Original paper

The impact of transcatheter aortic valve implantation on left ventricular performance and wall thickness – single-centre experience

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Abstract

Introduction: Transcatheter aortic valve implantation (TAVI) is a treatment alternative for the elderly population with severe symptomatic aortic stenosis (AS) at high risk for surgical aortic valve replacement (SAVR).

Aim: To assess the impact of TAVI on echocardiographic parameters of left ventricular (LV) performance and wall thickness in patients subjected to the procedure in a single-centre between 2009 and 2013.

Material and methods: The initial group consisted of 170 consecutive patients with severe AS unsuitable for SAVR. Logistic European System for Cardiac Operative Risk Evaluation (EuroSCORE) was 21.73 ±12.42% and mean age was 79.9 ±7.5 years.

Results: The TAVI was performed in 167 (98.2%) patients. Mean aortic gradient decreased significantly more rapidly after the procedure (from 58.6 ±16.7 mm Hg to 11.9 ±4.9 mm Hg, $p < 0.001$). The LV ejection fraction (LVEF) significantly increased in both short-term and long-term follow-up (57 ±14% vs. 59 ±13%, $p < 0.001$ and 56 ±14% vs. 60 ±12%, $p < 0.001$, respectively). Significant regression of interventricular septum diameter at end-diastole (IVSDD) and end-diastolic posterior wall thickness (EDPWth) was noted in early (15.0 ±2.4 mm vs. 14.5 ±2.3 mm, $p < 0.001$ and 12.7 ±2.1 mm vs. 12.4 ±1.9 mm, $p < 0.028$, respectively) and late post-TAVI period (15.1 ±2.5 mm to 14.3 ±2.5 mm, $p < 0.001$ and 12.8 ±2.0 mm to 12.4 ±1.9 mm, $p < 0.007$, respectively). Significant paravalvular leak (PL) was noted in 21 (13.1%) patients immediately after TAVI and in 13 (9.6%) patients in follow-up ($p < 0.001$). Moderate or severe mitral regurgitation (msMR) was seen in 24 (14.9%) patients from the initial group and in 19 (11.8%) patients after TAVI ($p < 0.001$).

Conclusions: The TAVI had an immediate beneficial effect on LVEF, LV walls thickness, and the incidence of msMR. The results of the procedure are comparable with those described in other centres.

Key words: aortic stenosis, transcatheter aortic valve implantation, echocardiography.

Introduction

Degenerative aortic stenosis (AS) is the most common valvular heart disease in the ageing population of Northern America and Europe. According to current registers, AS occurs in 12.4% of people aged 75 years and over, including 3.4% of people with haemodynamically significant pathology [1]. In case of severe symptomatic AS or asymptomatic but with concomitant left ventricular (LV) systolic dysfunction, the treatment of choice is surgical aortic valve replacement (SAVR) [2–4]. However, a significant number of patients with severe AS – estimated at up to 30% – cannot be treated traditionally due to high surgical risk (HSR) and/or contraindications to SAVR by standard median sternotomy [5, 6]. Successfully performed for the first time in France in 2002 by Cribier *et al.*, the transcatheter aortic valve implantation (TAVI) procedure has proved to be a safe alternative to SAVR in this group of patients [7]. Moreover, according to the results of *CoreValve High-Risk Study*, in patients with severe AS and HSR, 1-year all-cause mortality is significantly lower in TAVI than in the SAVR group [8].

Until now, a number of studies concerning the effects of TAVI on echocardiographic parameters in HSR patients have been published worldwide. It was proven that the

procedure effectively reduces maximal and mean aortic gradients [9] as well as improves LV ejection fraction (LVEF) [10–12] and is associated with the occurrence of paravalvular leak (PL) [13, 14] and the reduction of severity of mitral regurgitation (MR) [15]. The impact of TAVI on regression of LV hypertrophy (LVH) [16–20] was presented in few studies, and according to the latest analysis of the Placement of Aortic Transcatheter Valves (PARTNER) trial, LVH regression significantly reduced re-hospitalisations, specifically for heart failure [20].

Our study reports single-centre experiences in TAVI procedures and echocardiographic evaluation of the population treated in the Cardinal Stefan Wyszynski Institute of Cardiology in Warsaw. There has been no such observation in Poland yet. Moreover, currently the largest group of patients in the country, who have been subjected to TAVI, are just in our centre.

