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Abstract

Aim: Knowledge of longitudinal left and right ventricular (LV, RV) function after transcatheter aortic valve implantation (TAVI) is scarce. We hypothesized that longitudinal systolic biventricular function in aortic stenosis patients is affected differently by TAVI and surgical aortic valve replacement (SAVR). **Methods and Results:** 33 aortic stenosis patients (all-TAVI group, age 81±9 years, 18 female), with EuroSCORE 18±9%, were accepted for TAVI. Seventeen of these patients were matched by gender, age and LV function to 17 patients undergoing SAVR. Conventional echocardiographic parameters, systolic atrioventricular plane displacement (AVPD) at standard sites and peak systolic velocity (PSV) by pulsed tissue Doppler at basal RV free wall, LV lateral wall and septum were studied before and eight weeks after the procedure. Procedural success was 100%, 30-day mortality 9%. In all TAVI patients, $AVPD_{lateral}$, $PSV_{lateral}$, $AVPD_{septal}$ and PSV_{septal} increased ($p<0.001$, 0.003, 0.006 and 0.002). When studying the matched patients postoperatively, both the SAVR and TAVI-patients had increased $PSV_{lateral}$ and $AVPD_{lateral}$ (SAVR: $p=0.03$ and $p=0.04$, TAVI: $p=0.04$ and $p=0.01$). The PSV_{RV} increased in the all-TAVI group ($p=0.007$) while the $AVPD_{RV}$ was unchanged. SAVR-patients had decreased $AVPD_{RV}$ ($p=0.001$), and PSV_{RV} ($p=0.004$), while the matched TAVI-patients had unchanged RV function parameters. **Conclusions:** An improvement in regional longitudinal LV function in the septal and lateral wall could be seen after TAVI. Among the matched patients, both the TAVI and SAVR-patients seemed to improve LV function in the lateral wall. RV systolic function increased in TAVI-patients, but was impaired in the matched SAVR-group at the eight-week follow-up.

Key Words: Transcatheter aortic valve implantation, aortic stenosis, left ventricular function, right ventricular function, echocardiography

Introduction

Surgical aortic valve replacement (SAVR) is the treatment of choice in patients with symptomatic severe aortic stenosis (AS) since, following symptom onset and without SAVR, this patient group has an average survival of only two to three years.(1) Some of these patients have not been offered conventional open heart surgery because of a high mortality risk rate due to age and comorbidities. Transcatheter aortic valve implantation (TAVI) has rapidly developed into a feasible alternative for treating these high risk patients with severe AS.(2)

An abnormal longitudinal left ventricular (LV) function has been observed in AS patients before a decrease in LV ejection fraction (LVEF) has appeared.(3) Pulsed tissue Doppler imaging (TDI) has proven to be informative in a variety of cardiac disorders, with the potential of identifying a reduced longitudinal LV function before more established LV function parameters, such as EF, exhibit deterioration.(4, 5)

RV function assessed by tricuspid annular motion decreases after open heart surgery and cardiopulmonary bypass. Pericardial disruption and myocardial ischemia have been hypothesized as explanations of this phenomenon.(6-8)

The aim of this study was to determine changes in left and right ventricular global and longitudinal function in patients undergoing TAVI assessed by echocardiography and pulsed TDI. By matching a group of AS patients undergoing conventional aortic valve surgery, we also aimed to study whether the two procedures affect biventricular function differently.

Method

Patients

TAVI group

Between September 2008 and January 2010, 33 patients with severe symptomatic aortic stenosis were accepted for TAVI. These patients were assessed by a team of surgeons and cardiologists as not being candidates for conventional surgery, due to a high surgical risk or contraindications to AVR. Exclusion criteria were: an aortic annulus diameter of less than 18 mm, or more than 25 mm, or if life of a reasonable quality or duration of life was unlikely**.** Preprocedural investigations included transthoracic and transesophageal echocardiography, coronary angiography, iliofemoral angiography and CT-scan of the aorta with 3D reconstruction. The transfemoral approach was the first choice of treatment and in the case of contraindications to this approach, the transapical approach was chosen.

SAVR patients

Seventeen AS patients, referred to our center for surgical aortic valve replacement, could be matched to 17 TAVI patients by gender, age (± 10 years) and LV function.

Echocardiography

All patients were examined by echocardiography (Vivid 7 ultrasound system, GE Vingmed Ultrasound, Horten, Norway) one day before their procedure and were re-examined eight weeks postprocedurally. Echocardiographic images were saved for off-line analysis and parameters were measured as recommended in the appropriate guidelines.(9, 10) LVEF was visually estimated by an experienced investigator according to a four-grade scale where normal systolic function corresponds to EF >50%, slightly reduced EF 40-50%, moderately reduced EF 30-39% and severely reduced <30%. LV mass was calculated by using the

equation $0.8x(1.04x[LVEDD+PWTd+SWTd]^3-LVEDD^3)+0.6g$ and was indexed to body surface area (BSA). Left ventricular outflow tract (LVOT) dimension was measured from the parasternal long-axis view and LVOT area was calculated. Right and left atrial area was calculated by close outlining of the endocardial border in an apical 4-chamber view.

