

Aortic annulus dimensions and leaflet calcification from contrast MSCT predict the need for balloon post-dilatation after TAVI with the Medtronic CoreValve prosthesis

Carl Schultz^{1*}, MD, PhD; Alexia Rossi², MD; Nicolas van Mieghem¹, MD; Robert van der Boon¹; Stella-Lida Papadopoulou², MD; Ron van Domburg¹, PhD; Adriaan Moelker², MD, PhD; Nico Mollet², MD, PhD; Gabriel Krestin², MD, PhD; Robert-Jan van Geuns^{1,2}, MD, PhD; Koen Nieman^{1,2}, MD, PhD; Pim de Feyter^{1,2}, MD, PhD; Patrick Serruys¹, MD, PhD; Peter de Jaegere¹, MD, PhD

1. Department of Cardiology, ErasmusMC, Rotterdam, The Netherlands; 2. Department of Radiology, ErasmusMC, Rotterdam, The Netherlands

KEYWORDS

- aorta stenosis
- valvuloplasty
- valvular heart disease
- imaging

Abstract

Aims: We compared the measurement of aortic leaflet calcification on contrast and non-contrast MSCT and investigated predictors of the need for balloon post-dilatation after TAVI.

Methods and results: In 110 patients, who had TAVI with a Medtronic CoreValve prosthesis (MCS) for symptomatic aortic stenosis, calcification of the aortic root was measured on non-contrast MSCT (conventionally) and on contrast MSCT (signal attenuation >450 Hounsfield units). Calcium volume was underestimated on contrast- when compared to non-contrast MSCT: median (IQ-range)=759 (466 to 1295) vs. 2016 (1376 to 3262) and the difference between the two methods increased with higher calcium volumes (correlation coefficient $r=0.90$). Calcium mass was only slightly underestimated on contrast vs. non-contrast MSCT: median (IQ-range)=441 (268 to 809) vs. 555 (341 to 950) and there was no association between the differences and increasing calcium mass ($r=0.17$). Balloon post-dilatation was performed for significant aortic regurgitation after TAVI in 11 of 110 patients. When compared to controls, the patients who required balloon post-dilatation had higher aortic leaflet calcium on contrast CT ($p<0.01$), higher aortic annulus diameters ($p<0.01$) and higher annulus to prosthesis area ratio ($p=0.01$). ROC curves demonstrated that aortic root or aortic leaflet calcium measured on either contrast- or non-contrast MSCT showed excellent discrimination for the requirement of balloon post-dilatation (area under ROC >0.80 for all), whereas the discriminatory value of aortic annulus dimensions was moderate (area under ROC=0.69) and that of prosthesis to annulus ratio was poor (area under ROC = 0.36).

Conclusions: Dense aortic leaflet calcification measured on contrast MSCT discerned well the need for balloon post-dilatation after TAVI with an MCS for significant PAR. Non-contrast MSCT may no longer be needed to quantify aortic root calcium before TAVI.

*Corresponding author: Department of Cardiology, Erasmus MC, PB 412, 3000 CA Rotterdam, The Netherlands.
E-mail: c.schultz@erasmusmc.nl

Introduction

Transcatheter aortic valve implantation (TAVI) improves prognosis of patients with severe aortic stenosis who are deemed at too high a risk for surgical valve replacement (SAVR)¹. Heavy calcification of the aortic root is an almost universal finding in patients with severe symptomatic aortic stenosis². The gold standard for the measurement of calcification is standardised non-contrast MSCT, yet the precise anatomical distribution of calcification can be better appreciated on contrast MSCT, which usually shows dense calcification of the aortic leaflets. Balloon valvuloplasty is essential to crack open the calcified valve before it can be crossed with the TAVI prosthesis^{3,4}. The calcified aortic leaflets are then pushed aside and trapped by the prosthesis during implantation. Apposition of a sealing skirt to the disrupted aortic leaflets and or to the surrounding tissues within a few millimetres below them is necessary to prevent paravalvular aortic regurgitation (PAR) for both types of commercially available TAVI prostheses. It is likely that the calcified leaflets also play an important role in preventing device embolisation after deployment. Yet, dense calcification may contribute to deformation of the deployed frame of the prosthesis, which may result in malapposition and paraprosthetic aortic valve regurgitation.

Another factor which may cause PAR after TAVI is undersizing, where the prosthesis is small relative the native annulus⁵. Prosthesis size selection is based on the measurement of the aortic annulus^{6,7}. Yet, during SAVR the aortic annulus is partially decalcified before sizing proceeds under direct vision, whereas during TAVI sizing relies on non-invasive imaging without prior decalcification.

