inferior and superior vena cava as a suitable alternative for valve implantations.[11] The rationale for CAVI is to minimize backflow into the inferior vena cava thereby reducing peak systolic pressure in the hepatic and renal veins. Moreover, CAVI results in an increase in systolic right atrial pressure (RAP), which may lead to a reduction of regurgitant volume.

First-in-human studies reported a decrease in venous congestion and a symptom relief with improved physical performance after isolated implantation of bioprosthetic heart valves into the inferior vena cava or additionally into the superior vena cava.[12–15] Based on these findings, we initiated the TRICAVAL study (Treatment of Severe TRIcuspid Regurgitation in Patients with Advanced Heart Failure with CAval Vein Implantation of the Edwards Sapien XT VALve, NCT02387697) with the inferior vena cava as the landing zone for transcatheter heart valves.[16,17] TRICAVAL was the first prospective, randomized–controlled study to investigate differences between CAVI and optimal medical therapy (OMT).[16,17] The study did not observe a superior functional outcome after CAVI, but a significant increase in quality of life.[16,17] Follow-up examinations included echocardiographic measurements to assess changes in tricuspid valve performance and heart function. The aim of the present subanalysis was to determine the impact of CAVI on systolic hepatic vein flow reversal, TR severity as well as right heart function and morphology by echocardiography compared with OMT.

2 | METHODS

2.1 | Study design

The study design was described previously.[17] Briefly, TRICAVAL was a single-centre trial with a follow-up of twelve months approved by the local ethics committee (Landesamt für Gesundheit und Soziales Berlin, Germany) and state authorities (Bundesinstitut für Arzneimittel und Medizinprodukte, Bonn, Germany).[17] All patients gave written informed consent.[17]

Twenty-eight patients with severe, symptomatic TR and significant systolic hepatic vein flow reversal were randomized to OMT or CAVI in a 1:1 fashion (Figure 1). Patients had a New York Heart Association (NYHA) class of at least II, optimal medical therapy, high surgical risk, or contraindications for a surgery determined by our local heart team.[17] The pre-selection of patients with a potentially suitable inferior vena cava was based on 3D echocardiography.[17] After a first valve dislocation (in patient 10), additional computed tomography was used for precise measurements of the inferior vena cava.[17] Patients were not considered eligible for valve implantation if the inferior vena cava diameter exceeded 31 mm. The implantation of a single Edwards Sapien XT transcatheter valve (Edwards Lifesciences) into the inferior vena cava was guided by transthoracic echocardiography (Figure 2).[17] A landing zone in the inferior vena cava was prepared using up to three self-expandable stents (sinus XL, Optimed) protruding approximately 5 mm into the right atrium.[17]

2.2 | Echocardiography measurements

Transthoracic echocardiography was carried out at baseline, at the first postoperative day (CAVI group only), one, three, and twelve months after implantation. Examinations were performed as recommended by the guidelines of the American Society of Echocardiography (ASE) and European Association of Cardiovascular Imaging (EACVI) using a GE healthcare Vivid E9 (probes M4S and 4V, GE Healthcare).[18–20]