Using Doppler Echocardiography, peak aortic velocity, peak LVOT velocity, aortic and LVOT velocity time integral (VTI_{Ao} and VTI_{LVOT}) and mean pressure gradient (ΔP_{mean}) were determined. The effective orifice area (EOA) was calculated from the continuity equation: $EOA=(Area_{LVOT}xVTI_{LVOT})/VTI_{Ao}$, and was indexed to BSA (iEOA). The presence and degree of aortic regurgitation and mitral regurgitation were recorded in all patients. Post-procedurally, aortic regurgitation was further evaluated as paravalvular or transvalvular. In the case of tricuspid regurgitation (TR), the peak TR velocity was inserted into the Bernoulli equation and the pressure gradient between the right atrium and right ventricle was estimated.

Peak velocities of early (E) and late (A) diastolic filling, E/A ratio, isovolumic relaxation time (IVRT), deceleration time and pulmonary venous systolic and diastolic flow velocity were derived from Doppler recordings of the mitral inflow at the mitral leaflet tips and the venous inflow of the right upper pulmonary vein near the orifice. These variables were used for classification of LV diastolic function into four groups: normal, impaired relaxation, pseudonormal and restrictive.(11) Patients with atrial fibrillation formed a fifth group.

Pulsed Tissue Doppler Imaging (TDI). To estimate regional myocardial function, peak systolic (PSV), early diastolic (é) and late diastolic (á) myocardial velocity were measured in the LV septal, LV lateral and RV free wall. The 6 x 6 mm sample volume was placed directly underneath the mitral or tricuspid annulus in the basal myocardium in an apical 4-chamber view. The mean value of three beats was calculated.

Systolic atrioventricular plane displacement, measured by M-mode echocardiography was determined at the LV septal, LV lateral and RV lateral annulus as previously described.(12)

TAVI procedure

The transfemoral and transapical procedures were performed in a catheterization laboratory under general anesthesia and with guidance of transesophageal echocardiography (TEE) and fluoroscopy. Cardiopulmonary bypass was not used. Edwards SAPIEN bioprostheses (Edwards Lifesciences; Inc, Irvine, California), 23-mm or 26-mm were implanted. The bioprostheses were deployed during rapid ventricular pacing.

Statistics

Continuous data are expressed as mean±SD. All categorical variables are given as frequencies or percentages with the exception of the grade of aortic and mitral regurgitation which are reported as median (25^{th} -75^{th}). Pre- and postimplantation data within the entire TAVI group (all-TAVI), and within and between the two matched groups, were analysed by Wilcoxon signed rank test. Pearson correlation coefficient was used to explore possible relations between RV long axis function and RA-RV pressure difference. A probability value of $p \leq 0.05$ was considered significant. Data analyses were performed with SPSS 16.0. All patients gave their written informed consent prior to their participation. The study complies with the Declaration of Helsinki and the study was approved by the Regional Ethical Review Board in Linköping.

Results

TAVI Patients

Clinical Characteristics

Baseline characteristics and co-morbidities of the 33 TAVI patients are presented in table 1. Because of extensive aortic or ilio-femoral vascular disease, transapical TAVI was the chosen procedure in 16 patients. The overall success rate was 100% for both the transapical and transfemoral procedure. The prosthesis size was 23-mm in 16 patients and 26-mm in 17. Early postoperative complications were: bleeding requiring transfusion (>2 units) in 16 patients, atrioventricular block in two, acute renal failure in four, pneumonia in two, pericardial effusion in three, bradycardia requiring pacemaker implantation in one and right ventricular failure in one. Before the follow up, four patients died; one of multiorgan failure, one of intramyocardial hematoma and two of non-cardiac reasons. Four patients were not studied postprocedurally because of administrative error (2), planned non- cardiac surgery (1) and stroke (1). Chronic atrial fibrillation was considered to be the most probable underlying cause of the stroke. In total, 25 patients were included in the follow up eight weeks after TAVI.

Aortic valve and prosthesis function

Preprocedurally the iEOA in the all-TAVI group was 0.3±0.1 cm^2/m^2. Mean pressure gradient, maximal aortic velocity and VTI_{Ao} decreased significantly after TAVI (all $p<0.001$, see table 2). Postprocedurally a paravalvular leakage was observed in 60% (n=15) and a transvalvular leakage in 36% (n=9) of the TAVI patients, however, the highest observed degree of postoperative prosthesis insufficiency was mild.

Global LV function

Among the 25 TAVI patients who were included in the follow up, 19 (76 %) had an EF of 50 % or more before TAVI. At follow up, EF was unchanged but septal wall thickness and indexed LV mass had decreased significantly (see table 2).

Seven TAVI patients had a moderate mitral regurgitation (MR) preprocedurally. At follow up, there was a significant reduction of MR (p=0.024, table 2).

