A case report: intravalvular regurgitation during percutaneous valve-in-ring implantation due to eccentric bulging of a balloon-expandable valve in a patient with severe right heart failure

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Background
Severely reduced right heart function and high operative risk are major challenges in the treatment of tricuspid regurgitation (TR) as both can lead to low cardiac output heart failure (LCO-Hf). Alternative methods and criteria for patient selection are actively being sought.

Case summary
We report on a 66-year-old patient with severe right heart failure (rHF) with recurrent TR after prior surgical valve repair with a 32-mm-Edwards-MC3 annuloplasty ring (AR). Surgical revision was discarded due to extreme high surgical risk. A right ventricular assist device was discussed but declined by the patient. Percutaneous edge-to-edge repair was not applicable due to massive tethering of the anterior leaflet and complete lack of coaptation. According to the Heart team decision, percutaneous tricuspid valve-in-ring implantation was performed using a 29-mm Sapien-3 prosthesis (SP3) under moderate balloon overinflation. Despite satisfying positioning, the prosthesis showed massive intravalvular regurgitation due to immobility of the septally oriented cusp, which was most likely caused by eccentric bulging of the prosthesis in the opening region of the AR. Implantation of a second prosthesis leads to a perfectly functional result. Importantly, no major haemodynamic complications ensued.

Discussion
Although being a potential risk of tricuspid valve repair LCO-hf could not be observed in the present case. Additionally, deformation of the implanted transcatheter aortic valve replacement prosthesis resulting from the regional lack of abutment in AR should be considered as a potential complication. Hence, further careful evaluation of the feasibility of percutaneous tricuspid valve treatment, also in patients with rHF, is needed.

Keywords
Tricuspid valve • Tricuspid regurgitation • Transcatheter therapy • Right ventricle • Case report

Learning points
- The case demonstrated two key points that could be important for the further development of interventional tricuspid valve therapy.
- Percutaneous tricuspid valve in ring treatment is feasible in patients with severely impaired right heart function.
- Oval deformation of the prosthesis resulting from the regional lack of abutment in annuloplasty rings should be considered, particularly when balloon overinflation is intended.

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Introduction

Severely reduced right heart function and high operative risk are major challenges in the treatment of tricuspid regurgitation (TR) as it can lead to low cardiac output heart failure (LCO-hf; pop-off valve phenomenon). Until today, alternative methods and criteria for patient selection are being sought. In patients with recurrent secondary TR after prior surgical tricuspid valve repair with annuloplasty ring (AR), percutaneous tricuspid valve-in-ring implantation should be considered as an alternative technique.

Timeline

| Date                  | Event                                                                 |
|-----------------------|----------------------------------------------------------------------|
| January 2010          | Symptom onset and diagnosis of dilated cardiomyopathy               |
| January 2015          | Diagnosis of tricuspid regurgitation and surgical valve repair with a 32-mm-Edwards-MC3 annuloplasty ring |
| August 2018–October 2018 | Recurrence of right heart failure symptoms and failure of pharmacological treatment |
| 06 November 2018      | Patient was admitted with pronounced right heart decompensation     |
| 12 November 2018      | Declining right ventricular assist device                            |
| 22 November 2018      | Percutaneous tricuspid valve-in-ring implantation                    |
| 30 November 2018      | Discharge in good clinical condition                                 |
| 21 January 2019       | Follow-up at 2 months: the patient showed slightly improved right and left heart function and an improved general condition without signs for right heart and liver failure |

Case presentation

A 66-year-old female patient with a history of dilated cardiomyopathy, first diagnosed 4 years ago, who had undergone surgical tricuspid valve repair with an incomplete three-dimensional-shaped rigid AR (Figure 1B) due to severe secondary TR 3 years ago presented with pronounced right heart decompensation (Figure 1A–O) including ascites, pitting pretibial oedema, bilateral pleural effusion, chronic kidney disease but without signs of liver dysfunction.

The transthoracic echocardiogram performed after 5 days of intensive diuretic therapy showed a severely impaired systolic left ventricular ejection fraction of 30% with dilation of all heart chambers and a resulting moderate secondary mitral regurgitation and severe TR. The basal diameter of the right heart was 50 mm and right heart function was severely impaired (Table 1). A transoesophageal echocardiogram (TOE) confirmed severe TR (Figure 1D) as a consequence of severe leaflet tethering but showed no signs of dehiscence of the AR. Right heart catheterization revealed moderate post-capillary pulmonary hypertension filling pressures of the right heart were significantly elevated. Right ventricular stroke work index was 1.0 g/m²/beat and central venous pressure-to-pulmonary capillary wedge pressure-ratio 0.9.