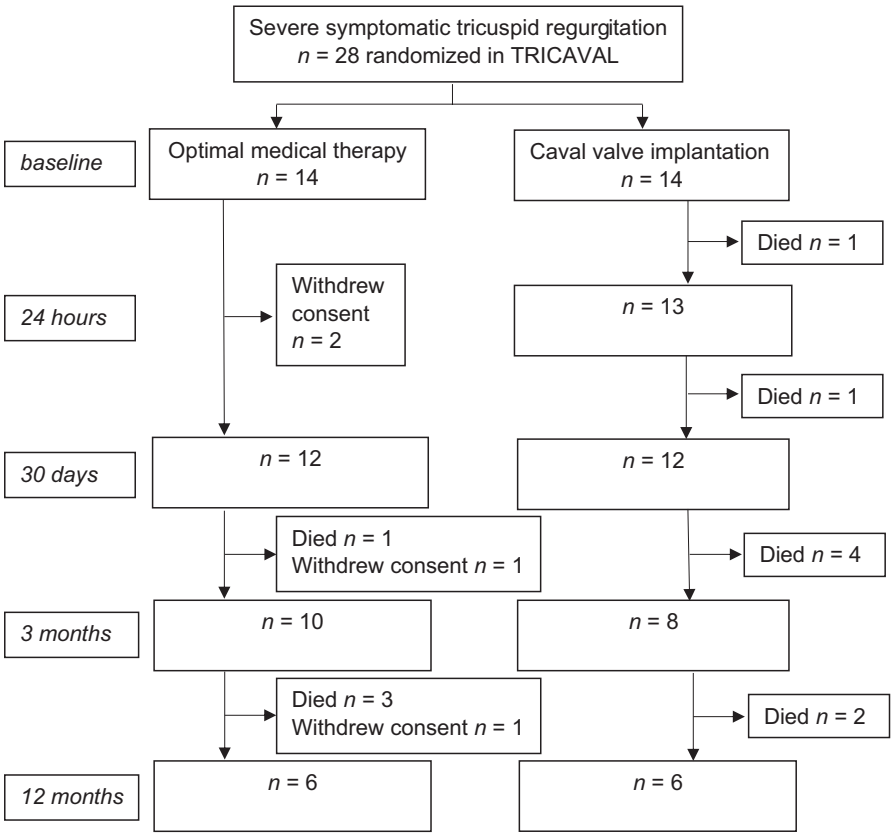

FIGURE 1 Flowchart of the TRICAVAL study with enrolled patients at baseline, the first postoperative day, thirty days, three-, and twelve-month follow-up

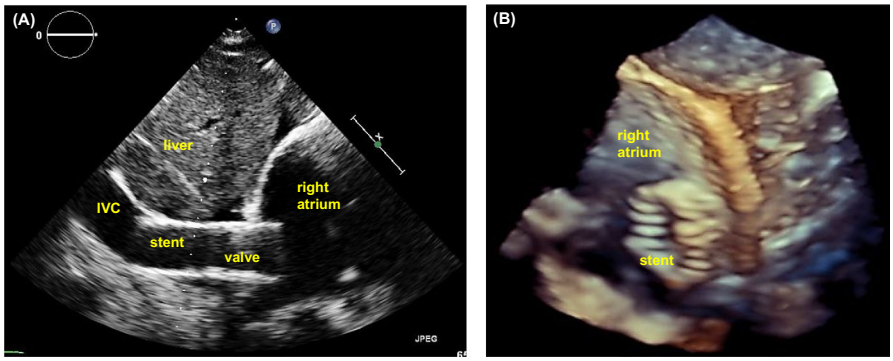

FIGURE 2 Echocardiographic imaging of the caval valve after implantation in the subcostal view (A) and by 3D echocardiography demonstrating the valve protruding 5 mm into the right atrium (B). IVC, inferior vena cava

To verify the effectiveness of our valve implantations, we quantified the systolic hepatic vein reflux volume by identifying a major hepatic vein and measuring its diameter (D) and the velocity time integral (VTI) of the pulsed wave-Doppler signal. The regurgitation volume was then calculated using the continuity equation ($\pi/4 \times D^2 \times VTI$). Follow-up measurements were performed in the same hepatic vein, under continued diuretic therapy and in the supine position without holding one's breath. Grading of TR severity was based on the effective regurgitant orifice area (EROA) and regurgitant volume (RegVol) as determined by the proximal isovelocity surface area (PISA) method and measured from the apical four chamber view. We classified the severity of TR retrospectively according to a novel grading scheme suggested by Hahn et al[21] In addition, we assessed right (RV) and left ventricular (LV) function and morphology. The LV ejection fraction (LVEF) was measured using Simpson's biplane method. Further parameters are listed in Tables 3–6.

At baseline, right heart catheterization was used to identify pulmonary hypertension.