Longitudinal LV function

When considering all TAVI patients, $AVPD_{Lateral}$ (9±3 vs. 11±3 mm, p<0.001) and $AVPD_{Septal}$ had increased (6 ±2 vs. 7±3 mm, p=0.006) at follow up (figure 1). In addition, the PSV had increased significantly in the lateral and the septal walls; 5±2 vs. 6±3 cm/s, p=0.003 and 4±1 vs. 5±2 cm/s, p=0.002, respectively.

RV function

Postprocedurally, RV systolic and diastolic function measured by AVPD, é and á were unchanged in the TAVI group (table 3 and figure 2), while PSV_{RV} had increased (8±2 vs. 10±3 cm/s, p=0.007). The change in RV long-axis function was independent of the decrease in RA-RV pressure difference.

Diastolic LV function

The classification of LV diastolic function, showed in figure 3, was unchanged postoperatively. By TDI parameters, higher é-septal, á-septal and á-lateral velocities were observed postprocedurally (all $p<0.03$, table 4). Moreover, there was a significant reduction of the average E/é-ratio (27±15 to 20±9, p=0.001, table 4). Also the pressure difference between the right atrium and ventricle, reflecting pulmonary artery pressure, had decreased at the follow up (p=0.03, table 3).

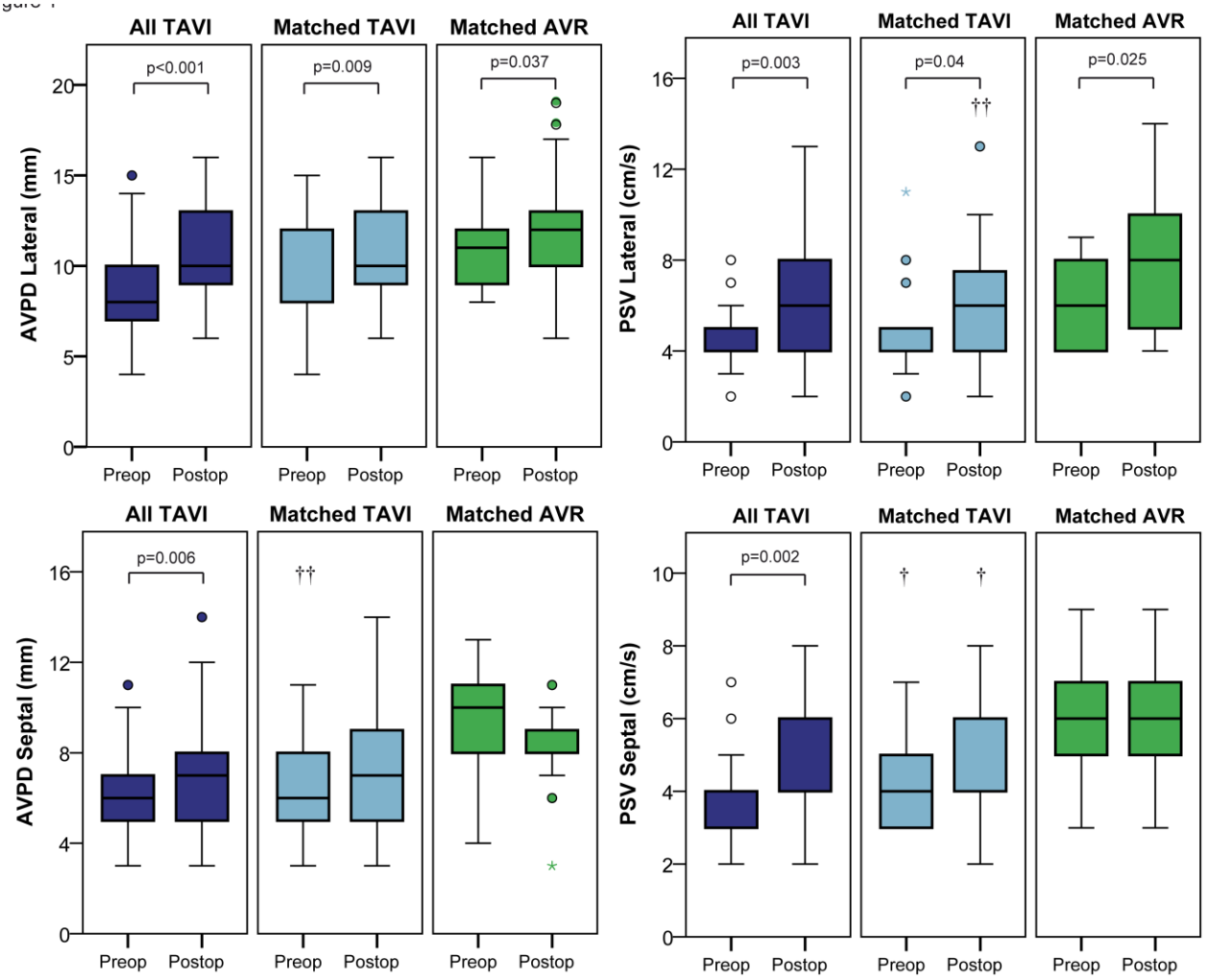

Figure 1: Longitudinal left ventricular function evaluated as atrioventricular plane displacement (AVPD) and peak systolic velocity (PSV) in all transcatheter aortic valve implantation (TAVI, dark blue), matched TAVI (light blue) and surgical aortic valve replacement (SAVR, green) patients pre- and postoperatively. The box and whiskers represent values within the 25th-75th percentile and 1.5 of the interquartile range respectively. Significant differences preoperatively vs. postoperatively within each group are presented as actual P values. Matched SAVR group vs. matched TAVI group; † p<0.05, †† p<0.01, ††† p<0.001.