Aim

The aim of this study is to report the influence of TAVI on echocardiographic parameters in a large population of patients with severe AS treated in one medical centre between 2009 and 2013.

Material and methods

It was a single-centre – up to 2013, retrospective – long-term follow-up analysis. Initially, all 171 patients who qualified for TAVI in our medical centre between January 2009 and September 2013 were included in the study. One female patient was excluded from the group due to the dysfunction of calcified aortic homograft with severe aortic regurgitation (AR) and HSR as a reason to perform TAVI. Finally, 170 patients with severe symptomatic AS were included.

The following patients were qualified the procedure: with severe symptomatic AS and aortic valve area (AVA) < 1 cm², unsuitable for SAVR due to HSR and logistic EuroSCORE [21, 22] ≥ 20% or logistic EuroSCORE < 20%, but with debilitating comorbid condition or predictor of adverse outcomes as past mediastinal radiotherapy, coronary artery bypass grafting (CABG) with internal thoracic artery and risk of the graft injury during sternotomy or porcelain aorta, as well as frailty syndrome [23–26]. The qualification process was conducted by the local Heart Team, consisting of clinical and interventional cardiologists, a cardiovascular surgeon, a neurologist, and an anaesthesiologist. Informed consent for diagnostic and treatment procedures was obtained from all the patients. Every patient was subjected to a complete medical assessment – anamnesis, physical examination, and laboratory tests were done as well as an electrocardiogram, a chest X-ray, a transthoracic echocardiography (TTE), a transoesophageal echocardiography (TEE), a coronary assessment with angiography or computed tomography (CT), and vascular access assessment with CT imaging.

Transcatheter aortic valve implantation technique

Transcatheter aortic valve implantation was performed in a hybrid operating room. The procedures were conducted under general or local anaesthesia with sedation [27]. The valves were implanted via transfemoral, transapical, transaortic, trans-subclavian, or transaxillary approach. The following types of valves were used: CoreValve (CV) no. 26, 29, and 31 or Engager valve (EV) no. 26 (Medtronic), as well as Edwards-Sapien (ES) no. 23 and 26, and SapienXT (SXT) no. 23, 26, and 29 (Edwards Lifesciences). The type of valve and the implantation access route (anterograde or retrograde approach) was established on the basis of the results of TEE and CT imaging. The device success was defined as a proper prosthesis placement with aortic mean gradient less than 20 mm Hg, without significant (i.e. moderate/severe) AR [24]. The procedure success was defined as an effective valve implantation procedure with no death within 24 h and no need for conversion to surgery.

Echocardiography and Doppler measurements

A standard complete TTE was performed in each patient prior to the procedure and after TAVI before hospital discharge. Also, at least one complete TTE was performed during the follow-up period if the patient was still alive and was able to come for a medical check-up. Echocardiograms, including Doppler measurements, were done according to current recommendations [28–32].

Echocardiographic measurements and haemodynamic calculations were performed by qualified echocardiographers experienced in the quantitative assessment of valvular heart diseases. The examinations were performed by using the following devices: Vivid 6S, Vivid E7 and E9 (General Electric Medical Systems, Milwaukee, WI, USA), and iE33 and HD15 (Philips, Andover, Massachusetts, USA). Left ventricular end-diastolic diameter (LVEDD), LV end-systolic diameter (LVESD), interventricular septum diameter at end-diastole (IVSDD), and end-diastolic posterior wall thickness (EDPWth) were assessed in long-axis parasternal 2D recordings, in left lateral decubitus position. Left ventricular end-diastolic volume (LVEDV) and LV end-systolic volume (LVESV) were calculated in apical 4- and 2-chamber view using the biplane method of disks (modified Simpson's method). The LVEF was estimated according to the following formula: (LVEDV − LVESV)/LVEDV × 100 or by visual assessment in case of no possibility to accurately delineate (> 80%) the LV endocardial border. The LV outflow tract (LVOT) and aortic annulus diameter were measured in parasternal long-axis and/or apical 3-chamber view (depending on the acoustic window quality), in zoom mode. The LVOT velocity and LVOT velocity time integral (VTI) were measured on spectral Doppler display using pulsed-wave Doppler. The continuous wave (CW) Doppler method was used to obtain