2.3 | Statistical analysis

Statistical analysis was performed in SPSS Statistics version 25 for Windows (IBM Corporation). Categorical variables are presented in percentages and were analyzed by chi-squared test. Continuous variables are listed uniform per variable as median with 25th and 75th

TABLE 1 Baseline characteristics of the study cohort

Characteristic	OMT (n = 14)	CAVI (n = 14)	*P*-value
Male sex, n (%)	7 (50%)	2 (14%)	.103
Age, y	77 (72.2–79.5)	77 (68.2–82.0)	.945
LVEF, % ± SD	58.1 ± 7.1	56.4 ± 6.4	.594
Pacemaker or implantable cardioverter defibrillator, n (%)	2 (14.3%)	5 (35.7%)	.385
Valvular heart disease (excluding tricuspid regurgitation)			
MR ≥ 2+, n (%)	3 (21.4%)	2 (14.3%)	1.000
MS ≥ 2+, n (%)	0 (0%)	1 (7.1%)	1.000
AR ≥ 2+, n (%)	0 (0%)	1 (7.1%)	1.000
AS ≥ 2+, n (%)	2 (14.3%)	2 (14.3%)	1.000
PR ≥ 2+, n (%)	2 (14.3%)	1 (7.1%)	1.000
PS ≥ 2+, n (%)	0 (0%)	0 (0%)	
TS ≥ 2+, n (%)	0 (0%)	1 (7.1%)	1.000
Atrial fibrillation and atrial flutter, n (%)	13 (92.9%)	10 (71.4%)	.326
Pulmonary hypertension, n (%)	10 (71.4%)	7 (50%)	.246
Carcinoid heart disease (Hedinger syndrome), n (%)	0 (0%)	2 (14%)	.481
Dilated cardiomyopathy, n (%)	1 (7%)	0 (0%)	1.000
Restrictive cardiomyopathy, n (%)	0 (0%)	1 (7%)	1.000

Abbreviations: AR ≥ 2+, moderate or severe aortic regurgitation; AS ≥ 2+, moderate or severe aortic stenosis; CAVI, caval valve implantation; LVEF, left ventricular ejection fraction; MR ≥ 2+, moderate or severe mitral regurgitation; MS ≥ 2+, moderate or severe mitral stenosis; OMT, optimal medical therapy; PR ≥ 2+, moderate or severe pulmonary regurgitation; PS ≥ 2+, moderate or severe pulmonary stenosis; TS ≥ 2+, moderate or severe tricuspid stenosis.

percentile or mean with standard deviation for a better inter- and intragroup comparison. Only patients who completed the three- or twelve-month follow-up were included in the respective statistical analysis. Continuous variables were analyzed by *t* test for equal and unequal variances assuming a normal distribution. In case of not normally distributed continuous parameters, Wilcoxon test was used to evaluate differences between follow-up visits and Mann–Whitney *U* test to compare CAVI and OMT groups. A *P*-value of <.05 was considered statistically significant. Due to the small number of cases, an exploratory analysis was also carried out.

3 | RESULTS

Twenty-eight patients were randomized to CAVI (n = 14) and OMT (n = 14) groups (Table 1). Median age in both groups was 77 years at baseline, and 82.1% of the patients were in NYHA class three or four. The mean logistic EuroSCORE I was 14.85 ± 11.41. TR mechanisms were functional in all but two patients, mostly driven by dilatation of the right heart and the tricuspid annulus resulting in a coaptation defect of the tricuspid leaflets. The underlying diseases causing right heart dilatation and TR comprise pulmonary hypertension due to chronic obstructive pulmonary disease and atrial septum defect as well as valvular, ischemic, restrictive, and dilated cardiomyopathy. Two patients had severe TR due to carcinoid heart disease with restrictive tricuspid leaflet motion. Fifty-four percent of patients with a right heart catheter measurement at baseline showed pulmonary hypertension including eight patients with post-capillary, four patients with pre-capillary, and two patients with combined pulmonary hypertension (Table 2).