Based on the severity of right ventricular disease a right ventricular assist device (RVAD) was considered but this option was eventually discarded as it was declined by the patient at least as primary treatment option. Redo tricuspid surgery was—in line with the literature—felt to be associated with a too high perioperative risk because of renal insufficiency and poor clinical condition of the patient.1,2 Due to massive tethering with restrictive motion of the anterior leaflet and complete lack of coaptation particularly in the antero-septal area of the valve percutaneous edge-to-edge repair was also regarded as unfavourable. Our Heart Team finally decided to perform a percutaneous valve-in-ring-implantation with the option of RVAD implantation as a bail-out strategy in case of acute rHF following elimination of TR.

The procedure was performed in general anaesthesia under angiographic and TOE-guidance. A soft-tip Amplatz extra-stiff wire was placed from the femoral vein in the right pulmonary artery via a 7-Fr balloon-tipped pulmonary artery catheter. SP3 was inserted via a 16-Fr eSheath, with the company label facing towards the patient to allow for flexing of the catheter towards the tricuspid valve. Subsequently, the balloon was retracted under the valve, the valve was advanced to the tricuspid annular plane, the pusher was pulled back a couple of centimetres beyond the designated markers to allow flexible alignment of the valve and the position of the prosthesis was optimized aiming at a 15/85 right atrium to right ventricle position. The balloon was then inflated slowly, while carefully checking for correct positioning without pacing of the heart. The prosthesis could be implanted in an optimal position under an intentional overinflation of the balloon of 2 mL (Figure 2A and B).

Echocardiographic control, also after complete removal of the wire revealed a massive transvalvular regurgitation, which was found to be caused by complete immobility of the cusp adjacent to the ventricular septum resulting in a large coaptation gap (Figure 3A), most likely caused by an asymmetric bulging of the valve stent in the area of the opening of AR (Figure 3C and D). As there was only mild paravalvular leakage (PVL) (Figure 3B), the decision was taken to implant a second SP3, which could be implanted uneventfully (Figure 2C and D) and lead to complete elimination of TR with only minimal septal PVL (Figure 3E and F). Haemodynamics remained stable throughout the whole course of the procedure. The patient was extubated in the hybrid operating room and transferred to the general ward after one night in the intensive care unit. Her creatinine levels dropped from 1.8 mg/dL to 1.3 g/dL on the first post-interventional day. After mobilization, the patient was discharged in good general condition to a follow-up treatment in a rehabilitation centre.

At follow-up after 2 months, the patient showed slightly improved right and left heart function and an improved general condition—felt to be associated with a too high perioperative risk because of renal insufficiency and poor clinical condition of the patient.1,2 Due to massive tethering with restrictive motion of the anterior leaflet and complete lack of coaptation particularly in the antero-septal area of the valve percutaneous edge-to-edge repair was also regarded as unfavourable. Our Heart Team finally decided to perform a percutaneous valve-in-ring-implantation with the option of RVAD implantation as a bail-out strategy in case of acute rHF following elimination of TR.
Figure 1 Computed tomography scan in transversal (A), frontal (B), and sagittal plane (C) presents pronounced right heart decompensation. Transoesophageal echocardiogram reveals severe secondary tricuspid regurgitation despite surgical tricuspid valve repair with an annuloplasty ring, which has a general lack of abutment (D).