the aortic valve peak velocities searching for an acoustic window with the highest values. Maximum and mean aortic valve pressure gradients were estimated by modified Bernoulli's equitation using the flow VTI over the ejection period in CW-Doppler recordings with a 50 mm/s timescale on the *x*-axis. AVA was calculated according to the continuity equitation. Valvular regurgitations were assessed according to the current guidelines [33–35] – semi-quantitatively and/or quantitatively, if possible. After TAVI, valvular regurgitations were defined according to Valve Academic Research Consortium (VARC) criteria [24]. Early and long-term TAVI effects were assessed using complete preprocedural TTE and complete TTE before discharge and during the follow-up period, respectively.

Statistical analysis

Continuous data are expressed as mean ± standard deviation (± SD), and categorical variables as numbers with percentages (%). Baseline and follow-up data were compared by paired Student's *t*-test. The association between categorical variables was evaluated with the χ^2 test. A value of $p < 0.05$ was considered to be statistically significant. Statistical analysis was performed with IBM SPSS version 20 (SPSS Inc., Chicago, IL, USA).

Results

Initially, the study population composed of 170 patients qualified to TAVI. Mean *logistic* EuroSCORE was 21.73 ±12.42% and the mean age was 79.9 ±7.5 years. Clinical characteristics of the study population are presented in Table I.

Finally, TAVI was performed in 167 (98.2%) patients. Two patients had only aortic balloon valvuloplasty due to technical problems during the procedure, and in 1 patient the procedure was cancelled because of life-threatening access site complications (eventually this female patient died). In the TAVI population, 3 types of prostheses were implanted: CV – in 87 (52.1%) patients, ES/SXT in 78 (46.7%) patients, and EV in 1 (0.6%) patient. Seven (4.1%) patients required second valve implantation due to a haemodynamically significant PL. Transfemoral access was the most frequent approach – in 128 (75.3%) patients, including 87 (51.2%) and 41 (24.1%) patients with left and right femoral artery approach, respectively. Transapical approach was used in 24 (14.1%) patients, anterior mini-thoracotomy in 7 (4.1%) patients, subclavian artery approach in 9 (5.3%) patients, and left axillary artery approach in 2 (1.2%) patients. Device success was 78.8%, and procedure success was 81.2%. The 30-day mortality rate was 13 (7.6%), including 6 (3.5%) patients who died shortly after the procedure (5 patients immediately after the procedure, 1 patient within 24 h), and 7 (4.2%) patients died within one month. In 2 patients, conversion do SAVR was needed. Because of these factors and technical issues, finally 161 echocardiographic

Table I. Clinical characteristics of the initial study population (170 patients qualified for TAVI)

Parameter	Results	
	n	%
Male	54	31.8
Female	116	68.2
NYHA functional class:		
Class I	0	0
Class II	13	7.6
Class III	138	81.2
Class IV	19	11.2
Hypertension	130	76.4
Diabetes mellitus type 2	58	34.1
Patients on insulin	7	4.1
Coronary artery disease (CAD):	123	72.3
Multivessel CAD	89	52.3
Myocardial infarction	35	20.5
Percutaneous coronary intervention (PCI)	50	29.4
Coronary artery bypass grafting (CABG)	25	14.7
Heart valve surgery	7	4.1
Pacemaker prior to TAVI	28	16.5
Chronic kidney disease (CKD):	100	58.8
Requiring chronic dialysis	2	1.2
Creatinine level, mean ± SD [μmol/l]	103.11 ±41.46	–
Glomerular filtration rate (eGRF), mean ± SD [ml/min/1.73 m^2]	55.68 ±18.22	–
Anaemia:	89	52.3
Haemoglobin level, mean ± SD [g/dl]	12.5 ±1.6	–
Chronic obstructive pulmonary disease (COPD)	32	18.8
Asthma	3	1.8
Pulmonary hypertension	25	14.7
Pulmonary embolism	4	2.3
Emphysema	6	3.5
Porcelain aorta	13	7.6
Carotid artery stenosis (≥ 50%)	34	20
Stroke	18	10.6

examinations were analysed in TAVI patients prior to valve implantation and in 136 patients after the procedure – before discharge and during the follow-up period. Early and late post-procedural effects were assessed by echocardiography within a median of 6 and 185 days, respectively. The initial echocardiographic characteristics of patients are presented in Table II.