Caval valve implantation resulted in a significant reduction of systolic hepatic vein reflux volume (11.0 [6.2–21.9] mL vs 3.5 [0.6–8.5] mL, *P* = .016) and hepatic vein diameter (11.5 [10.0–14.8] mm vs 10.0 [9.3–11.8] mm, *P* = .034) after thirty days. This effect remained stable over time (Table 3).

TABLE 2 Baseline measurements of right heart catheterization

	OMT (n = 14)	CAVI (n = 14)
Systolic PAP, mm Hg (IQR)	40.0 (30.8–52.5)	39.0 (32.3–56.0)
Diastolic PAP, mm HG (IQR)	16.5 (13.3–21.8) (n = 12)	13.5 (10.0–22.3)
Mean PAP, mm Hg ± SD	28.2 ± 8.3 (n = 12)	26.7 ± 11.8
Mean PCWP, mm HG ± SD	15.5 ± 3.6 (n = 11)	17.1 ± 7.2 (n = 13)
PVR, dyn·s cm^{-5} (IQR)	231.0 (132.5–414.0) (n = 13)	224.0 (199.5–318.0) (n = 13)

Note: Missing data in case of refusal of invasive diagnostics by the patient.

Abbreviations: CAVI, caval valve implantation; OMT, optimal medical therapy; PAP, Pulmonary artery pressure; PCWP, Pulmonary capillary wedge pressure; PVR, Pulmonary vascular resistance.

3.1 | Cardiac function

Left and right heart function after CAVI showed no significant change. Similarly, after three months, all parameters remained unchanged in the OMT group—with the exception of a decrease in LV outflow tract velocity time integral (LVOT-VTI). After three and twelve months, we observed no significant difference in cardiac function between the CAVI and OMT groups (Table 4). Severe TR with reduced left ventricular preload and additionally moderate mitral regurgitation in five patients resulted in a reduction of LVOT-VTI. Despite reduced LVOT-VTI, most patients showed a normal LVEF due to normal left ventricular contractility.

3.2 | TR severity

TR severity assessed by EROA and RegVol showed no significant intergroup differences, nor changes in the follow-up of the two groups compared with baseline (Figure 3, Table 5).

3.3 | Cardiac morphology

In the CAVI group, no significant changes of cardiac morphology were observed during the follow-up period (Table 6). In the OMT

TABLE 3 Systolic hepatic vein reflux volume and hepatic vein diameters in patients with completed twelve-month follow-up at baseline and twelve months

	OMT (n = 5)		CAVI (n = 6)	
	Baseline	12 mo	Baseline	12 mo
Reflux volume, ml (IQR)	13.0 (8.5–22.5)	14.0 (10.0–19.0) **	11.0 (5.5–24.0)	3.0 (2.0–3.7) *,***
Hepatic vein, mm (IQR)	13.0 (12.5–14.5)	13.0 (12.5–13.5) **	11.5 (9.8–14.3)	10.0 (8.8–11.0)**

Note: Missing data of one patient (OMT).

Abbreviations: CAVI, caval valve implantation; OMT, optimal medical therapy.

*$P < .05$ compared to baseline.

**$P < .05$ for comparison of OMT versus CAVI.

TABLE 4 Cardiac function at baseline, 24 h post-interventional, thirty days, and three-month follow-up

