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Association of aortic valve calcification severity with the degree of aortic regurgitation after transcatheter aortic valve implantation

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ABSTRACT

Background: This study sought to examine a possible relationship between the severity of aortic valve calcification (AVC), the distribution of AVC and the degree of aortic valve regurgitation (AR) after transcatheter aortic valve implantation (TAVI) for severe aortic stenosis (AS).
Methods: 57 patients (22 men, 81 ± 5 years) with symptomatic AS and with a logistic EuroSCORE of 24 ± 12 were included. 38 patients (67%) received a third (18F)-generation CoreValve® aortic valve prosthesis, in 19 patients (33%) an Edwards SAPIEN™ prosthesis was implanted. Prior to TAVI dual-source computed tomography for assessment of AVC was performed. To determine the distribution of AVC the percentage of the calcium load of the most severely calcified cusp was calculated. After TAVI the degree of AR was determined by angiography and echocardiography. The severity of AR after TAVI was related to the severity and distribution of AVC.
Results: There was no association between the distribution of AVC and the degree of paravalvular AR after TAVI as assessed by angiography ($r = -0.02$, $p = 0.88$). Agatston AVC scores were significantly higher in patients with AR grade ≥ 3 (5055 ± 1753, $n = 3$) than in patients with AR grade < 3 (1723 ± 967, $p = 0.03$, $n = 54$). Agatston AVC scores > 3000 were associated with a relevant paravalvular AR and showed a trend for increased need for second manoeuvres. There was a significant correlation between the severity of AVC and the degree of AR after AVR ($r = 0.50$, $p < 0.001$).
Conclusion: Patients with severe AVC have an increased risk for a relevant AR after TAVI as well as a trend for increased need for additional procedures.

1. Introduction

Transcatheter aortic valve implantation (TAVI) has been developed for high-risk patients with severe symptomatic aortic valve stenosis who are refused for conventional surgical aortic valve replacement. The majority of these patients receive either a CoreValve Revalving System® (CoreValve Inc., Irvine, California) using a retrograde percutaneous transvascular access or an Edwards SAPIEN™ prosthesis (Edwards Lifescience, Irvine, USA) using either the transfemoral or the transapical access. The technical feasibility has been shown for both approaches [1–3] and when successful transcatheter aortic valve replacement results in marked hemodynamic and clinical improvements [2,4–6].

However, periinterventional complications concerning device deployment may limit the short-term and long-term results. One common problem is perivalvular aortic regurgitation. While predictors for left ventricular functional recovery or survival following valve replacement have been investigated, predictors for paravalvular aortic regurgitations after TAVI are less established [6–9]. Postprocedural aortic regurgitation grade 2 is noted in about 12–20% of patients [4,10]. Although severe postprocedural aortic regurgitation is rare [5,11], up to one-fifth of the percutaneously implanted patients required ballon redilatation after valve implantation or implantation of a second valve due to moderate to severe aortic regurgitation diagnosed during the index procedure in order to improve seating of the prosthesis in the space of the annulus [6].

Thus, the aim of the study was to examine a possible relationship between the distribution of aortic valve calcification as well as the severity of aortic valve calcification and degree of aortic valve regurgitation after TAVI.

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2. Material and methods

2.1. Study group

In this observational study 57 patients (22 men, mean age 81 ± 5 years) with severe symptomatic aortic valve stenosis (aortic valve area ≤1 cm^2) and with a logistic EuroSCORE of 24 ± 12 were included. All patients were refused for conventional surgical aortic valve replacement. 38 patients (67%) had percutaneous implantation of the third (18F)-generation CoreValve® aortic valve prosthesis (CoreValve Inc., Irvine, USA). In 19 patients (33%) a transapical access was applied for implantation of the Edwards SAPIEN™ prosthesis (Edwards Lifescience, Irvine, USA). Prior to TAVI all patients underwent non-enhanced and contrast-enhanced dual-source computed tomography.

All patients were evaluated by transthoracic echocardiography prior to TAVI as well as after TAVI. In addition, echocardiographic follow-up examinations were available in 38 (67%) patients.

Informed consent was obtained from each patient prior to the investigation in accordance with local Ethics Committee requirements.