When significant PAR is encountered after deployment of the prosthesis balloon post-dilatation of the prosthesis (PDP) may reduce the amount of regurgitation, but carries the risks of potential damage to the new valve leaflets as well as of vascular sequelae that may result from the additional instrumentation, for example potentially aortic root rupture and cerebrovascular events⁸⁻¹¹. Yet if it were possible to identify a priori which patients would be at risk of requiring PDP, it may be possible to modify the procedure so as to obviate the need for it, for example by selecting a larger pre-dilatation balloon or larger size prosthesis. This study investigates first the measurement of aortic valve calcification on contrast vs. non-contrast MSCT and second, the clinical and anatomical determinants of PDP after TAVI.

Methods

POPULATION

The study population consisted of 110 consecutive patients who received TAVI with a Medtronic CoreValve prosthesis (MCS) between June 2007 and August 2010 and who had a MSCT for pre-procedure planning at our centre. MSCT was performed in all patients before TAVI, except on patients with an estimated glomerular filtration rate below 20 ml/min, or where the MSCT could not be arranged for logistical reasons. No patients were specifically excluded.

MSCT WITHOUT CONTRAST ENHANCEMENT

A scan without contrast enhancement was available in 98 of 110 patients because it was initially not performed in patients with previous CABG or coronary stents. The non-contrast MSCT acquisition was performed in a prospectively ECG-triggered, sequential (step-and-shoot) mode with a reference tube current of 80 mAs, a tube voltage of 120 kV and slice thickness of 3 mm in the early or mid diastolic heart phase depending on the heart rate. For analysis on a dedicated cardiovascular CT workstation (MMWP, Siemens AG, Forchheim, Germany) the aortic root was defined as the stretching from the caudal aspect of the aortic annulus to the origin of the left main stem as seen on axial images¹². The threshold for the detection of calcium was set at 130 HU. Agatston score, calcium volume and mass were measured¹³⁻¹⁷. In cases where aortic root calcification was confluent with calcium in adjacent structures (mitral annulus, ascending aorta, coronary arteries) only the stack of images that contained the aortic root were selected.

CONTRAST ENHANCED MSCT

The MSCT acquisition method using 64-slice dual-source CT has been described before¹⁸. In brief, the acquisition was performed using the spiral scan mode, a variable table speed (depending on the heart rate), no ECG-triggered tube output modulation and an ECG-gated image reconstruction. Further acquisition parameters: detector collimation 2×32×0.6 mm with rapid alternation of focal spot position in the Z-axis (Z-sharp[®]), roentgen tube rotation time 330 ms, tube voltage 120 kV. The scan ranged from the top of the aortic arch to the diaphragm. The volume of iodinated contrast material was adapted to the expected scan time. A 50-60 ml bolus of iodixanol (Visipaque[®] 320 mg I/ml; GE Health Care, Eindhoven, The Netherlands) was injected in an antecubital vein at a flow rate of 4.5 ml/s followed by a second contrast bolus of 30-40 ml at 3.0 ml/s. Bolus tracking was used to trigger the start of the scan with the arrival of contrast in aortic root. Reconstructions were made in end-systole using a single-segmental reconstruction algorithm with slice thickness 1.5 mm; increment 0.4 mm; medium-to-smooth convolution kernel (B26f) resulting in a spatial resolution of 0.6-0.7 mm in-plane and 0.4-0.5 mm through-plane and a temporal resolution of 83 ms. The radiation doses ranged from 8 to 20 mSv depending on body habitus and table speed.

The aortic annulus was defined as a virtual ring with three anchor points at the bases of the three aortic leaflets¹⁹. This definition was visually reproduced by setting up a viewing plane axial to the aortic root as described before²⁰. The minimum and maximum diameters and area of the annulus were measured. Proprietary software was developed to allow measurement of aortic leaflet calcification on a contrast MSCT (3mensio Medical Imaging, Bilthoven, the Netherlands). On images axial to the aortic annulus, a region of interest was defined from the aortic annulus to the most cranial aspect of the aortic leaflets. The threshold for detecting calcification in the region of interest was set at 450 Hounsfield units (HU), which was approximately 150 HU above contrast density of the blood pool when sampled just above the aortic leaflets in the majority

of patients. This was found to be the lowest level at which contrast was not detected as calcium. Non-detection of contrast was visually verified. If necessary, the region of interest was then edited to ensure that calcification detection were limited to the three aortic leaflets (**Figure 1**). Calcium volume and mass was measured. The density of calcium can be determined from the amount of signal attenuation^{16,17}. Due to the high signal attenuation threshold selected for the detection of calcium it was anticipated that only dense calcium would be measured on contrast MSCT.