	OMT (n = 10)			CAVI (n = 8)			
	Baseline	30 d	3 mo	Baseline	24 h	30 d	3 mo
LVEF, % (IQR)	60.0 (54.3–61.3)	56.5 (50.0–61.8)	52.5 (48.0–61.0)	60.0 (52.5–62.0)	60.0 (54.8–68.0)	63.0 (56.3–67.5)	58.5 (46.3–63.8)
LVOT-VTI, cm (IQR)	15.9 (13.9–19.8)	15.0 (13.6– 17.0)	14.3 (11.6–17.6)*	19.7 (14.9–24.1)	21.3 (13.4–24.6)	20.3 (12.7–23.9)	17.2 (15.2–22.9)
RVOT-VTI, cm (IQR)	9.9 (8.8–11.6)	8.9 (7.5–13.0)	10.7 (8.3–11.8)	14.1 (7.6–22.0)	11.7 (10.0–20.2)	10.5 (9.1–15.9)	10.5 (9.6–15.8)
RVFAC, % (IQR)	36.0 (28.9–54.8)	43.4 (35.0–51.7)	45.2 (35.6–52.5)	37.0 (28.5–38.9)	43.7 (33.9–45.5)	41.0 (36.0–56.0)	49.6 (26.1–51.0)
RV-S', cm/s (IQR)	10.1 (9.4–10.9)	10.9 (9.8–12.6)	10.8 (9.1–11.8)	10.0 (8.0–12.7)	9.9 (7.6–12.7)	9.3 (6.8–12.8)	9.0 (7.7–11.6)
TAPSE, mm (IQR)	15.0 (11.8–22.0)	17.0 (14.8–21.8)	17.0 (15.8–20.5)	16.5 (13.3–18.0)	18.5 (13.5–21.8)	17.0 (15.0–22.0)	16.0 (13.0–18.8)
MPEI (IQR)	0.5 (0.3–0.7)	0.5 (0.4–0.7)	0.5 (0.5–0.7)	0.5 (0.4–0.9)	0.5 (0.4–0.6)	0.5 (0.4–0.6)	0.6 (0.5–0.9)

Abbreviations: CAVI, caval valve implantation; LVEF, left ventricular ejection fraction; LVOT-VTI, left ventricular outflow tract velocity time integral; MPEI, myocardial performance index; OMT, optimal medical therapy; RVFAC, right ventricular fractional area change; RVOT-VTI, right ventricular outflow tract velocity time integral; RV-S', systolic tricuspid annular velocity; TAPSE, tricuspid annular plane systolic excursion.

*$P < .05$ compared to baseline.

group, a progressive dilatation of the right atrium occurred after three months. However, a significant difference between CAVI and OMT was not found at the three- and twelve-month follow-ups.

4 | DISCUSSION

TRICAVAL is the first prospective randomized study to evaluate differences between CAVI and OMT.[16] CAVI did not lead to an improvement in functional capacity measured by spiroergometry, but resulted in a significant increase in quality of life.[16,17] All implanted valves showed normal function in the echocardiographic examination after three and twelve months but four dislocations resulted in early termination of recruitment.[16,17]

The present subanalysis of TRICAVAL focused on the impact of CAVI on systolic hepatic vein reflux, cardiac morphology, function, and TR severity compared with OMT. CAVI primarily aims at decongestion of the hepatic and renal veins by reduction of regurgitation into the inferior vena cava. As a proof of concept, we observed a significant long-term reduction of reflux into the hepatic veins (Figure 4) and of hepatic vein diameters (Figure 5).

As reported by a previous study, bicaval valve implantation leads to an increase in RAP, a reduction of mean pressure in the vena cava, and an improvement in cardiac output.[14] We therefore hypothesized that an increase in RAP might result in a reduction of TR regurgitation volume due to a decrease in the systolic pressure gradient between RV and RA as the driving force of the regurgitation jet. We also expected a consecutive increase in cardiac output as a result of improved right heart hemodynamic with an increase in left ventricular preload. Based on patients with a three-month follow-up after CAVI, we observed no significant change of mean RAP before and immediately after valve implantation (12.0 [7.0–21.0] mm Hg vs 14.0 [11.0–25.9] mm Hg, n = 7, $P = .236$). Moreover, the RA area and diameter remained unchanged after three months. In summary, we did not observe significant changes of cardiac function, morphology, or