2.2. Dual-source computed tomography

All CT examinations were performed with a dual-source (DSCT) scanner (Definition, Siemens, Forchheim, Germany) using a standardized imaging protocol with retrospective ECG gating. The scan parameters for non-enhanced DSCT examination were as follows: 2 × 64 × 0.6 mm collimation, tube voltage 120 KV, 130 mAs_{rot} tube current; for contrast-enhanced images 380 mAs per rotation plus tube current modulation (Care Dose 4D, Siemens, Germany). ECG pulsing was performed during diastole reducing tube current to 4% of its nominal value [12].

The average heart rate of the patients was 69 ± 6 beats per minute. Axial images were reconstructed using a motion map algorithm (Cardio BestPhase, Siemens, Germany) during the diastolic phase with least motion as recommended for coronary calcium screening with an effective slice thickness of 3 mm and a reconstruction increment of 2 mm using a dedicated convolution kernel (B35f). The field of view was 180 × 180 mm^2 with a 512^2 matrix.

DSCT images were assessed in a consensus reading by an experienced radiologist and an experienced cardiologist. Both readers were blinded to all patient data. Image analysis was performed on a separate computer workstation (Leonardo, Siemens, Forchheim, Germany) equipped with a dedicated software tool for calcium scoring (Calcium Scoring CT, Siemens, Forchheim, Germany). For quantitative assessment of aortic valve calcification a total valvular Agatston score was calculated with a detection threshold of 130 Hounsfield units [13]. Total valvular calcification analysis has been performed as described in a previously published study by our group [14]. As a clear separation of aortic valve cusps in case of severely calcified valves is not always possible on non-enhanced DSCT images, we used contrast-enhanced DSCT images to calculate Agatston AVC scores for every single aortic valve cusp. The analysis on contrast-enhanced images was performed with a detection threshold of 500 Hounsfield units. To determine the distribution of AVC the percentage of the calcium load of the most seriously calcified cusp was calculated.

2.3. Echocardiography

A comprehensive transthoracic echocardiography was performed in all patients using a commercially available ultrasonographic system (GE Vingmed, Vivid 7, Horten, Norway) by one experienced echocardiographer. Severity of aortic valve stenosis as well as aortic valve regurgitation was graded according to the ACC/AHA guidelines [15]. Concerning quantification of aortic valve regurgitation we used a combined approach of Doppler parameters consisting of jet deceleration rate (i.e. pressure half time), jet width or jet area in the left ventricular outflow tract as well as diastolic flow reversal in the descending aorta according to the criteria of the American Society of Echocardiography [16].

2.4. TAVI procedure and angiography

The procedure was performed either with the patient being under general anesthesia or with a combination of local anesthesia and mild systemic sedative and analgesic medication. The use of transesophageal echocardiographic guidance was left to the discretion of the operator. Balloon valvuloplasty with a balloon of 20- to 23 mm diameter was performed during simultaneous rapid pacing before device placement. Using the transfemoral access, the device was deployed retrograde in the stenotic valve with fluoroscopic guidance. Using the transapical access, the device was deployed antegrade also with fluoroscopic guidance. Evaluation of postprocedural aortic regurgitation was performed by supra-valvular angiography after withdrawal of the delivery guidewire. The degree of aortic regurgitation was determined angiographically (RAO projection 30°) according to the Sellers classification (degrees I–IV) by an independent interventional cardiologist blinded to clinical as well as CT data.

In addition, all patients received a transthoracic echocardiography to exclude pericardial effusion and to assess the degree of aortic valve regurgitation. In case of discrepancies between echocardiography and angiography concerning the degree of aortic valve regurgitation the severity of aortic regurgitation was graded according to the results of angiography. Echocardiography was repeated at follow-up to reevaluate the degree of aortic regurgitation.

2.5. Statistical analysis

Continuous variables are expressed as mean values ± standard deviation. Student's *t* test was used for comparisons of continuous variables. Categorical data are presented as frequencies and were compared by Chi-square analysis. ANOVA analysis was performed for comparison of mean percentual calcium load between the aortic valve cusps. Spearman-Rho correlation coefficients were calculated between the distribution as well as the severity of AVC and the degree of aortic valve regurgitation. A p value <0.05 was considered statistically significant. Statistical analysis was performed with the use of SPSS 17.0 (SPSS Inc.,Chicago, USA).