Statistically significant early decrease in maximal (96.0 ±25.3 mm Hg vs. 21.8 ±8.2 mm Hg, $p < 0.001$) and in mean aortic gradient (58.6 ±16.7 mm Hg vs. 11.9 ±4.9 mm Hg, $p < 0.001$) was observed (Figure 1). Also, early positive changes of LVEF were noted – there was a significant increase in LVEF in both short-term (57 ±14% vs. 59 ±13%, $p < 0.001$) and long-term (56 ±14% vs. 60 ±12%, $p < 0.001$) observation (Figure 2). Significant decreases in IVSDD and EDPWth were observed also in early post TAVI (15.0 ±2.4 mm vs. 14.5 ±2.3 mm, $p < 0.001$ and 12.7 ±2.1 mm vs. 12.4 ±1.9 mm, $p < 0.028$, respectively) and

Table II. Echocardiographic characteristics of the initial study population (170 patients)

Parameter	Before TAVI	
Maximal aortic gradient, mean ± SD [mm Hg]	96.0 ±25.3	
Mean aortic gradient, mean ± SD [mm Hg]	58.6 ±16.7	
AVA (continuity equation VTI), mean ± SD [cm²]	0.66 ±0.15	
IVSDD, mean ± SD [mm]	15.0 ±2.4	
EDPWDth, mean ± SD [mm]	12.7 ±2.1	
LVEDD, mean ± SD [mm]	47.4 ±7.5	
LVESD, mean ± SD [mm]	31.3 ±9.0	
LVEF, mean ± SD (%)	57 ±14	
	n	%
LVEF (%):		
> 50	129	75.9
40–49	11	6.5
30–39	24	14.1
< 30	6	3.5
msMR	24	14.9

late post TAVI (15.1 ±2.5 mm vs. 14.3 ±2.5 mm, *p* < 0.001 and 12.8 ±2.0 mm vs. 12.4 ±1.9 mm, *p* < 0.007, respectively) period (Figure 3). The LVEDD decrease after TAVI in the first observations was non-significant (47.4 ±7.5 mm vs. 47.6 ±7.0 mm, *p* < 0.541) but was statistically significant during follow-up (47.3 ±7.6 mm vs. 46.1 ±7.5 mm, *p* < 0.030). In case of LVESD, the decrease was not significant either in short-term (31.3 ±9.0 mm vs. 30.0 ±8.4 mm, *p* < 0.062) or in long-term (30.9 ±8.4 vs. 30.1 ±7.9, *p* < 0.261) echocardiograms. Moderate/severe PL was observed in 21 (13.1%) patients before hospital discharge but in 13 (9.6%) patients during follow-up (*p* < 0.001, Figure 4). Significant MR was seen in 24 (14.9%) patients of the initial group but in 19 (11.8%) patients in an early and in late period after TAVI (*p* < 0.001, Figure 4).

Discussion

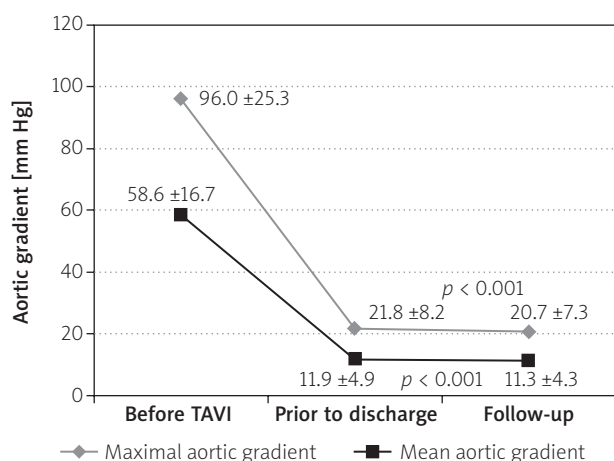Similarly to studies and registries evaluating TAVI effects [9], we observed a comparably statistically signifi-