Left atrial area had decreased from 28±7 cm^2 to 26±7 cm^2, *p*=0.047 (table 2). When analysing the change in left atrial area in patients with atrial fibrillation and sinus rhythm separately, a significant decline was only possible to detect in the atrial fibrillation group (p=0.047). However in this group a majority of the patients had a moderate mitral insufficiency.

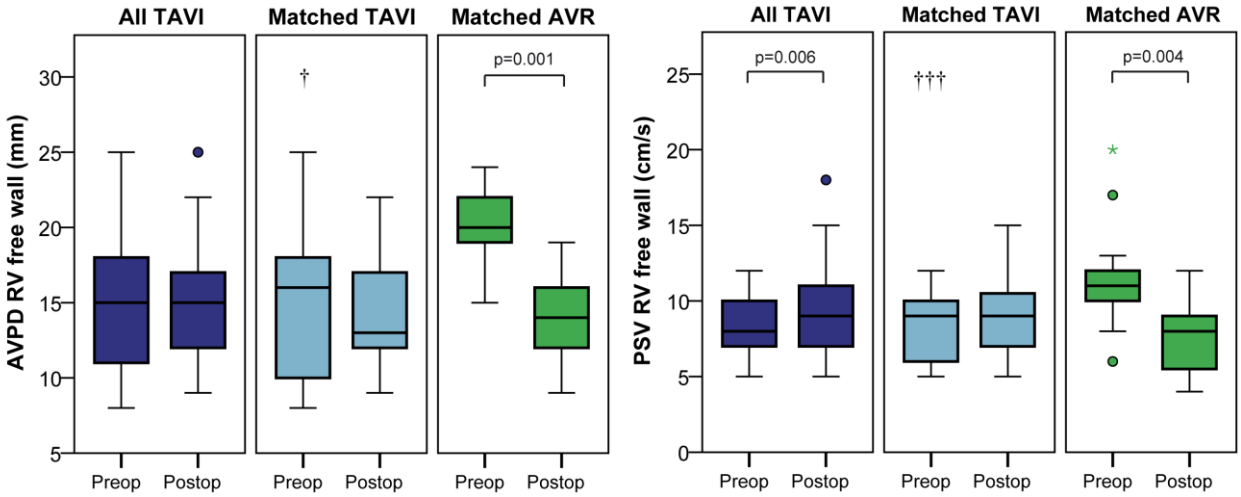

Figure 2: Longitudinal right ventricular (RV) function evaluated as atrioventricular plane displacement (AVPD) and peak systolic velocity (PSV). Abbreviations and symbols as in figure 1.