Figure 2 Implantation of the first (A and B) and second SP3 (C and D).
| Characteristics                                         | Pre-procedural | Two months post-procedural follow-up |
|--------------------------------------------------------|---------------|--------------------------------------|
| Weight (kg)                                            | 84            | 76                                   |
| Height (cm)                                            | 173           | 173                                  |
| New York Heart Association classification              | III           | II                                   |
| Laboratory parameters                                  |               |                                      |
| Glomerular filtration rate (mL/min)                   | 25            | 30                                   |
| Creatinine (mg/dL)                                     | 1.8           | 1.9                                  |
| Alanine transaminase (U/L)                            | 12            | 8                                    |
| Aspartate transaminase (U/L)                           | 35            | 24                                   |
| Gamma-glutamyltransferase                             | 130           | 70                                   |
| Echocardiographic parameters                          |               |                                      |
| Left atrial diameter (mm)                             | 50            | 50                                   |
| Left atrial volume (mL)                               | 132           | 126                                  |
| Left atrial volume index (mL/m²)                       | 65            | 66                                   |
| Right atrial area (cm²)                               | 37.5          | 32                                   |
| Left ventricular mass (g)                             | 212           | 183                                  |
| Left ventricular mass index (g/m²)                    | 112           | 96                                   |
| Diastolic septal wall thickness (mm)                   | 9             | 9                                    |
| Diastolic posterior wall thickness (mm)                | 9             | 9                                    |
| Left ventricular end-diastolic volume (mL)             | 143           | 154                                  |
| Left ventricular end-systolic volume (mL)              | 100           | 98                                   |
| Left ventricular ejection fraction (%)                 | 30            | 37                                   |
| Right ventricular basal diameter (mm)                  | 50            | 47                                   |
| Right ventricular fractional area change (%)           | 25            | 27                                   |
| Right ventricular index of myocardial performance     | 0.4           | 0.4                                  |
| Tricuspid annular plane systolic excursion (mm)        | 9             | 11                                   |
| Tricuspid regurgitation grading                        | Torrential    | Mild                                 |
| Tricuspid regurgitation max velocity (m/s)             | 1.68          | 3.2                                  |
| Tricuspid valve inflow max velocity (m/s)              | 1.68          | 0.96                                 |
| Tricuspid valve inflow mean velocity (m/s)             | 0.83          | 1.06                                 |
| Tricuspid valve max diastolic pressure gradient (mmHg) | 11            | 5                                    |
| Tricuspid valve mean diastolic pressure gradient (mmHg)| 3.63          | 3.49                                 |
| Tricuspid four-chamber view tethering area (cm²)       | 2.4           | Ø                                    |
| Systolic pulmonary artery pressure (mmHg)              | 35            | 50                                   |
| Parameters derived from right heart catheterization    |               |                                      |
| Mean pulmonary artery pressure (mmHg)                  | 31            | Ø                                    |
| Mean pulmonary capillary wedge pressure (PCWP) (mmHg)  | 24            | Ø                                    |
| Right ventricular end-diastolic pressure (mmHg)        | 17            | Ø                                    |
| Mean right atrial pressure (mmHg)                      | 28            | Ø                                    |
| V wave (mmHg)                                          | 32            | Ø                                    |
| Right ventricular stroke work index (g/m²/beat)        | 1             | Ø                                    |
| Central venous pressure-to-PCWP-ratio                  | 0.9           | Ø                                    |
Discussion

The case demonstrated two key points that could be important for the further development of interventional tricuspid valve therapy:

- Treatment of atrioventricular valve regurgitation in right as in left heart failure is considered to be associated with a risk of LCO-hf (pop-off valve phenomenon). Nevertheless, percutaneous tricuspid V-i-R implantation was performed without any sign of low cardiac output. Rather, rapid improvement of renal function ensued as a clear sign to the contrary in our patient despite pronounced echocardiographic and haemodynamic signs of rHF and was confirmed in the follow-up after 2 months. Accordingly, further careful evaluation of the feasibility of percutaneous tricuspid valve treatment in patients with rHF is warranted.

- The first prosthesis showed an oval deformation with complete immobility of one cusp adjacent to the septum. The deformation seems to be caused by eccentric bulging of the valve stent at the intraventricular septum (red arrow) and the paravalvular leakage (orange arrows).
opening site of the ring following moderate overinflation of the balloon. This complication possibly results from the regional lack of abutment in open ARs should be taken into account in the context of interventional tricuspid valve therapy, particularly when balloon overinflation is considered.

**Lead author biography**

Since March 2017 Muhammed Gerc¸ek is a resident at the Clinic for General and Interventional Cardiology/Angiology at the Heart and Diabetes Center NRW in Bad Oeynhausen, Germany. He graduated from RWTH-Aachen University medical school (Germany) and Erciyes University medical school (Kayseri, Turkey) in 2016. After completing his doctoral thesis on arrhythmogenic right ventricular cardiomyopathy his research now focuses on valvular heart disease and heart failure.

**Supplementary material**

Supplementary material is available at European Heart Journal - Case Reports online.

**Slide sets:** A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

**Consent:** The author/s confirm that written consent for submission and publication of this case report including image(s) and associated text has been obtained from the patient in line with COPE guidance.

**Conflict of interest:** T.K.R. is proctor for Edwards Lifesciences and received speaker’s honoraria.

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