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Comparison of right ventricular function in patients undergoing transcatheter aortic valve implantation and surgical aortic valve replacement

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Abstract. *Aim:* Comparison of the impact of surgical and transcatheter aortic valve replacement on the right ventricular function in patients with severe aortic stenosis.

Methods and results: We performed a prospective analysis of right ventricular function parameters (TAPSE, RVPSV and FAC) of 50 TAVI and 50 AVR patients at three time intervals – preoperatively, up to 7 days and after 6 months postoperatively. Although the patients undergoing AVR were younger and had less complex cardiac impairment, their right ventricular function deteriorated significantly in the early post-operative phase (TAPSE –10.52mm, RVPSV -4.23cm / s, FAC -10.22%, p <0.001) and the right ventricular dysfunction was still present after 6 months in 35.9% of patients. In the more complex TAVI cohort, RV function remained unchanged in the early phase (TAPSE -0.04mm, RVPSV +0.58 cm/s, FAC +0.96%; p = 0.94, p = 0.07, p = 0.43, respectively), and at 6 months follow-up (RVD in 35% at 6m vs 38% at baseline, p = 0.73). The difference in the postoperative behaviour of right ventricular function was statistically significant and consistent after accounting for the preprocedural difference between the cohorts.

Conclusion: Although patients undergoing TAVI have more complex cardiac impairment, TAVI, unlike AVR, does not cause periprocedural deterioration of RV function. Fig. 5, Tab. 5, Ref. 13, on-line full text (Free, PDF) www.cardiologyletters.sk

Key words: aortic stenosis – transcatheter aortic valve replacement – right ventricular dysfunction – risk prediction

Poliačiková P, Hriňová M, Hudec M, Belicová M. **Porovnanie funkcie pravej komory srdca po transkatétrovej a chirurgickej náhrade aortálnej chlopne.** Cardiology Lett. 2022;31(4):213–220

Abstrakt. *Cieľ:* Porovnanie vplyvu chirurgickej a transkatétrovej náhrady aortálnej chlopne na funkciu pravej komory u pacientov s ťažkou aortálnou stenózou.

Metóda a výsledky: Zrealizovali sme prospektívnu analýzu echokardiografických parametrov funkcie pravej komory (TAPSE, RVPSV a FAC) pri 50 TAVI a 50 AVR pacientov v troch časových intervaloch – predoperačne, do siedmich dní a po šiestich mesiacoch pooperačne. Napriek tomu, že pacienti podstupujúci AVR boli mladší a mali menej komplexné kardiálne postihnutie, periprocedurálne u nich

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došlo k významnému poklesu funkcie PK (TAPSE –10,52 mm, RVPSV -4,23 cm/s, FAC -10,22 %, p < 0,001) a dysfunkcia pravej komory bola aj po šiestich mesiacoch prítomná u 35,9 % pacientov. V komplexnejšej TAVI kohorte ostala funkcia PK nezmenená včasne po zákroku (TAPSE -0,04 mm, RVPSV +0,58 cm/s, FAC +0,96 %; p = 0,94, p = 0,07, p = 0,43, v tomto poradí), ako aj po šiestich mesiacoch (RVD u 35 % po šiestich mesiacoch vs. 38 % preprocedurálne, p = 0,73). Rozdiel v pooperačnom vývoji funkcie PK bol jednoznačne štatisticky významný a konzistentný aj po zohľadnení preprocedurálnej odlišnosti dvoch sledovaných kohort.
Záver: Napriek tomu, že pacienti podstupujúci TAVI majú komplexnejšie kardiálne postihnutie, TAVI, na rozdiel od AVR, nespôsobuje periprocedurálnu deterioráciu funkcie PK. Obr. 5, Tab. 5, Lit. 13, on-line full text (Free, PDF) www.cardiologyletters.sk
Kľúčové slová: aortálna stenóza – transkatétrová náhrada aortálnej chlopne – dysfunkcia pravej komory – predikcia rizika