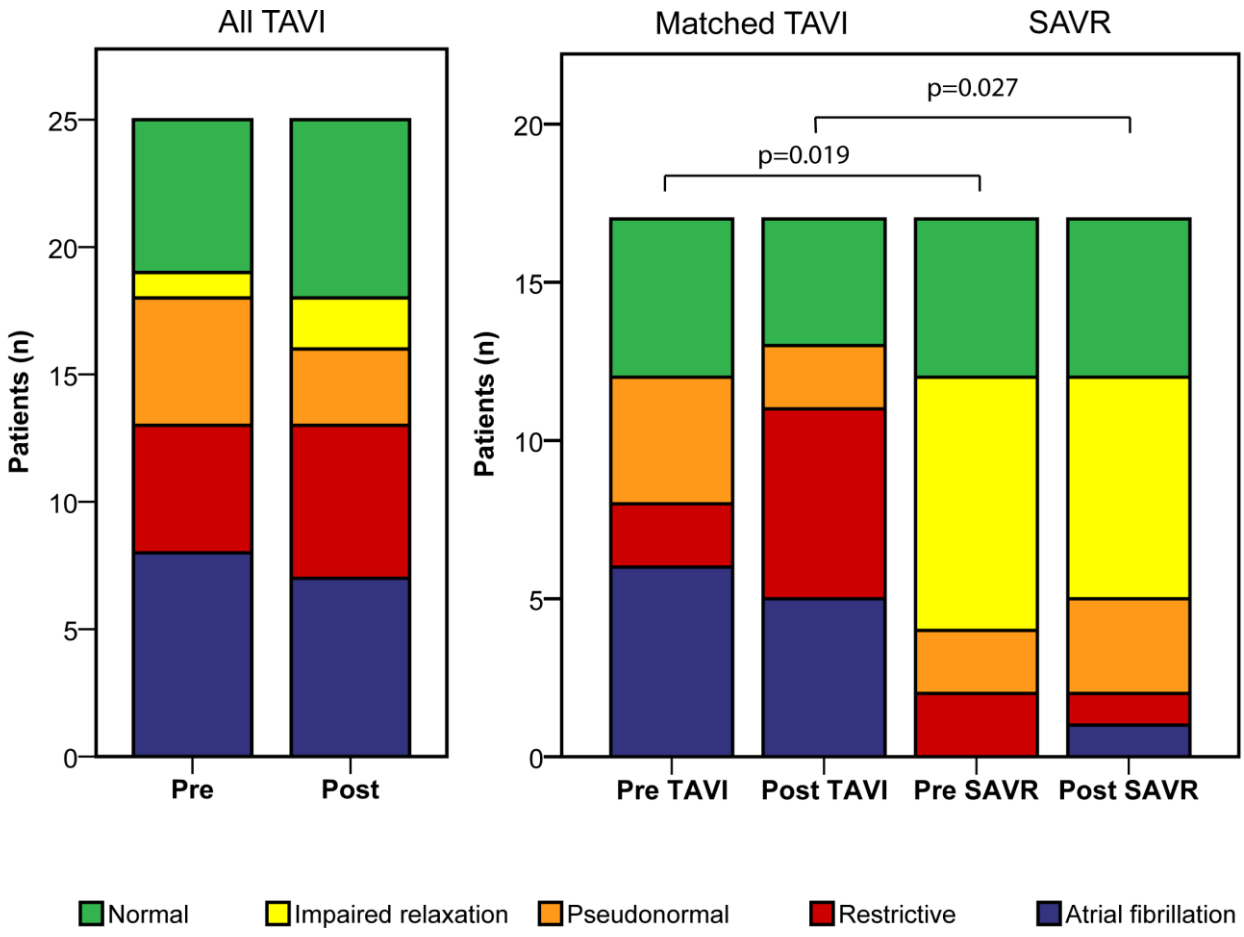

Figure 3: Classification of LV diastolic function pre- and postprocedurally in all TAVI patients, matched TAVI-patients and matched SAVR-patients. Neither TAVI- or SAVR-patients significantly changed classification postprocedurally. TAVI-patients had a more severely disturbed diastolic function, both pre- and postprocedurally, than the SAVR-group.

The matched SAVR patients

Baseline characteristics are presented in table 1. Ten patients had undergone combined SAVR and coronary artery bypass surgery and seven patients isolated AVR. There were perioperative complications in three patients: two needing a pacemaker implant due to a third degree AV block and one needing blood transfusion due to bleeding. The preoperative iEOA was 0.4±0.1 cm^2 and the postoperative hemodynamic function of the prosthetic aortic valves, evaluated according to guidelines, was as expected for the prostheses used (table 2).

TAVI patients vs. SAVR patients: Left and right ventricular function

Among the matched TAVI patients, there was a significantly increase of both AVPD and PSV in the LV lateral wall postprocedurally (9±3 vs. 11±3 mm, p=0.01 and 5±2 vs. 6±3 cm/s, p=0.04, figure 1). Also the SAVR patients increased their LV lateral wall function estimated by AVPD and PSV (11±2 vs. 13±3 mm, p=0.04 and 6±2 vs. 8±3 cm/s, p=0.03). In both groups, the $AVPD_{Septal}$ and PSV_{Septal} were unchanged. The septal long axis function was significantly lower in the TAVI patients, as compared to the AVR patients both pre- and postprocedurally (figure 1).

Postoperatively, the RV function was unchanged among the matched TAVI patients. The SAVR patients, however, decreased both in AVPD and PSV. Although the TAVI patients had lower $AVPD_{RV}$ and PSV_{RV} than the SAVR patients preprocedurally, there was no difference between the two groups after the procedure (figure 2).

With regard to the LV diastolic function classified after filling pattern, the TAVI patients had signs of more severely disturbed diastolic function, i.e. increased filling pressures, than SAVR patients, both pre- and postprocedurally (figure 3). Also the average E/é was higher among the TAVI patients than the SAVR patients postprocedurally (20±9 vs. 13±6, p=0.041). E/é

was unchanged in the SAVR group after surgery ($p=0.093$), while the TAVI patients decreased significantly ($p=0.031$).

Discussion

This prospective study reports a detailed evaluation of left and right ventricular function by means of echocardiography and TDI in patients who have undergone TAVI. The study also includes a group of SAVR patients matched to TAVI patients by gender, age and LV function. Although the included number of matched SAVR patients is limited, these data allow a unique possibility to compare the two treatments regarding ventricular function.

Our main findings were those of increased longitudinal systolic LV and RV function postprocedurally among the TAVI patients. Both the matched SAVR and TAVI patient groups increased their LV lateral longitudinal function parameters, while the SAVR patients showed a decreased RV function postoperatively.