Figure 1. Reduction in maximal and mean transvalvular aortic gradient after TAVI
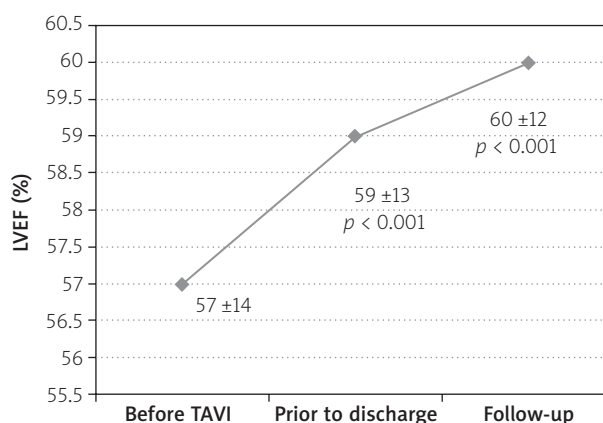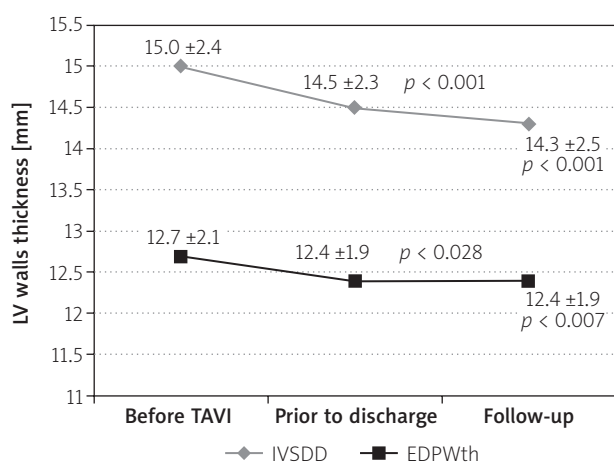

Figure 2. LVEF increase after TAVI

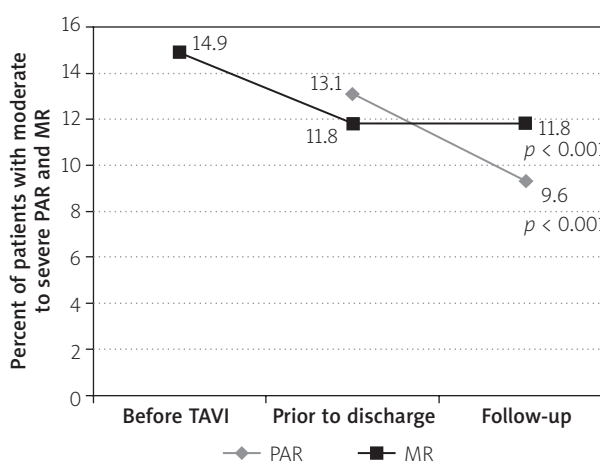**Figure 3.** Reduction in LV wall thickness after TAVI

Figure 4. Paravalvular aortic regurgitation (PAR) and mitral regurgitation (MR) after TAVI

cant early decrease in mean aortic gradient, which was the main aim of the procedure – afterload reduction subsequently translates into the improvement of LV parameters and better clinical condition and survival. Cribier *et al.* observed a rapid and significant decrease in transvalvular gradients after TAVI in the early post-procedural period [36–38]. If the TAVI procedure was not performed for technical reasons and then a significant reduction in meant aortic gradient could not be achieved, heart failure symptoms were definitely more **pronounced** and the mortality rate was significantly higher.

Rapid and significant increase in LVEF – within 24 h after TAVI – was also demonstrated in first Cribier's observations [37]. Similarly to our study, the significant improvement in LVEF before hospital discharge in patients subjected to TAVI was also noted in recent observations [10–12, 16, 39]. However, De Jaegere *et al.* [40] and Tzikas *et al.* [17] did not notice the comparably fast LVEF improvement (in 6 ±2 and 80 ±64 days or 365 days, respectively), which may have resulted from the small patient groups. A fast increase in LVEF translates into almost immediate heart failure symptoms alleviation and clinical improvement and is thus correlated with better late survival. It seems that the lower the baseline LVEF, the better the LVEF improvement [11, 12], which was noted in the very first observations after TAVI procedures. According to more recent observations by Unbehaun *et al.*, considering patients with very low LVEF and/or with cardiogenic shock, the early LVEF increase was significantly higher when it was ≤ 20% prior to the procedure [39]. Moreover, some studies indicate that the improvement of LV performance in patients with basic LV systolic dysfunction due to AS is better after TAVI than after SAVR [41]. Further statistically significant improvement of LVEF seen in our group in follow-up echocardiograms shows the long-term efficacy of TAVI.