Transcatheter aortic valve replacement (TAVI) is currently considered to be at least equivalent to surgical valve replacement (AVR) across the entire risk spectrum of patients with severe aortic stenosis. Standard risk prediction models (STS and Euroscore) have lost their relevance in the decision-making algorithm of selecting the appropriate treatment approach for a particular patient. The need to identify the factors predicting the procedural outcome and the patients´ prognosis has therefore become increasingly relevant. Several retrospective and small prospective studies suggest that aortic valve replacement (AVR) results in deterioration of right ventricular (RV) function and that perioperative RV dysfunction is a predictor of morbidity and mortality after AVR (1, 2). Other authors question this theory and point to the complexity of the RV function assessment (3, 4, 5). Preservation of right ventricular function after mini-invasive surgical aortic valve replacement has previously been described, suggesting that the negative impact of AVR on RV function may be inherent to AVR, and that less invasive procedures might be preferable in this regard. The behaviour and prognostic relevance of right ventricular function after TAVI has until recently been the subject of only a few small, mostly retrospective studies, with conflicting results (6, 7, 8). Our aim was to help to clarify the issue, and thus contibute to the optimisation of the management of patients with severe aortic stenosis.

Methods

Population

Between 2019 and 2022, we enrolled 50 patients with severe aortic stenosis (defined as Vmax ≥4 m / s, and / or MG ≥40 mm Hg, and / or AVA <1.0 cm^2) planned for surgical aortic valve replacement and 50 patients planned for TAVI. The method of valve replacement (AVR versus TAVI) was chosen based on multidisciplinary team (MDT) decision, taking into account results of CT aortography, coronary angiography and clinical characteristics of the patients. We evaluated the right ventricular function behaviour in patients after TAVI, in patients after AVR and compared the two groups.

Procedure

AVR was performed under general anesthesia, using median sternotomy and extracorporeal circulation. Concomitant coronary artery disease as well as combined valve disease were treated as per the MDT decision. TAVI was performed using transfemoral minimalist approach – fully percutaneous, in analgosedation, under fluoroscopic and transthoracic echocardiographic guidance, using cerebral protection in case of suitable carotid artery anatomy. Patients were mobilized within 24 hours after the procedure.

Echocardiogpraphy

We performed a comprehensive echocardiographic examination in 3 time intervals: before AVR / TAVI, within 7 days after AVR / TAVI and after 6 months from AVR / TAVI. We assessed the right ventricular function using a) tricuspid annular plane systolic excursion (TAPSE), b) right ventricular peak systolic velocity (RVPSV) as parameters of longitudinal RV function and c) fractional area change as parameter of global contractile function. Right ventricular dysfunction (RVD) was defined as the presence of: a) TAPSE below 18mm, b) RVPSV below 10cm / s, c) FAC below 36%. Longitudinal RV dysfunction (RVD long) was defined as the presence of: a) TAPSE below 18 mm and/or b) RVPSV below 10 cm / s. Global contractile RV dysfunction (RVD glob) was defined as FAC below 36%. We compared the

procedure related change of the parameters within the groups, as well as between the two groups.

Statistical evaluation

Interval variables are presented as mean ± SD, categorical variables are expressed in number or percentage. The pre-and postprocedural parameters are compared using Student's t-test. Comparison between the groups was performed using t-test for two independent selections. Potential impact of preprocedural difference of the studied groups was evaluated with multivariaate regression analysis.

Results

Demographic and clinical parameters

Our study was not randomized, therefore the two cohorts differed significantly in several demographic and clinical parameters. The differences reflect the real world clinical practice, with TAVI patients being older and with higher prevalence of concomitant comorbidities (**Table 1**).

Preprocedural echocardiographic parameters

Combined valvular disease, left ventricular systolic dysfunction, as well as right ventricular systolic dysfunction (38% vs 18%; TAVI versus AVR, respectively, p = 0.02) were more frequent in the TAVI cohort. All baseline RV function parameters were significantly worse in the TAVI arm (TAPSE 21.8 vs 24.4mm, RVPSV 12.1 vs 13.7 cm / s and FAC 41 vs 43.9%; TAVI vs AVR, respectively) (**Table 2**).

Table 1 Demography

	AVR	TAVI	P-value
Age (years)	67 (± 8)	77 (± 5)	<0.001
Female (%)	40	70	<0.001
Height (cm ± SD)	169 (± 12)	163 (± 8)	<0.001
Weight (kg ± SD)	85 (± 16)	75 (± 16)	<0.001
Diabetes mellitus (%)	26	38	0.20
Chronic renal failure (%)	2	42	<0.001
History of MI (%)	8	16	0.22
COPD (%)	10	16	0.38
Peripheral artery disease (%)	12	40	0.14
Atrial fibrillation (%)	20	32	0.17

AVR – aortic valve replacement, TAVI – transcatheter aortic valve replacement, SD – standard deviation, MI – myocardial infarction, COPD – chronic obstructive pulmonary disease