RELEVANT ASPECTS OF THE TAVI PROCEDURE

The patient selection and TAVI implantation procedure has been described before²¹. Balloon valvuloplasty of the native valve was performed in all cases. As is the case in the majority of TAVI procedures performed worldwide, a cine-aortogram was performed after device deployment to assess device position and to detect and grade aortic regurgitation¹¹. A 6 FR pigtail catheter was placed in the out-flow part of the frame just above the commissures of the prosthesis leaflets. A radiographic contrast of 20 ml was injected with a power injector at a rate of 20 ml/s. Aortic regurgitation (AR) was graded by the operator during the implantation procedure according to the method of Sellers: grade 0=no AR; grade 1=trace; grade 2=mild; grade 3=moderate; grade 4=severe²². In the event of aortic regurgitation grade 3 or 4, one of two approaches was taken: PDP was performed if the operators judged that the AR may be reduced by improved apposition of the sealing skirt to the tissues surrounding the inflow of the prosthesis. Alternatively, if a too deep position of the prosthesis inflow below the annulus was judged to be the cause

of AR, then a second valve was implanted (valve-in-valve)²³. In practice this meant that if the prosthesis was clearly positioned too deep (inflow >12 mm below the annulus given that the sealing skirt stretches for 12 mm above the inflow of the frame) a second prosthesis was implanted, whereas in other cases post-dilatation was performed. Snare manoeuvres were not performed in any patients to correct AR.

COMPARISON OF CALCIUM MEASUREMENT ON CONTRAST AND NON-CONTRAST MSCT

We anticipated that the calcium score would be underestimated on the contrast MSCT relative to the conventional non-contrast method given the much higher threshold for the detection of calcification on a contrast CT (on average 450 HU vs. 130 HU). In order to compare the measurement of aortic leaflet calcification by the two methods (contrast compared to non-contrast MSCT), 47 patients were selected with calcification largely limited to the aortic leaflets and with none, or limited, calcification in the adjacent structures so as to ensure that the regions of interest corresponded as closely as possible. This was necessary because: 1) aortic leaflet calcification may have an effect on the need for PDP, whereas additional aortic root calcification in the wall of the aorta, mitral valve or coronary ostia would not; 2) the region of interest on the non-contrast images is defined on images axial to the patient and fine anatomical detail cannot be readily appreciated, whereas on the contrast MSCT the region of interest is defined on images axial to the aortic annulus and calcification of individual leaflets can be measured.

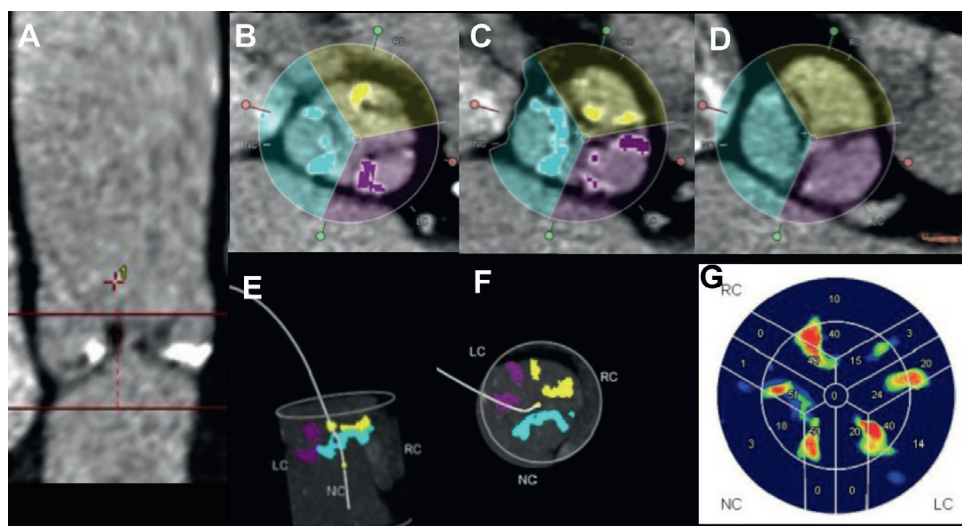


Figure 1. Calcium quantification on aortic leaflets on contrast MSCT. On two longitudinal views the region of interest was defined from the base of the three aortic leaflets to just above the aortic leaflets (Panel A). The threshold for detecting calcification was set at 450 Hounsfield units (HU), which was approximately 150 HU above contrast density of the blood pool when sampled just above the aortic leaflets in the majority of patients. This was found to be the lowest level at which contrast was not detected as calcium. Non-detection of contrast was visually verified at different levels and, if necessary, the region of interest was then edited (Panels B-D) to ensure that calcification detection was limited to and measured individually for the three aortic leaflets. The correct segmented calcium was also verified on 3D views (Panels E, F). Panel G shows a collapsed (2D) calcium density plot after segmentation.