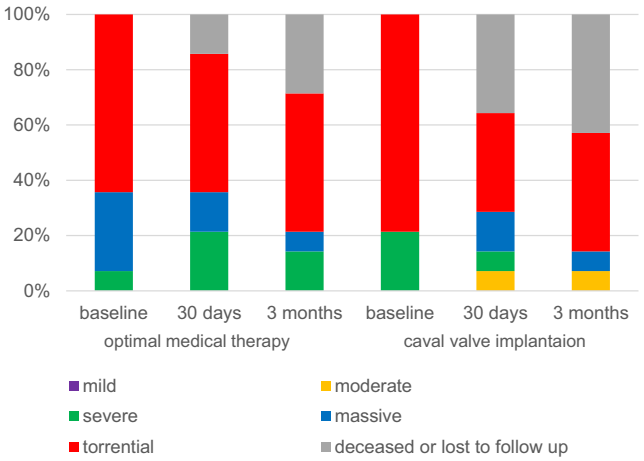

FIGURE 3 Changes of tricuspid regurgitation severity over time after inferior caval vein implantation of an Edwards Sapien XT valve (CAVI) and under optimal medical therapy (OMT)

TABLE 5 TR severity at baseline, 24 h post-interventional, 30 d, and three-month follow-up

	OMT (n = 10)			CAVI (n = 8)			
	Baseline	30 d	3 mo	Baseline	24 h	30 d	3 mo
EROA, cm^2 (IQR)	0.8 (0.7–1.5)	0.9 (0.6–1.6)	1.0 (0.7–1.3)	1.0 (0.5–1.7)	0.8 (0.5–1.0)	1.1 (0.6–1.7)	1.1 (0.7–1.8)
RegVol, ml (IQR)	72.0 (59.0–80.5)	76.5 (62.5–103.3)	77.0 (61.5–90.8)	59.1 (44.3–83.5)	55.0 (39.3–75.5)	69.0 (38.3–101.8)	78.5 (36.5–104.3)

Abbreviations: CAVI, caval valve implantation; EROA, effective regurgitant orifice area; OMT, optimal medical therapy; RegVol, regurgitant volume; TR, tricuspid regurgitation.

TABLE 6 Cardiac morphology at baseline, 24 h post-interventional, thirty days, and three-month follow-up

	OMT (n = 10)			CAVI (n = 8)			
	Baseline	30 d	3 mo	Baseline	24 h	30 d	3 mo
LVEDD, mm (IQR)	42.5 (39.3–46.8)	46.0 (41.0–49.0)*	42.5 (41.8–46.3)	45.5 (42.5–52.8)	48.0 (40.5–51.0)	48.0 (40.8–54.3)	48.5 (42.3–52.0)
LV sphericity index (IQR)	1.2 (1.1–1.4)	1.2 (1.1–1.3)	1.1 (1.0–1.4)	1.3 (1.0–1.4)	1.2 (1.0–1.4)	1.2 (1.0–1.3)	1.1 (1.0–1.5)
RVOT1, mm (IQR)	40.0 (31.8–41.8)	39.5 (33.0–42.0)	39.0 (33.8–43.0)	37.5 (35.5–44.0)	36.0 (33.5–43.8)	39.0 (33.8–42.8)	41.0 (37.3–45.3)
RVOT2, mm (IQR)	31.5 (28.5–34.8)	31.0 (26.8–33.5)	30.0 (25.3–34.5)	29.5 (25.8–31.0)	29.0 (25.0–33.3)	29.0 (25.3–33.0)	31.5 (26.3–36.0)
RVD basal, mm (IQR)	54.0 (46.5–59.3)	54.0 (42.3–66.3)	53.0 (47.0–65.3)	52.5 (49.0–55.8)	51.0 (47.3–55.0)	53.0 (45.0–55.8)	52.0 (48.0–56.8)
RVD mid, mm (IQR)	38.5 (33.5–48.3)	43.5 (32.0–54.8)	43.0 (36.8–48.5)	40.0 (39.0–42.5)	37.5 (34.5–43.5)	41.0 (40.0–43.5)	37.5 (35.5–41.0)
RV apex-base, mm (IQR)	70.5 (61.3–76.3)	71.0 (67.3–79.5)	68.5 (62.8–75.3)	70.5 (65.5–74.5)	69.5 (65.8–77.3)	69.0 (66.5–73.5)	72.0 (64.3–77.0)
RA area, cm^2 (IQR)	35.0 (29.8–38.2)	35.3 (30.4–38.1)	35.2 (31.4–42.0)	34.2 (24.9–44.6)	30.3 (25.9–51.3)	38.9 (28.6–47.3)	36.3 (27.4–53.6)
RA diameter, mm (IQR)	58.5 (48.3–65.8)	62.5 (53.8–64.5)	64.0 (54.0–71.0)*	60.0 (46.0–69.0)	55.0 (52.0–69.0)	60.0 (55.0–70.0)	58.0 (53.0–74.0)