Table 2 Preprocedural echocardiographic parametres

	AVR	TAVI	P-value
Ao PG (mmHg ± SD)	92 (± 26)	89 (± 28)	0.57
Ao MG (mmHg ± SD)	53 (± 14)	51 (± 17)	0.60
AVA (cm2 ± SD)	0.7 (± 0.2)	0.7 (± 0.2)	0.25
MR moderate/severe (%)	26	78	**<0.001**
TR moderate/severe (%)	8	50	**<0.001**
PH moderate/severe (%)	10	62	**<0.001**
sPAP (mmHg ± SD)	36 (± 5.9)	52 (± 15)	**<0.001**
LVEF < 50% (%)	10	34	**0.003**
LVEF (% ± SD)	56.6 (± 6.9)	50.8 (± 9.2)	**<0.001**
TAPSE (mm ± SD)	24.4 (± 3.7)	21.8 (± 6.2)	**0.01**
RVPSV (cm/s ± SD)	13.7 (± 2.4)	12.1 (± 3.0)	**<0.01**
FAC (%± SD)	43.9 (± 9.2)	41 (± 11.1)	0.15
RVD (%)	18	38	**0.02**
RVD – longitudinal (%)	2	26	**<0.001**
RVD – global (%)	18	28	0.24

AVR – aortic valve replacement, TAVI – transcatheter aortic valve replacement, SD – standard deviation, Ao PG – aortic peak gradient, Ao MG – aortic mean gradient, AVA – aortic valve area, MR – mitral regurgitation, TR – tricuspid regurgitation, PH – pulmonary hypertension, sPAP – systolic pulmonary artery pressure, LVEF – left ventricular ejection fraction, TAPSE – tricuspid annular plane systolic excursion, RVPSV – right ventricular peak systolic velocity, FAC – fractional area change, RVD – right ventricular dysfunction

Postoperative evaluation of right ventricular function

AVR

Soon after surgical valve replacement all RV parameters deteriorated significantly (TAPSE –10.5 mm, RVPSV –4.2 cm / s and FAC –10.2%.) (**Table 3, 5, Figure 1**), which resulted in postoperative right ventricular dysfunction in 91.8% of patients. Interestingly, longitudinal contractile function was impaired in most of the patients (89.8% of patients), while global contractile function expressed by FAC remained preserved in some (global contractile dysfunction present in 50% of patients) (**Table 3, Figure 2**). Although the deterioration was partially reversible, even after 6 months the parameters did not reach their preprocedural values (TAPSE –5.1mm, p, RVPSV –2.4cm / s, FAC -1.8%) and a degree of right ventricular dysfunction was still present in more than a third of patients, mainly in its longitudinal component (**Table 3**).

TAVI

After percutaneous aortic valve replacement the right ventricular function remained unchanged (**Table 4, 5, Figure 3, 4**). In the early postoperative phase there

was slight improvement in the individual RV function parameters (TAPSE -0.04 mm, RVPSV +0.58cm / s, FAC +0.96%), and the preexisting right ventricular dysfunction resolved in a small proportion of patients (RVD 34% vs 38%, P =0.32). The improvement was more pronounced in the longitudinal component of RV contractile function, while there was mild postprocedural increase in global contractile dysfunction as expressed