Concerning prosthesis function, the mean gradients were consistent with the findings from previous studies of both TAVI and SAVR.(13, 14)

Global LV function

Following SAVR and TAVI, improvement in LV function, estimated by EF, has predominantly been seen in patient groups with preoperatively reduced or severely reduced EF.(13, 15, 16) Ewe et al showed an immediate increase in EF in TAVI patients with preoperative reduced EF while TAVI patients with normal LV function were unchanged. At follow up patients with preoperative normal EF continued to be unchanged while there was a further improvement of EF in the reduced EF patient group.(16) Because the majority of our patients had normal EF preoperatively, unchanged EF was expected in both patient groups.

Longitudinal LV function

An impairment in long axis function can be seen early in the natural history of AS patients with normal EF.(3) The long axis excursion is due mainly to subendocardial myocytes.(17) These cells are considered more vulnerable to ischemia and stress than cells of the intermediate layers of the myocardium.(3, 18) After SAVR, an improved longitudinal function in the lateral wall has been reported.(19) In this study, we observed an improvement of LV function shown by increased AVPD and PSV in the lateral and septal wall eight weeks after TAVI. These findings are supported by earlier studies which have shown increased PSV 24 hours and increased AVPD 6 weeks after TAVI. (20, 21) The most probable explanation of the absence of an increase of $AVPD_{Septal}$ and PSV_{Septal} in the SAVR patients would be paradoxical septal motion (PSM), which is often seen after open heart surgery and has been proposed as being more frequent after valve surgery.(22) Although the etiology of PSM is debated, the most accepted explanation is that PSM is an artifact caused by postoperative sternal-cardiac adhesions.(23)

Right ventricular function

Longitudinal RV function, measured by TDI and M-mode has shown a correlation with "gold standard" measurements of RVEF.(24) The SAVR patients included in this study had decreased AVPD, PSV, é and á in the free wall of the RV at follow up, implying RV dysfunction, while the TAVI patients showed an improved or unaltered longitudinal RV function by the different parameters used. These findings are supported by the results from Zhao et al, which showed a decreased AVPD in the RV free wall 1 week after SAVR but unchanged RV AVPD after TAVI.(21) Furthermore, in our study, with a matched SAVR group, we could show that despite a superior RV function before surgery in the SAVR group the RV function parameters did not differ between the groups at follow up. The etiology of

RV dysfunction after open heart surgery is unknown but intraoperative ischemia, myocardial damage and pericardial disruption have been suggested as underlying mechanisms.(6-8) However, an altered pattern of right ventricular contraction and, consequently, a mechanical explanation of the decreased longitudinal RV function postoperatively has also been proposed.(7, 25) In line with this, TAVI would due to its less invasive nature, probably cause both less intraoperative trauma to the RV and less postoperative pericardial adhesions and influence on cardiac motion. However the exact mechanism to preservation of RV function after TAVI but not SAVR is unknown. These results have their clinical relevance by expanding our understanding of right ventricular function after aortic valve intervention.

LV diastolic function

Short-term follow up of diastolic function after TAVI has not been extensively studied earlier. Although the LV diastolic classification based on filling patterns remained unchanged in the TAVI patients postprocedurally, the decrease of left atrial area and E/é could be interpreted as a reduction of LV filling pressure, however the latter continued to be elevated postprocedurally.

Among patients undergoing SAVR, LV diastolic function estimated by TDI variables have demonstrated prognostic value.(26) The TAVI group had increased é-velocity of the septal LV wall postoperatively and this pattern has been shown earlier after AVR by Giorgi et al.(19) The significant increase of LV é- and á-velocity and decreased E/é among the TAVI patients in our study may imply an early recovery of LV diastolic function. Bauer et al found an increase of é and á measured by pulsed TDI in the LV septal wall but no difference in LV diastolic function measured by blood flow Doppler echocardiography when they examined TAVI patients 24 hours postprocedurally.(20) Gotzmann et al, who studied the CoreValve

prosthesis, were only able to establish a significant change in é-velocity and decrease of E/é at the 6-month follow up.(27)

Our data suggest a more pronounced elevation of postoperative LV filling pressures in TAVI as compared to SAVR patients, despite a comparable EF. One reason could be that the TAVI-patients were, at first, not accepted for SAVR due to co-morbidities and therefore had a delay in receiving aortic valve intervention. Normalization of diastolic dysfunction after correction of AS takes years, and further follow up of data on LV diastolic function and filling pressures after TAVI is therefore of interest.(14)

Limitations

A majority of the SAVR patients had concomitant coronary bypass surgery and long axis function could have been affected by their coronary disease. On the other hand, an equal number of TAVI patients also had coronary disease and previous heart surgery in these patients may also have influenced their longitudinal function.

Conclusions

An improvement in LV systolic and diastolic function assessed by echocardiography and TDI could be seen already eight weeks after TAVI. Although the matched TAVI patients had significantly lower PSV_{Septal} and $PSV_{Lateral}$ than did the SAVR patients, a similar reaction with increased LV longitudinal lateral function could be observed in both groups postprocedurally. Postoperatively RV function assessed by tricuspid annular motion and PSV was unaffected or improved in the TAVI-patients: a more favorable alteration of RV function than the SAVR patients had. We conclude that patients with severe aortic stenosis and a high surgical risk profile have a favorable change in longitudinal LV and RV function eight weeks after TAVI.