3. Results

3.1. Baseline characteristics

The baseline characteristics of the patient population are demonstrated in Tables 1 and 2. There were no relevant differences between the CoreValve and the Edwards cohort. All patients had a severe symptomatic aortic valve stenosis with a preprocedural mean calculated aortic valve area of 0.69 ± 0.13 cm^2. In 6 patients a moderate aortic regurgitation was present ($n=5$ with grade 2, $n=1$ with grade 3, respectively), whereas 51 patients presented with grade 1 ($n=37$) or no aortic ($n=14$) regurgitation. The mean calculated logistic EuroSCORE of the study population was 24 ± 12% and 81% of patients were New York Heart Association functional class III or IV.

3.2. TAVI: Acute and long-term success

Acute procedural success defined as device success with absence of periprocedural major adverse cardiovascular and cerebral events (MACCEs) in the first 48 h after device implantation was achieved in 51 (89%) of the 57 patients (Table 3). Four deaths occurred periprocedurally: 2 patients died after major strokes, one patient died of myocardial infarction after occlusion of the left main stem and one patient died of major bleeding due to vascular complications. One patient with good long-term outcome required blood transfusions due to vascular complications. The 30-day mortality was 9% ($n=5$) as one additional patient died of septic shock.

After successful TAVI, an excellent improvement of hemodynamic parameters was observed in all patients as illustrated in Table 4. After a mean follow-up of 83 ± 80 days the hemodynamic benefit after TAVI was unchanged in these 38 patients who participated in the follow-up examination (Table 4). NYHA functional class declined from 2.86 ± 0.62 before to 1.48 ± 1.12 after valve implantation ($p<0.001$).

Table 1
Demographic and clinical characteristics of the study population.

	Overall	CoreValve	Edwards	p value*
	($n=57$)	($n=38$)	($n=19$)	
Age (years)	81 ± 5	82 ± 5	79 ± 5	$p=0.05$
Men	22 (39%)	10 (26%)	12 (63%)	$p=0.01$
Logistic EuroScore (%)	24 ± 12	24 ± 12	22 ± 10	$p=0.41$
Valvular Agatstonscore	1966 ± 1342	2021 ± 1462	1861 ± 1108	$p=0.65$
NYHA functional class				
I and II	11 (19%)	9 (24%)	2 (11%)	
III and IV	46 (81%)	29 (76%)	17 (89%)	$p=0.30$
Creatinine (mg/dl)	1.05 ± 0.8	1.08 ± 1.0	1.00 ± 0.4	$p=0.69$
Hypertension	43 (75%)	30 (79%)	13 (68%)	$p=0.52$
Diabetes mellitus	13 (23%)	7 (18%)	6 (32%)	$p=0.32$
Coronary artery disease	39 (68%)	25 (66%)	14 (74%)	$p=0.77$
Prior myocardial infarction	9 (16%)	6 (16%)	3 (16%)	$p=1.00$
Previous CABG	7 (12%)	2 (5%)	5 (26%)	$p=0.04$
Prior stroke	0 (0%)	0 (0%)	0 (0%)	$p=1.00$
COPD	16 (28%)	12 (32%)	4 (21%)	$p=0.54$
Pulmonary hypertension#	5(9%)	5(13%)	0 (0%)	$p=0.16$
Peripheral vascular disease	5 (9%)	1 (3%)	4 (21%)	$p=0.04$

*:CoreValve versus Edwards group; #: systolic pulmonary artery pressure >60 mm Hg; CABG: coronary artery bypass grafts; COPD: chronic obstructive pulmonary disease.

Table 2
Baseline echocardiographic characteristics of the study population.

	Overall ($n=57$)	CoreValve ($n=38$)	Edwards ($n=19$)	p value*
Mean gradient (mm Hg)	49.3 ± 15.8	51.6 ± 17.6	44.7 ± 10.3	$p=0.07$
Peak gradient (mm Hg)	86.0 ± 25.0	89.5 ± 27.9	78.2 ± 17.0	$p=0.07$
Peak aortic velocity (m/s)	4.48 ± 0.67	4.57 ± 0.69	4.27 ± 0.40	$p=0.05$
Aortic valve area (cm^2)	0.69 ± 0.13	0.68 ± 0.14	0.73 ± 0.11	$p=0.16$
LV ejection fraction				
<50%	10 (18%)	5 (13%)	5 (26%)	$p=0.28$
Prior AI ≥ grade 2	4 (7%)	1 (3%)	3 (16%)	$p=0.10$

*:CoreValve versus Edwards group; AI: aortic insufficiency; LV: left ventricular.