Publications concerning the pace of LV wall thickness reduction after TAVI differ. Jilaihawi et al. were the first to observe an early (just 1 month after TAVI), significant (13%) reduction in IVSDD comparable to that observed 1 year after SAVR [42]. More recent observations by Vizzardi et al. [43] in a group of 135 patients also show a significant (again 13%) reduction in IVSDD as well as in EDPWth (16%), but 6 months after TAVI, comparable to the SAVR effects in the systematic review of 27 studies concerning 1546 patients, in which significant regression of LVH was observed up to 6 months after open heart surgery [44]. Conversely, Tzikas et al. [17] reported a significant regression of LVH in TAVI patients only after 1 year of observation. In our study, like Jilaihawi *et al.*, we demonstrated an early decrease in IVSDD, but also in EDPWth. We showed IVSDD and EDPWth decrease in long-term follow-up as well. Indeed, the latest analysis of a patient population included in the PARTNER trial seems to confirm that these observations show a significant regression of LVH within 30 days of TAVI and in the

one-year follow-up period [20]. Importantly, patients with the biggest early LVH regression were less than half as likely to require re-hospitalisation during the year after TAVI. It seems that early LVH regression due to afterload reduction is associated with the regression of contractile elements of cardiomyocyte, and its late reduction results from time-consuming interstitial collagen matrix remodelling [45]. Regression of LV wall thickness after TAVI or SAVR is associated with reverse remodelling and improvement of systolic and diastolic function, as well as with better survival [16, 46, 47].

We observed significant (moderate or severe) PL after TAVI in 13.1% and in 9.6% of our patients in short- and in long-term follow-up, respectively. No significant transvalvular leak was recorded, which is confirmed by prior observations. According to a number of TAVI registries, significant transvalvular leakages occur rarely. However, PL is observed quite frequently [13]. It is estimated that significant PL occurs in 7% to 24% of patients, and the results of follow-up examinations confirm that the degree of leak tends to decrease, rather than increase [13]. It was shown that significant PL adversely affects LV performance and patient survival [14].

Significant moderate or severe mitral regurgitation (msMR) is frequent in patients undergoing TAVI [48]. In our study, msMR in the initial group was observed in 24 (14.9%) patients and in 19 (11.8%) patients in both short- and long-term follow-up (*p* < 0.001). According to Khawaja *et al.* [48], msMR occurred initially in not less than 19% of patients and in less than 8% of patients after the procedure, during a 30-day observation period. They showed that one-year and all-cause mortality was higher if there was msMR observed before TAVI. Indeed, reduced grade of concomitant MR was associated with decreased mortality rate. Similarly, according to Sannino *et al.* [15] in their meta-analysis of 13 studies concerning 4839 patients who underwent TAVI, the mortality rate of patients with msMR was already significantly higher in a 30-day period but also in 1-year and 2-year follow-up, regardless of LVEF value. Significant MR definitely had negative impact on TAVI results, and a trend toward a reduction in msMR was noted.

In our study, we did not find any early, statistically significant decrease in LV dimensions, which is comparable to a few earlier reports [16, 17]. However, a significant reduction in LVDD was noted in long-term follow-up.

Conclusions

Our study, concerning the biggest population of patients with severe AS subjected to TAVI in one centre in Poland, demonstrates that the procedure, in a short period of time (within a median of 6 days), can improve LV performance and parameters. A rapid increase in LVEF and fast decrease in LV wall thickness as well as a rapid, advantageous reduction of significant MR can be

achieved. However, there was no early decrease in LV dimensions. The incidence of significant PL was similar to previous studies and registries and **tended** to decrease with time.

Acknowledgments

Conflict of interest

The authors declare no conflict of interest.

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