Acknowledgements

The authors gratefully acknowledge Inger Huljebrant, research nurse and Mirjam Johansson, medical technician for their valuable assistance in patient inclusion and performing the echocardiographic studies.

This work was supported by the Swedish Heart Lung Foundation, Medical Research Council of Southeast Sweden and ALF Grants from the County Council of Östergötland, Sweden.

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Table 1 Baseline Characteristics

Feature (n)	**All-TAVI** n=33	**Matched-TAVI** n=17	**Matched-SAVR** n=17
Age (years)	81±9	76±8	72±6
Female sex	18	9	9
Body mass index (kg/m^2)	25.7±25.3	26.5±6.2	26.3±4.1
Body surface area (m^2)	1.8±0.2	1.9±0.2	1.9±0.2
Logistic EuroSCORE (%)	18±9	17±9	7±5
STS score (%)	19±7	16±6	11±7
NYHA pre			
II	2	2	9
III	28	13	8
IV	3	2	0
Heart failure	13	8	3
Atrial fibrillation	11	6	0
Hypertension	25	13	12
Diabetes (insulin)	5(4)	3(2)	4(1)
Coronary artery disease	15	11	11
Peripheral vascular disease	7	2	1
Stroke	6	3	0
PAP >60 mmHg	9	3	1
COPD	1	1	0
Creatinine (µmol/l)	119±54	108±29	93±24
Previous heart surgery	12	10	1
Previous PCI	6	4	11

Chest radiation	3	1	0
Porcelain aorta	4	1	0

Data are presented as mean±SD or frequencies. Syst; systolic, diast; diastolic, NYHA; New York Heart Association, STS Society of Thoracic Surgeons, PAP; Pulmonary arterial pressure, COPD; Chronic obstructive pulmonary disease, PCI; Percutaneus coronary intervention

Table 2 Echocardiographic variables

Variable	All-TAVI			Matched-TAVI			Matched-SAVR		
	Pre	Post		Pre	Post		Pre	Post	
	n=33	n=25	*p**	n=17	n=17	*p**	n=17	n=17	*p**
Heart rate (bpm)	66±11	69±9	0.101	68±9	70±10	0.408	63±6	69±11	0.017
Systolic blood pressure (mmHg)	146±27	150±24	0.351	135±31	140±24	0.624	145±19	138±16	0.284
Diastolic blood pressure (mmHg)	78±11	69±13	0.033	71±11	67±12	0.109	81±11	78±9	0.306
Aortic Valve									
EOA (cm^2)	0.5±0.2	1.4±0.3	<0.001	0.6±0.1	1.5±0.3	0.001	0.7±0.2	1.2±0.2	0.007
iEOA(cm^2/m^2)	0.3±0.1	0.8±0.2	<0.001	0.3±0.1	0.8±0.2	0.001	0.4±0.1	0.6±0.1	0.007
ΔP mean (mmHg)	60±21	11±5	<0.001	53±15	11±6	0.001	47±19	12±3	0.001
Aortic $Velocity_{max}$ (m/s)	4.7±0.9	2.2±0.6	<0.001	4.4±0.7	2.0±0.6	<0.001	4.5±0.9	2.4±0.3	<0.001
Aortic VTI (cm)	124±30	47±11	<0.001	113±23	45±12	<0.001	111±29	48±9	<0.001
LVOT VTI (cm)	20±5	22±7	0.153	19±4	20±6	0.690	21±5	20±4	0.279
Left Atrial area, s (cm^2)	28±7	26 ±7	0.047	28±8	27±7	0.168	21±3	23±5	0.138
Left Ventricle									

Septal Wall Thickness, d (mm)	13±3	12±3	0.044	13±3	12±3	0.192	13±2	12±3	0.100
Posterior Wall Thickness, d (mm)	13±3	12±2	0.584	12±3	12±2	0.692	12±2	11±2	0.106
LV end diastolic dimension (mm)	51±6	49±7	0.164	52±6	50±6	0.140	49±6	45±5	0.115
LV end systolic dimension (mm)	34±7	32±8	0.347	35±7	33±8	0.100	32±8	33±5	0.059
Fractional Shortening (%)	33±8	34±8	0.733	34±8	35±9	0.683	35±9	26±6	0.009
Indexed LVmass (g/m^2)	157±55	134±38	0.036	147±54	129±32	0.551	126±30	98±24	0.041
Ejection fraction (n)									
>50%	25	21		14	14		15	13	
50-40%	4	2		1	1		0	2	
			0.083			1.000			0.564
40-30%	2	1		1	1		1	2	
<30%	1	0		1	0		1	0	
Aortic Regurgitation (0-3)	1(0.5-1)	0.5(0.5-1)	0.171	1(0.5-1)	0.5(0-1)	0.250	1(0-1)	0.5(0-0.5)	0.040
Mitral regurgitation (0-3)	1(0.5-1.5)	1 (0.5-1)	0.024	1(0.5-2)	1(0.5-1.0)	0.102	0.5(0.5-1)	0.5(0.5-0.5)	0.660

Data are expressed as mean±SD, median (25^{th}-75^{th} percentile) or frequencies. D: diastolic, iEOA: indexed effective orifice area, LV: left ventricle, LVOT: Left Ventricular Outflow Tract, n: number, ΔP; pressure gradient, s: systolic, VTI: Velocity Time Integral. Remaining abbreviations as in table 1. Regurgitation scale; 0-none, 0.5-trivial, 1-mild, 2-moderate, 3-severe. *Preoperatively vs. postoperatively.