Table 4
Echocardiographic results after TAVI.

	Before implantation ($n=57$)	After implantation ($n=56$[a])	Follow-up[b] ($n=38$)
Mean gradient (mm Hg)	49.3 ± 15.8	11.2 ± 3.9	9.8 ± 4.4
Peak aortic velocity (m/s)	4.48 ± 0.67	2.19 ± 0.38	2.11 ± 0.46
Aortic regurgitation grade			
4+	0 (0%)	0 (0%)	0 (0%)
3+	1 (2%)	3 (5%)	0 (0%)
2+	5 (9%)	5 (9%)	2 (5%)
1+	37 (65%)	43 (77%)	31 (82%)
0	14 (25%)	5 (9%)	6 (16%)

[a] One death during implantation excluded.
[b] Mean follow-up after 83 ± 80 days.

3.2.1. Postprocedural paravalvular aortic regurgitation

In most patients postprocedural paravalvular aortic regurgitation was mild (Table 4). However, a redilatation was needed in 6 of 57 patients (11%) due to postprocedural aortic valve regurgitation. One patient showed a postprocedural aortic valve regurgitation grade 4+, two patients demonstrated paravalvular aortic regurgitation grade 3+, of whom one patient was redilatated, and four patients showed aortic regurgitation grade 2+ related to paravalvular leakages as determined angiographically as well as by echocardiography. After redilatation with a mean ballon diameter of 24 ± 1 mm, the grade 4+ aortic regurgitation was reduced to grade 3+. However, the severity of a paravalvular aortic regurgitation in another patient with grade 3+ aortic regurgitation was unchanged and needed conversion to surgery the next day. In the third patient with postprocedural aortic regurgitation grade 3+ the positioning of the valve was difficult resulting in a slightly ventricular position. Despite no redilatation was performed, the aortic regurgitation decreased from grade 3+ to grade 1+ to grade 2+ during the 180 day follow-up. Four patients with grade 2+ aortic regurgitation were redilatated and showed only mild final paravalvular aortic regurgitation.

3.2.2. Relationsship between aortic valve calcification and aortic regurgitation

All patients with aortic regurgitation grade 3+ showed extremely calcified aortic valves on DSCT scans. In 29 patients (51%) the non-coronary cusp, in 15 patients (26%) the right-coronary cusp and in 13 patients (23%) the left-coronary cusp was the most severely calcified cusp. ANOVA analysis showed no significant differences in mean percentual calcium load of the most severely calcified cusp (52 ± 11% for the non-coronary cusp, 47 ± 8% for the right-coronary cusp and 45 ± 8% for the left-coronary cusp, $F=2{,}29$, $p=0.112$). There was no association between the distribution of AVC and the degree of aortic valve regurgitation after TAVI as assessed by angiography ($r=-0.02$, $p=0.88$) and echocardiography ($r=0.06$, $p=0.69$). However, Agatston aortic valve calcification scores were significantly higher in patients with aortic regurgitation grade ≥3 (5055 ± 1753) than in patients with aortic regurgitation grade <3 (1723 ± 967, $p=0.03$). There was a significant association between the severity of AVC and the degree of aortic valve regurgitation after AVR ($r=0.50$, $p<0.001$, Fig. 1). However, no significant differences in baseline patient characteristics were observed between patients with aortic regurgitation grade ≥3+ compared to patients with aortic regurgitation grade <3. All patients with relevant paravalvular aortic regurgitation showed severely calcified valves with Agatston AVC scores above 3000**.** In addition, patients with the need for redilatation showed almost significantly higher Agatston AVC scores (3884 ± 2188) than patients without need for redilatation (Agatston AVC score 1731 ± 1005, $p=0.06$). Aortic valve calcification score above 3000 showed a sensitivity of 86%, a specificity of 80%, a positive predictive value of 70% and a negative predictive value of 98% for aortic regurgitation grade ≥3 or the need for redilatation.

Table 3
Procedural MACCEs and 30-day clinical outcome.

	Total cohort ($n=57$)
Death	4 (7%)
Major stroke	2 (4%)
Myocardial infarction	1 (2%)
Cardiac tamponade	0
Aortic dissection	0
Conversion to surgery	1 (2%)
Major bleeding[a]	2 (4%)
Procedural MACCE	6 (11%)
Procedural success	51 (89%)
30 day mortality	5 (9%)
Cardiovascular deaths	4 (7%)

[a] Defined as hemorrhage requiring surgery and/or 3 or more units of blood transfusion.