STATISTICAL ANALYSIS

The MSCT interpreter was blinded to procedural outcome and TAVI operators blinded to calcification data. Prosthesis inflow to annulus area was calculated by dividing the nominal area of the prosthesis inflow (size 26 MCS: 5.32 cm² and size 29 MCS: 6.62 cm²) by the cross-sectional area of the aortic annulus. Correlation coefficients and Bland-Altman plots were used for the comparison of measurement of aortic leaflet calcification on contrast and non-contrast MSCT. Calcification score data were not normally distributed, and are given as median (interquartile range). Normally distributed data are given as mean (SD). For comparison between groups Student's *t*-test or the Mann-Whitney U-test were used. The odds ratio and 95% confidence interval was used to investigate the association between the exposure variables (calcium volume, mass) and outcome (PDP). To determine which variable best discrimi-

nated the need for PDP receiver operator characteristic (ROC) curves were plotted (sensitivity vs. 1-specificity) and the areas under the curve were calculated. Statistical significance was defined as $p < 0.05$. SPSS 15.0 was used.

Results

DEMOGRAPHICS

Clinical and anatomical details of the study population are given in **Table 1**. The calcium burden of the aortic root and leaflets was high in all patients, **Table 1**. The degree of calcification was highest for the non-coronary leaflet (calcium mass median [IQR]=187 [121-360]), followed by the right (calcium mass=138 [67-249]) and left coronary leaflets (calcium mass=129 [62-217]).

AR grade 3-4 was seen immediately after device implantation in 15 of 110 patients. In four of these 15 patients a second MCS was

Table 1. Clinical and anatomical characteristics of the patients who did and did not have balloon post-dilatation of the prosthesis frame (PDP) during TAVI.

N [%]; Mean (SD); Median [IQ-range]	All n=110	No PDP n=99	PDP n=11	p-value
Age (y)	80 (7)	81 (7)	79 (8)	
Female: male	62:48	57:42	5:6	
Height (cm)	167 (9)	167 (9)	168 (11)	
Weight (kg)	73 (14)	72 (14)	75 (13)	
BMI (kg/m ²)	26 (4)	26 (4)	27 (4)	
Serum creatinine (µmol/l)	91 [71-117]	87 [70-117]	103 [91-144]	0.06
LV function				
Normal	66 (60)	59 (60)	7 (64)	
Mild to moderate	34 (31)	31 (31)	3 (27)	
Poor	10 (9)	9 (9)	1 (9)	
Echo annulus	23 (2)	23 (2)	23 (2)	
EuroSCORE	15 (9)	15 (9)	12 (9)	
MSCT annulus diameter				
Minimum	21.7 (2.6)	21.5 (2.5)	23.0 (3.1)	0.03
Maximum	26.9 (2.6)	26.6 (2.4)	28.8 (3.4)	0.01
Mean	24.1 (2.3)	23.9 (2.2)	25.9 (3.1)	<0.01
Aortic root calcium				
Agatston	2904 [2008-4484]	2841 [1909 to 4239]	4729 [4010 to 7871]	<0.01
Volume	2333 [1577-3695]	2231 [1506 to 3595]	3710 [3277 to 6156]	<0.01
Mass	647 [402-1138]	606 [380 to 1014]	1166 [872 to 1925]	<0.01
Total aortic leaflet calcium				
Volume	783 [531-1421]	759 [502 to 1278]	1545 [1295 to 2186]	<0.01
Mass	442 [295-911]	420 [290 to 802]	1003 [809 to 1395]	<0.01
Depth of implantation				
Non-coronary sinus	8.2 (3.5)	8.1 (3.5)	8.9 (3.6)	NS
Left coronary sinus	8.9 (3.6)	8.7 (3.6)	10.0 (3.8)	NS
Prosthesis size implanted 26:29	35:75	33:66	2:9	
Prosthesis inflow to annulus area	1.38 (0.21)	1.40 (0.20)	1.25 (0.24)	0.02
Prosthesis inflow to annulus diameter	1.17 (0.09)	1.18 (0.09)	1.11 (0.11)	0.01