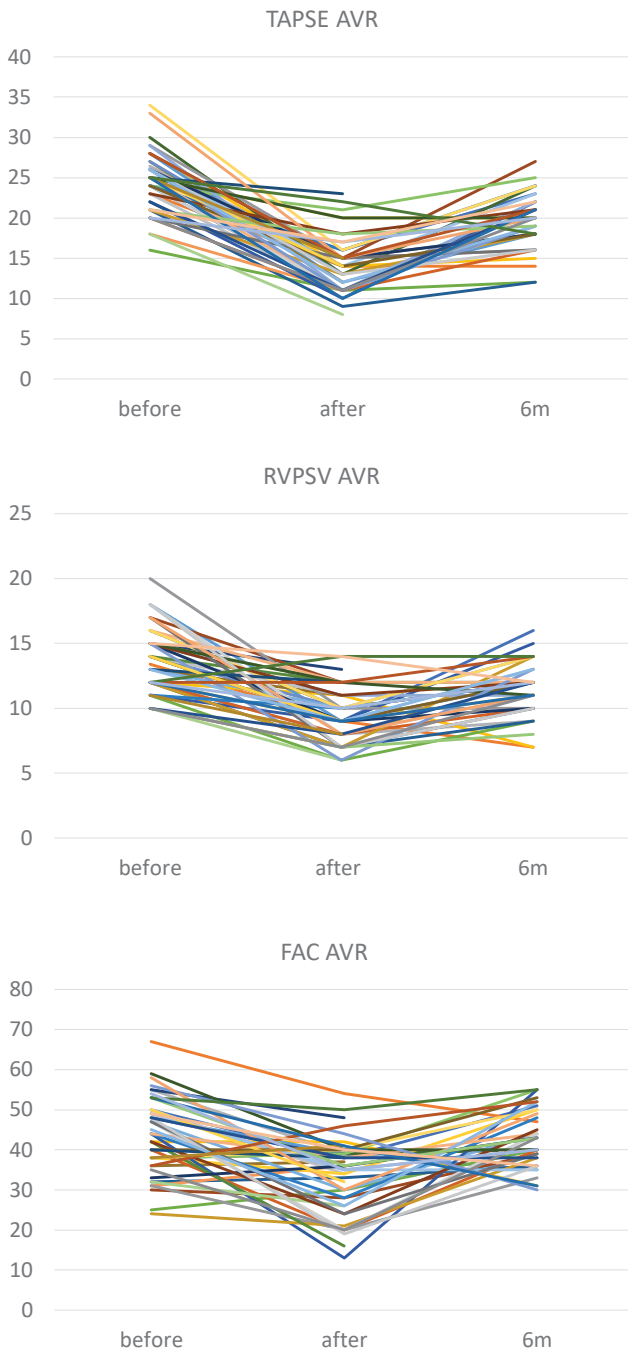

Figure 1 RV function parameters after AVR
AVR – aortic valve replacement, RV – right ventricle, TAPSE – tricuspid annular plane systolic excursion, RVPSV – right ventricular peak systolic velocity, FAC – fractional area change

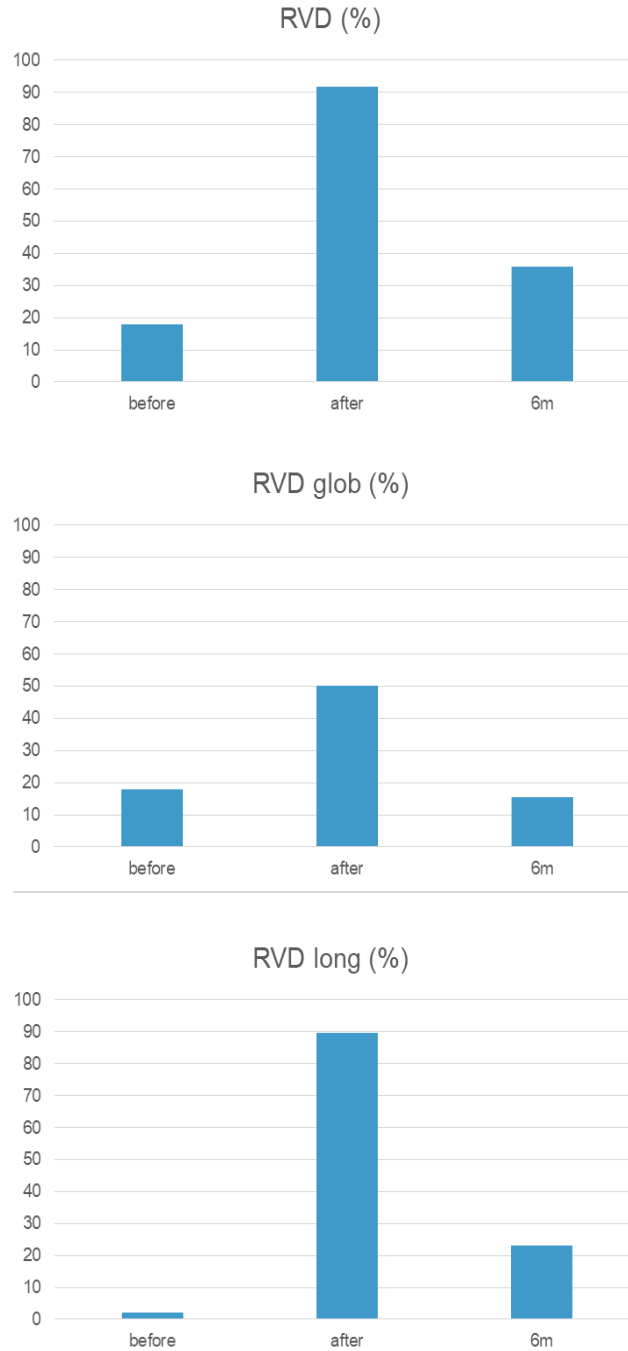

Figure 2 RV dysfunction after AVR
AVR – aortic valve replacement, RV – right ventricle, RVD – right ventricular dysfunction, glob – global, long – longitudinal, m – months