Abbreviations: CAVI, caval valve implantation; LV, left ventricular; LVEDD, left ventricular end diastolic diameter; OMT, optimal medical therapy; RA area, right atrium area; RA diameter, right atrium diameter; RV apex-base, right ventricle apex to base; RVD, right ventricular diameter; RVOT, right ventricular outflow tract.

*$P < .05$ compared to baseline.

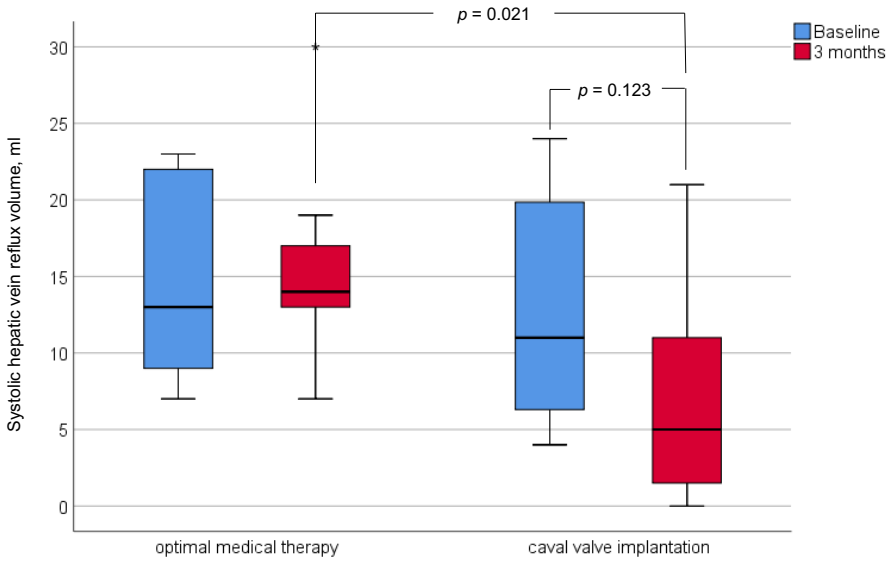

FIGURE 4 Systolic hepatic vein reflux volume at baseline and three-month follow-up