Table 3 Right ventricular systolic and diastolic function

	All-TAVI			Matched-TAVI			Matched-SAVR		
Variable	Pre	Post	*p**	Pre	Post	*p**	Pre	Post	*p**
RV free wall									
AVPD (mm)	15±5	15±4	0.613	15±6	14±4	0.476	20±3†	14±3	0.001
PSV RV (cm/s)	8±2	10±3	0.006	8±2	9±3	0.120	11±3††	8±2	0.004
é-RV (cm/s)	10±4	9±4	0.936	9±4	9±4	0.508	10±2	6±2	0.005
á-RV (cm/s)	13±5	12±6	0.459	11±6	10±6	0.526	17±4	9±4	0.001
é/á	0.8±0.6	0.9±0.8	0.943	1.0±0.8	1.1±1.0	0.721	0.6±0.2	0.8±0.4	0.133
RA Area (cm^2)	20±6	19±5	0.076	21±5	20±6	0.543	17±3	18±3	0.124
RA-RV pressure difference (mmHg)	44±13	33±16	0.030	41±12	32±14	0.040	33±10	28±7	0.044

RV; right ventricle, AVPD; atrioventricular plane displacement, PSV; peak systolic velocity, é; early peak diastolic velocity, á; late peak diastolic velocity, RA; right atrial. *Preoperatively vs. postoperatively, † matched SAVR vs. matched TAVI group $p<0.05$, ‡ $p<0.001$.

Table 4 Left ventricular diastolic variables by tissue Doppler imaging before and 8 weeks after TAVI and SAVR

	All-TAVI			Matched-TAVI			Matched-SAVR		
Variable	Pre	Post	*p**	Pre	Post	*p**	Pre	Post	*p**
Doppler Echocardiography									
E (m/s)	1.2±0.4	1.1±0.3	0.450	1.1±0.4	1.1±0.3	0.692	0.8±0.2†	0.8±0.3	0.077
A (m/s)	0.8±0.4	0.9±0.3	0.131	0.8±0.4	0.9±0.4	0.380	0.8±0.3	0.9±0.3	0.504
E/A (m/s)	1.5±0.6	1.4±0.9	0.617	1.3±0.5	1.6±1.0	0.575	1.2±0.8	1.0±0.5	0.670
Deceleration time (ms)	194±87	211±86	0.322	192±102	206±99	0.326	284±99†	232±89	0.055
IVRT (ms)	54±22	73±35	0.014	57±25	67±37	0.121	78±25†	77±21	0.959
PVs /PVd(m/s)	1.0±0.8	1.0±0.9	0.911	0.9±0.7	0.9±1.0	0.191	1.3±0.5	1.2±0.5	0.142
Tissue Doppler Imaging									
Septal									
é-septal (cm/s)	4.0±2.0	5.2±2.6	0.028	4.9±2.4	5.8±2.6	0.122	4.8±1.6	5.6±2.0	0.167
á-septal (cm/s)	5.0±2.0	5.9±2.3	0.015	6.0±1.9	6.0±2.6	0.366	8.6±2.2†	6.9±2.1	0.033
é/á-septal	0.9±0.5	0.8±0.4	0.532	0.8±0.5	0.9±0.5	0.139	0.6±0.2	0.9±0.5	0.013
Lateral									

é-lateral (cm/s)	6.6±3.1	7.2±2.6	0.118	7.3±3.2	7.6±2.8	0.418	5.9±1.9	8.9±3.1	0.005
á-lateral (cm/s)	4.8±2.5	6.6±3.5	0.006	5.1±2.7	6.5±3.4	0.058	7.0±3.2	8.0±3.7	0.166
é/á-lateral	1.4±0.8	1.4±1.0	0.538	1.5±0.8	1.5±1.0	0.610	1.3±1.6†	1.6±1.5	0.116
E/é- average	27±15	20±9	0.001	23±13	20±9	0.031	16±5	13±6†	0.093
E/é-septal	34±18	26±15	0.045	31±19	26±24	0.234	18±6	18±10	0.868
E/é-lateral	24±15	18±9	0.013	20±12	18±10	0.177	15±8	11±4†	0.016

E; early diastolic filling, A; late diastolic filling, IVRT; isovolumic relaxation time, PVs; Systolic pulmonary venous flow velocity, PVd; diastolic pulmonary venous flow velocity, e´; early diastolic myocardial velocity, á; late diastolic velocity. Remaining abbreviations as in table 1. *Preoperatively vs. postoperatively, † matched SAVR vs. matched TAVI group $p<0.05$, ‡ $p<0.01$.