Table 3 Early and late post-AVR RV assessement

AVR					
	Preprocedural	Posptrocedural	P- value	6 months	P-value
TAPSE mm	24.4 (± 3.7)	14.0 (± 3.4)	**<0.001**	19.6 (± 3.4)	**<0.001**
RVPSV (cm/s)	13.7 (± 2.4)	9.5 (± 2.1)	**<0.001**	11.5 (± 2.0)	**<0.001**
FAC (%)	43.9 (± 9.2)	33.3 (± 9.1)	**<0.001**	42.6 (± 7.1)	0.29
RVD (%)	18	91.8	**<0.001**	35.9	0.91
RVD glob (%)	18	50.0	**<0.001**	15.4	0.74
RVD long (%)	2	89.8	**<0.001**	23.1	**<0.001**
sPAP	37.7 (± 7.7)	41.5 (± 12.13)	**<0.01**	35.1 (± 12.3)	0.63

AVR – aortic valve replacement, RV – right ventricle, TAPSE – tricuspid annular plane systolic excursion, RVPSV – right ventricular peak systolic velocity, FAC – fractional area change, RVD – right ventricular dysfunction, sPAP – systolic pulmonary artery pressure

by FAC. None of the differences was statistically significant (**Table 4, 5**). In the TAVI arm, as opposed to AVR, we observed progressive improvement of sPAP (54.3 vs 51.3 vs 47.7 mmHg), as well as improvement of moderate to severe pulmonary hypertension (34.8% vs 62%, p <0.001).

Table 4 Early and late post-TAVI RV assessement

TAVI					
	Preprocedural	Postprocedural	P-value	6 months	P-value
TAPSE mm	21.8 (± 5.5)	21.8 (± 5.1)	0.94	22.1 (± 4.8)	0.95
RVPSV (cm/s)	11.9 (± 2.9)	12.6 (± 3.5)	0.07	12.5 (± 3.2)	0.41
FAC (%)	41.6 (± 10.1)	42.0 (± 9.4)	0.43	43.2 (± 7.5)	0.25
RVD (%)	38	34	0.32	34.8	0.73
RVD glob (%)	28	32	0.42	21,7	0.55
RVD long (%)	26	20	0.08	26.1	1
sPAP (mmHg)	54.3 (± 14.5)	51.3 (± 13.1)	0.105	47.7(± 12.2)	**0.001**
PH 2 – 3 (%)	62	50	0.39	34.8%	**<0.001**

TAVI – transcatheter aortic valve replacement, TAPSE – tricuspid annular plane systolic excursion, RVPSV – right ventricular peak systolic velocity, FAC – fractional area change, RVD – right ventricular dysfunction, sPAP – systolic pulmonary artery pressure, PH – pulmonary hypertension

Table 5 Comparison of impact of AVR vs TAVI on RV function

	Early			Late		
	AVR	**TAVI**	**P-value**	**AVR**	**TAVI**	**P-value**
Delta TAPSE mm	-10.5 (± 4.5)	-0.04 (± 3.8)	**<0,001**	-5.1 (± 3.9)	0.04 (± 5.2)	**<0,001**
Delta RVPSV (cm/s)	-4.2 (± 2.8)	0.58 (± 2.3)	**<0,001**	-2.4 (± 3.2)	0.35 (± 3.0)	**<0,001**
Delta FAC (%)	-10.2 (± 10.11)	0.96 (± 8.5)	**<0,001**	-1.8 (± 11.8)	1.9 (± 11.4)	0.12
Delta RVD (%)	73.5	-4	**<0,001**	17,9	-2.2	0.05
Delta RVD long (%)	87.8	-0.06	**<0,001**	20.5	0	**0.01**
Delta RVD glob (%)	30.6	0.04	**0.004**	-2.56	-0.04	0.87
Delta sPAP (mmHg)	5 (± 12.9)	-2.25 (± 9.8)	**0.002**	-0.93 (± 13.6)	-7.16 (±15.7)	**0.03**
Delta PH (2-3) (%)	-2	-12	**0.39**	-3.2	-27.2	**<0,001**