4. Discussion

The results of this study confirm a significant reduction in mean valve gradient immediately as well as in the mid-term follow-up after TAVI [6,10,17]. Secondly, the results of this study suggest that patients with severe aortic valve calcification with Agatston AVC scores>3000 have an increased risk for a relevant paravalvular aortic valve regurgitation after transcatheter aortic valve replacement. Furthermore, there is a greater need for additional procedures (e.g. redilatation) as well as a higher risk of complications in these patients. Our findings

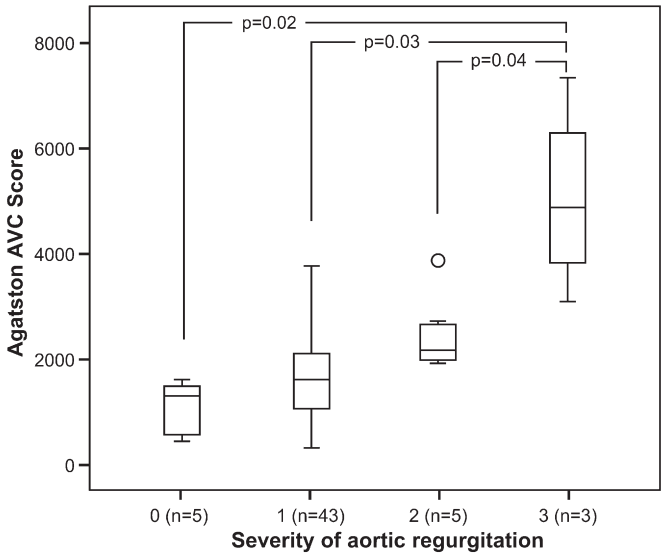

Fig. 1. Box plots including median (horizontal line within box) as well as 25th to 75th percentiles for Agatston aortic valve calcification score in relation to the severity of aortic regurgitation determined by supra-valvular angiography.

demonstrate a significant association between the aortic valve calcification scores assessed by DSCT and the degree of perivalvular aortic valve regurgitation. A previous smaller study of Wood et al [18] did not find a significant relationship between moderate perivalvular regurgitation and the amount of aortic valve calcium. In contrast to that study, we observed at least grade 3+ paravalvular aortic regurgitation only in patients with severe aortic valve calcification. In addition, our findings are in line with preliminary findings of John and Grube et al [19], who reported a positive correlation between the grade of paravalvular aortic regurgitation and the amount of aortic valve calcification in a cohort of 100 patients with TAVI.

Perivalvular regurgitations, mainly of mild degree, are common due to stiff calcifications of the native aortic valve. In case of severely calcified native aortic valves the prosthesis may not throughout the circumference be tightly in contact to the aortic annulus as well as to the aortic wall resulting in relevant perivalvular aortic regurgitation. In addition, the positioning of the prosthesis may be difficult due to the tilt of the inflow and outflow portion of the prosthesis, respectively, especially in case of unequal distribution of AVC. Thus, in accordance with previous reports up to one-fifth of the percutaneously implanted patients required balloon redilatation after valve implantation due to moderate to severe paravalvular aortic regurgitation diagnosed during the index procedure in order to improve seating of the prosthesis in the space of the annulus [6]. Since DSCT may provide a tool in the preinterventional diagnostic workup to identify patients at risk for a relevant aortic regurgitation and the need for additional procedures in this context our preliminary findings might be of special clinical interest.

The limitations of the study include the retrospective design, the low number of patients with postprocedural paravalvular aortic regurgitation as well as the analysis of two study populations. Nevertheless, there were no differences in the demographic baseline data between the two study groups.

5. Conclusions

The results of this study suggest that patients with severe aortic valve calcification assessed by cardiac DSCT have an increased risk for a relevant aortic regurgitation as well as a trend for an increased need for second manoeuvres after TAVI.

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The authors of this manuscript have certified that they comply with the Principles of Ethical Publishing in the International Journal of Cardiology [20].