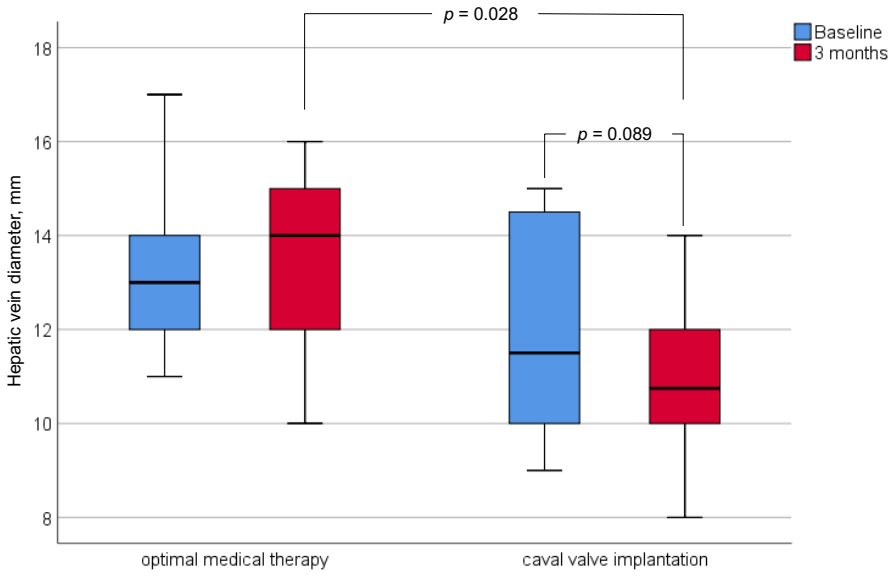

FIGURE 5 Hepatic vein diameter at baseline and three-month follow-up

TR severity after CAVI in our study population. This corresponds to a previously published case series with mainly valve implantation into the inferior vena cava that showed a stable TAPSE and only a slight increase in cardiac index.[15] The differences in study results may be explained by the procedures: bicaval valve implantation versus valve implantation into the inferior vena cava.[14,15]

Caval valve implantation is a palliative concept designed to ameliorate deleterious consequences of TR-mediated abdominal venous congestion. Compared with other interventional approaches, it is characterized by a comparatively easy and fast procedure without the necessity of intraprocedural guidance by transoesophageal echocardiography—and, hence, of general anesthesia and mechanical ventilation which can worsen right heart failure. Therefore, patients with advanced right heart failure are possible candidates for CAVI if adequate symptom control can no longer be achieved by drug therapy due to diuretic resistance. Moreover, CAVI may be considered in patients which are not suitable for other interventional TR therapies due to anatomical characteristics of the tricuspid valve or in patients with a high procedural risk resulting from general anesthesia and mechanical ventilation. Based on our results, however, CAVI using a balloon-expandable valve can currently not be recommended. CAVI using dedicated devices may be investigated in patients not suitable for TR repair.

Our results are limited by the low number of patients. Two valve dislocations and two stent migrations occurred during the first 48 hours and lead to open-heart surgery.[17] These complications were associated with an in-hospital mortality of 21% of the CAVI group (due to resuscitation-related splenic rupture, acute-on-chronic right heart failure, and pneumonia) and resulted in early termination of recruitment.[17] After twelve months, all-cause mortality comprised 57% in the CAVI and 29% in the OMT group.[17]

As CAVI does not directly aim at a reduction of TR, it is difficult to compare its effects to other interventional approaches for TR therapy. It is noteworthy, however, that most of the approaches

that described effective reduction of TR also failed to detect sustained improvement in cardiac output or morphology. In particular, percutaneous valve annuloplasty systems such as Trialign, TriCinch and Cardioband reduced TR severity which was associated with a peri-interventional improvement in left ventricular stroke volume in several published case series.[8,22–27] Long-term improvement in cardiac function and morphology, however, has not been demonstrated so far.[23,28] In contrast, recent studies suggested that edge-to-edge techniques result in reverse remodeling of the right heart. The TRILUMINATE study and small case series using the MitraClip device in the tricuspid position reduced the TR grade and led to an improvement in ventricular function and diameters up to six months after implantation.[29–31] Another study using the MitraClip could not confirm this effect with the exception of decreased post-procedural TR severity.[9] The TriValve registry which compared interventional TR therapy with medical treatment observed a reduced mortality and rehospitalization for heart failure after interventional therapy but also a more frequent procedural failure in patients with severe right ventricular dysfunction.[32]

Taken together, our results provide evidence that CAVI effectively reduces systolic backflow into the inferior vena cava and hepatic veins without affecting TR severity, cardiac function, or morphology. Importantly, the procedural failure in severe right ventricular dysfunction reported by the TriValve registry underscores that structural interventions may prove futile in patients in advanced stages of heart failure.[32] Accordingly, a lack for potential negative RV remodeling in our high-risk patient cohort might have influenced our negative findings. Future studies may be needed to re-evaluate the efficiency of CAVI using dedicated devices in patients in earlier stages of heart failure.

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