immediately implanted (valve-in-valve), which resulted in AR grade 1-2 in all four patients. In 11 of these 15 patients PDP was performed, which resulted in AR grade ≤ 2 in eight of 11 patients. One further patient received a second prosthesis (valve-in-valve) that improved the AR grading to trivial. The grade of AR spontaneously reduced to grade 2 in the first week after TAVI in another patient. One other patient with persistent AR grade 3 despite PDP died 12 days after the procedure. With the exception of this patient, there were no patients with PAR grade >2 on echocardiography one week after TAVI. PDP was associated with the development of a VSD in one patient who had an unusually long ventricular membranous septum²⁴.

COMPARISON OF CALCIUM VOLUME AND MASS ON CONTRAST AND NON-CONTRAST MSCT

In the 47 patients with calcification limited to aortic leaflets the measurements of both calcium volume and mass were lower on contrast when compared to non-contrast MSCT: calcium volume median (IQ-range)=759 (466 to 1295) vs. 2016 (1376 to 3262); calcium mass=441 (268 to 809) vs. 555 (341 to 950). There was a high degree of correlation between the contrast and non-contrast MSCT measurement of both calcium volume and mass (respectively $r=0.93$ and $r=0.95$), see **Figure 2**. The Bland-Altman plot showed that there was a negative bias for the measurement of calcium volume on contrast scans and the difference between the two methods increased as calcium volume increased (correlation coefficient $r=0.90$), **Figure 2**. On the other hand, the calcium mass was also underestimated on contrast MSCT, but there was no association between the difference between the two methods and increasing calcium values (correlation coefficient $r=0.17$), **Figure 3**.

CHARACTERISTICS OF PATIENTS WHO UNDERWENT PDP

There were no differences in the clinical characteristics of patients who did and did not have PDP (**Table 1**). On preprocedural MSCT the patients who required PDP had larger annulus dimensions (minimum, maximum, mean diameters), higher degrees of aortic root calcification on non-contrast MSCT and higher levels of aortic leaflet calcification on contrast MSCT, **Table 1**. The ratio of nominal prosthesis inflow to annulus dimensions was lower in patients who received PDP when compared to those who did not, **Table 1**. There was no difference depth of implantation between the two groups.

The implanted prosthesis was correctly sized or over-sized based on the sagittal annulus measurement from echocardiography in all patients who subsequently required PDP. Yet if sizing was based on the maximum annulus diameter obtained from MSCT, which is not accurately measured on 2D echocardiography, the selected prosthesis would have been undersized in eight out of 11 patients who required PDP. If the sizing was based on the mean annulus diameter obtained from MSCT, the selected prosthesis would have been undersized in five out of 11 patients who required PDP and oversized in one patient. Undersizing, defined as a mean annulus diameter ≥ 23.5 for a size 26 and ≥ 27.5 for a size 29 MCS implant, was associated with PDP: odds ratio (95% CI)=11.0 (2.7-45).

An aortic leaflet dense calcium mass ≥ 800 (contrast MSCT) was more frequent in cases of patients who had PDP than those who did not (91% vs. 25%), and was significantly associated with PDP: odds ratio (95% CI) = 29.6 (3.6 to 242.9). Of patients with an aortic leaflet dense calcium mass ≥ 800 , 29% required PDP compared to 1% of those with a dense calcium mass <800 . Similar data were seen for an aortic leaflet dense calcium volume ≥ 1200 (contrast MSCT), which was seen respectively in 91% and 26% of