References

[1] Grube E, Laborde JC, Zickmann B, et al. First report on a human percutaneous transluminal implantation of a self-expanding valve prosthesis for interventional treatment of aortic valve stenosis. Catheter Cardiovasc Interv 2005;66:465–9.
[2] Grube E, Laborde JC, Gerckens U, et al. Percutaneous implantation of the CoreValve self-expanding valve prosthesis in high-risk patients with aortic valve disease: the Siegburg first-in-man-study. Circulation 2006;114(15):1616–24.
[3] Lichtenstein SV, Cheung A, Ye J, et al. Transapical transcatheter aortic valve implantation in humans. Initial clinical experience. Circulation 2006;114:591–6.
[4] Bleiziffer S, Ruge H, Mazzitelli D, et al. Results of percutaneous and transapical transcatheter aortic valve implantation performed by a surgical team. Eur J Cardiothorac Surg 2009;35(4):615–20.
[5] Walther T, Simon P, Dewey T, et al. Transapical minimally invasive aortic valve implantation. Multicentre experience. Circulation 2007;116 Suppl I:240–5.
[6] Piazza N, Grube E, Gerckens U, et al. Procedural and 30-day outcomes following transcatheter aortic valve implantation using the third generation (18Fr) CoreValve ReValving system: results from the multicentre, expanded evaluation registry 1-year following CE mark approval. EuroIntervention 2008;4(2):242–9.
[7] Ding WH, Lam YY, Kaya MG, et al. Echocardiographic predictors of left ventricular functional recovery following valve replacement surgery for severe aortic stenosis. Int J Cardiol 2008;128(2):178–84.
[8] Nemes A, Galema TW, Soliman OI, et al. Improved aortic distensibility after aortic homograft root replacement at long-term follow-up. Int J Cardiol 2009;136(2):216–9.
[9] Ding WH, Lam YY, Duncan A, et al. Predictors of survival after aortic valve replacement in patients with low-flow and high-gradient aortic stenosis. Eur J Heart Fail 2009;11(9):897–902.
[10] Grube E, Schuler G, Buellesfeld L, et al. Percutaneous aortic valve replacement for severe aortic valve stenosis in high-risk patients using the second and current third generation self expanding CoreValve prosthesis. J Am Coll Cardiol 2007;50:69–76.
[11] Laborde JC. Transcatheter aortic valve implantation with the CoreValve ReValving device. Paper Presented at: Transcatheter Cardiovascular Therapeutics; October 12 2008. Washington, DC, USA.
[12] Mahnken AH, Bruners P, Schmidt B, Bornikoel C, Flohr T, Günther RW. Left ventricular function can reliably be assessed from dual-source CT using ECG-gated tube current modulation. Invest Radiol 2009;44:384–9.
[13] Agatston AS, Janowitz WR, Hildner J, Zusmer NR, Viamonte Jr M, Detrano R. Quantification of coronary artery calcium using ultrafast computed tomography. J Am Coll Cardiol 1990;15:827–32.
[14] Koos R, Mahnken AH, Sinha AM, Wildberger JE, Hoffmann R, Kuehl HP. Aortic valve calcification as a marker for aortic stenosis severity: assessment on 16-MDCT. Am J Roentgenol 2004;183(6):1813–8.
[15] Bonow RO, Carabello BA, Chatterjee K, et al. ACC/AHA 2006 guidelines for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines developed in collaboration with the Society of Cardiovascular Anesthesiologists endorsed by the Society for Cardiovascular Angiography and Interventions and the Society of Thoracic Surgeons. J Am Coll Cardiol 2006;48(3):e1–e148.
[16] Zoghbi WA, Enriquez-Sarano M, Foster E, et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. J Am Soc Echocardiogr 2003;16(7):777–802.
[17] Cribier A, Eltchaninoff H, Tron C, et al. Treatment of calcific aortic stenosis with the percutaneous heart valve: mid-term follow-up from the initial feasibility studies: the French experience. J Am Coll Cardiol 2006;47(6):1214–23.
[18] Wood DA, Tops LF, Mayo JR, et al. Role of multislice computed tomography in transcatheter aortic valve replacement. Am J Cardiol 2009;103:1295–301.
[19] John D, Yuecel S, Buellesfeld L, et al. Amount and distribution of aortic valve calcification impair the short-term device outcome of the CoreValve ReValving System in patients with severe aortic valve disease. Eur Heart J 2009;30(abstract supplement):691.
[20] Coats AJ. Ethical authorship and publishing. Int J Cardiol 2009;131:149–50.