AVR – aortic valve replacement, TAVI – transcatheter aortic valve replacement, RV – right ventricle, TAPSE – tricuspid annular plane systolic excursion, RVPSV – right ventricular peak systolic velocity, FAC – fractional area change, RVD – right ventricular dysfunction, sPAP – systolic pulmonary artery pressure, PH – pulmonary hypertension

Comparison of the impact of TAVI versus AVR on the right ventricular function

We observed a clear difference in favor of TAVI in terms of the early periprocedural impact on RV function and its individual parameters (**Table 5, Figure 5**). Over time, the global contractile function became comparable in the two groups, while the deteriorating effect of AVR, compared to TAVI, on the longitudinal contractile function persisted. The different impact of AVR versus TAVI on pulmonary hypertension was apparent early in the post-procedural period and, after 6 months, the superiority of TAVI in this regard was clearly confirmed.

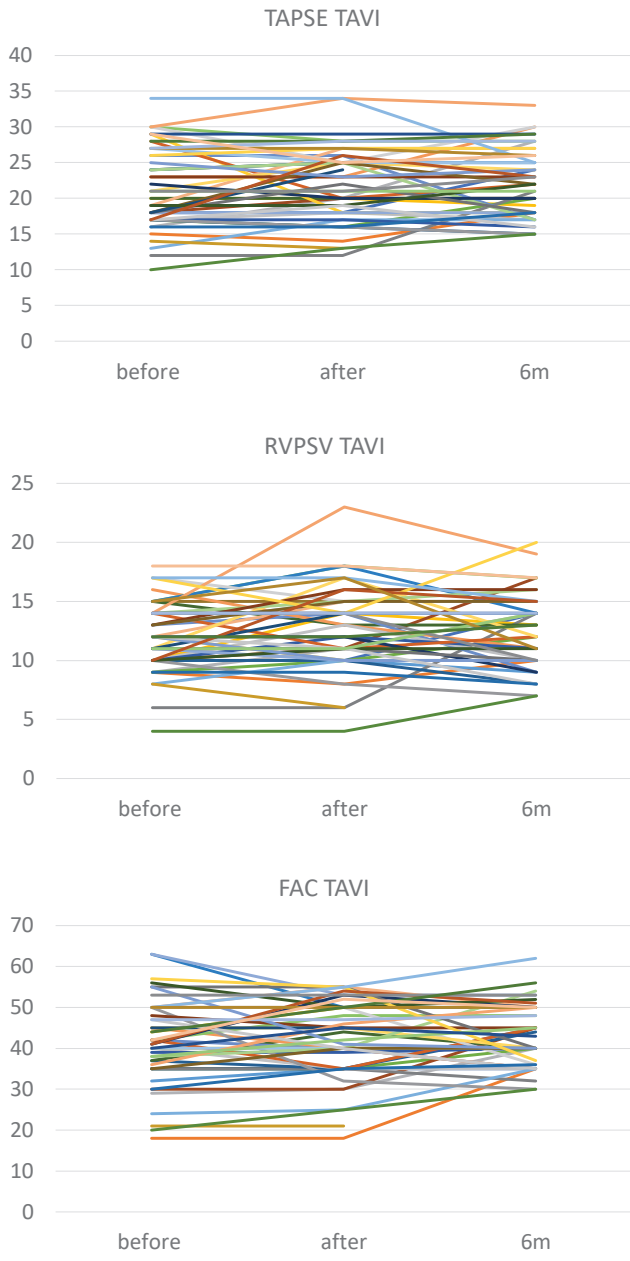

Figure 3 RV function parameters after TAVI
RV – right ventricle, TAVI – transcatheter aortic valve replacement, TAPSE – tricuspid annular plane systolic excursion, RVPSV – right ventricular peak systolic velocity, FAC – fractional area change

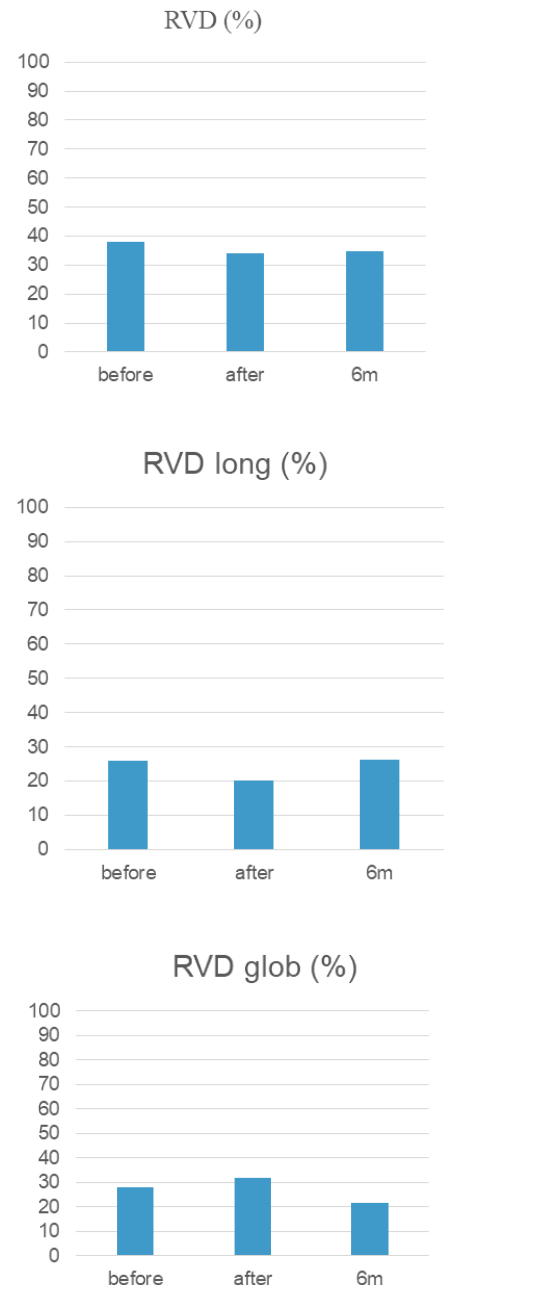

Figure 4 RV dysfunction after TAVI
RV – right ventricle, TAVI – transcatheter aortic valve replacement, RVD – right ventricular dysfunction, glob – global, long – longitudinal, m – months

Discussion

We confirmed a significant difference in the behaviour of the right ventricular function after TAVI and AVR. Although the patients undergoing AVR were younger and had less complex cardiac impairment, their RV function deteriorated significantly. Importantly, this change was only partially reversible, the preprocedural level of the individual RV function parameters was not reached in most patients and the right ventricular dysfunction was still present in a significant proportion of patients over time. On the contrary, in the overall more complex TAVI cohort, the RV function remained intact. In addition, pre-existing RV dysfunction resolved in a proportion of TAVI patients, although this change was not statistically significant in our study.

The difference in the impact on the RV function between the two treatment groups (TAVI vs AVR) was unambiguously statistically significant and consistent after taking into account the preprocedural difference of the two studied cohorts.

Our results support the findings of previously published works describing periprocedural deterioration of RV function early after AVR (7, 8) and neutral (5, 7), ev. positive effect of TAVI (9, 10).

The pathophysiological background of the described difference is not clearly explained and will most probably be a combination of several periprocedural factors. Mechanical ventilation, cold cardioplegia, and prolonged extracorporeal circulation may result in increased pulmonary vascular resistance and subsequent RV impairment after AVR (11). In our study, we observed a significant increase in sPAP, which may have contributed to the postsurgical RV impairment. Both the sPAP increase, as well as the RV dysfunction, were transient to some extent, supporting the theoretical assumption of a pathophysiological link. In contrast, in the TAVI cohort, we observed postprocedural improvement of sPAP and pulmonary hypertension, which might have played a protective role with regard to RV function.

Violation of pericardial integrity and consequent impairment of the right ventricular filling and RV geometry after AVR might result in selective impairment of the longitudinal contractile function (4, 5, 12). In our study, the RV impairment was indeed more pronounced in its longitudinal component (TAPSE, RVPSV), but the deterioration of FAC as a parameter of global contractile function was also statistically significant.

After TAVI, we observed a tendency of postprocedural RV improvement, although in our study the difference remained statistically insignificant. In a recent study of 144 TAVI patients Leclerq et al. described a statistically significant recovery of pre-existing RV dysfunction (9). On the other hand Crouch et al., who used magnetic resonance imaging to evaluate RV function, described more significant RV impair-

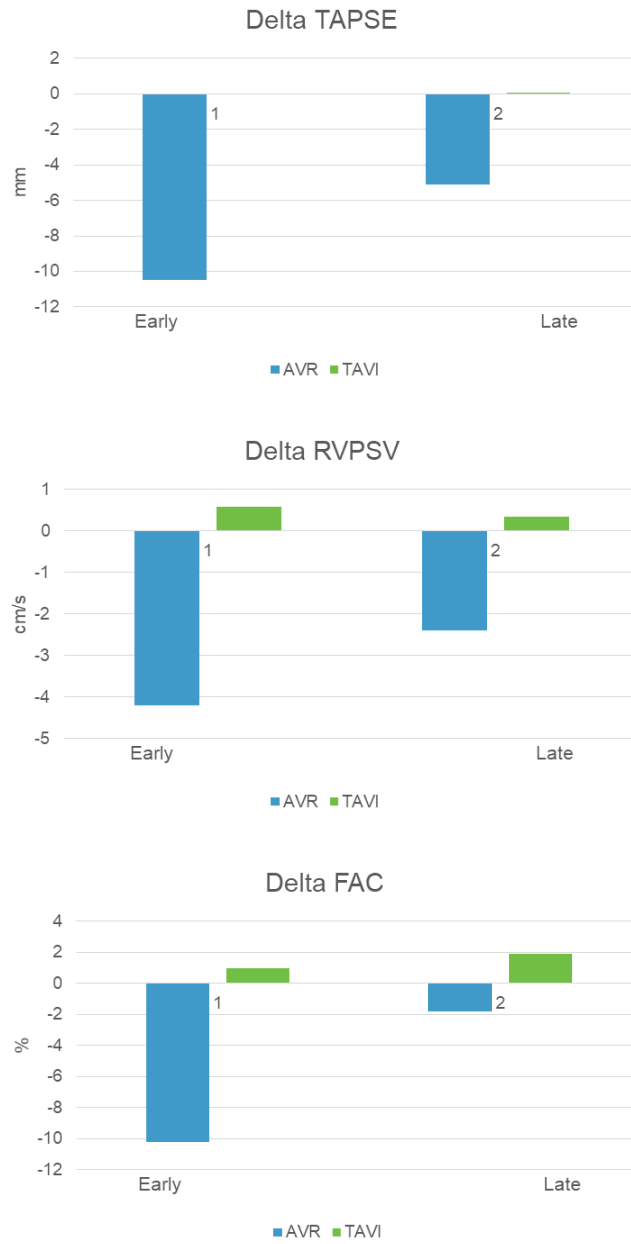

Figure 5 Comparison of RV function change after AVR vs TAVI

RV – right ventricle, TAVI – transcatheter aortic valve replacement, AVR – aortic valve replacement, TAPSE – tricuspid annular plane systolic excursion, RVPSV – right ventricular peak systolic velocity, FAC – fractional area change

ment (assessed by RVEF) after TAVI than after AVR, which in the absence of periprocedural ischemia was explained by periprocedural rapid RV pacing (4). In our study, we did notice an early increase in postprocedural global contractile RV dysfunction assessed by FAC, but it was insignificant and only temporary – both total right ventricular dysfunction as well as its global contractility component were less prevalent after 6 months.

The size of our cohort did not allow us to evaluate the impact of RV function and its periprocedural change on patients' prognosis. We know that the RVD is a negative prognostic factor after AVR. The impact of pre-existing RVD on prognosis of TAVI patients is less studied, but recently published data suggest that although preprocedural RVD can be considered a negative prognostic factor, postprocedural improvement of RV function can neutralize the negative prognostic impact (10, 13).

In our study we confirmed that TAVI, unlike conventional aortic valve replacement surgery, has no deleterious effect on the right ventricular function. Therefore, taking into account the prognostic implications of the right ventricular dysfunction, TAVI might be the first-line treatment for a group of patients with pre-existing RV dysfunction and for those in whom potential deterioration of RV function would be associated with a prohibitive risk.

Conclusion

While surgical AVR is associated with significant and only partially reversible deterioration of right ventricular function, the RV function remains preserved after TAVI. We consider our findings important for treatment selection in patients with severe aortic stenosis.

Limitations

The size of our cohorts did not allow for evaluation of the impact of pre- and postoperative RV dysfunction on the patients' prognosis. We find this question to be an interesting topic for future research.

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