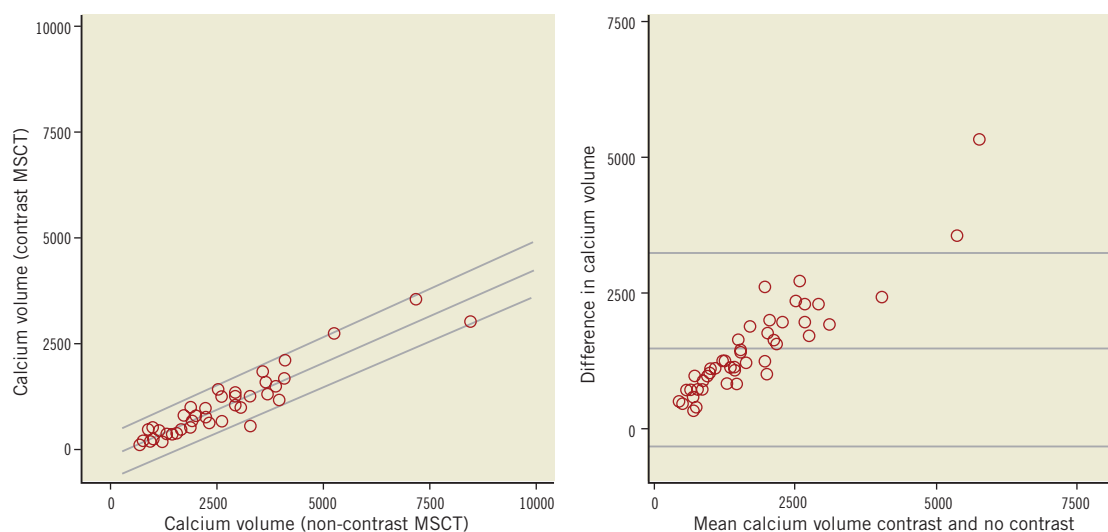


Figure 2. Scatter plot (left panel) and Bland-Altman plot (right panel) of calcium volume measured on contrast and non-contrast MSCT. The linear regression lines with 95% confidence intervals are shown for scatter-plot (left panel: intercept -99, slope 0.45, R -squared = 0.86). Reference lines represent the mean difference $\pm 2SD$ for the Bland-Altman plot (right panel).

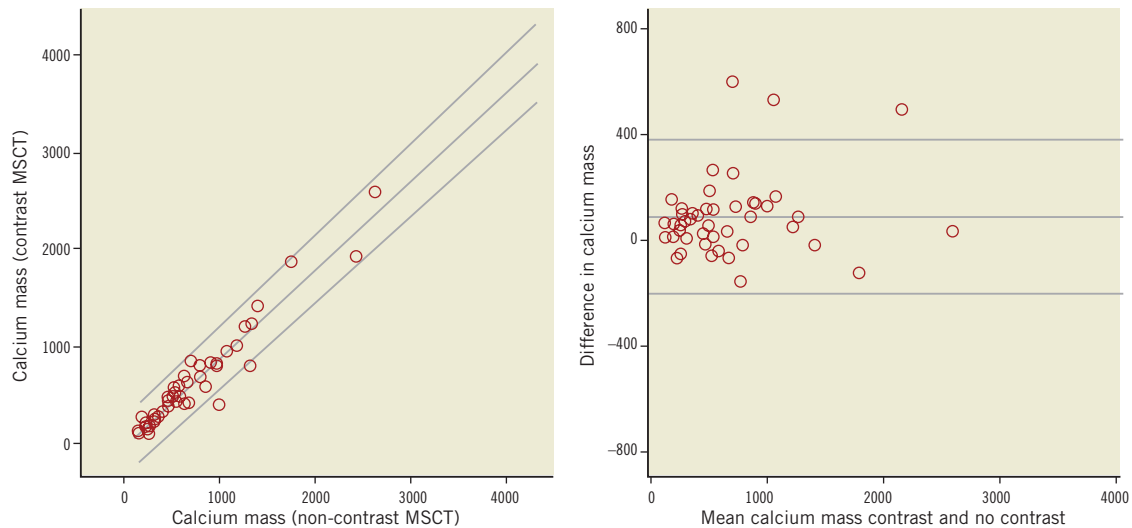


Figure 3. Scatterplot (left panel) and Bland-Altman plot (right panel) of calcium mass measured on contrast and non-contrast MSCT. The linear regression lines with 95% confidence intervals are shown for the scatterplot (left panel: intercept -26, slope 0.91, R-squared =0.93). Reference lines represent the mean difference \pm 2SD for the Bland-Altman plot (right panel).

patients who did and did not have PDP. On non-contrast MSCT an Agatston score ≥ 3000 was seen in all patients who had PDP and in 43% of those who did not.

When evaluated by ROC curve, all measures of aortic root or aortic leaflet calcium showed excellent discrimination for the requirement of PDP (all >0.80 , **Table 2**), whereas the discriminatory value of aortic annulus dimensions was moderate (0.68) and that of prosthesis to annulus ratio was poor (0.39), **Table 2**.

Table 2. Receiver operating characteristic (ROC) curves plotted as sensitivity vs. 1 minus specificity; areas under the curves were calculated to determine which variable was best able to discriminate the need for PDP.

Test variable	Area under the ROC curve
Aortic root calcium (non-contrast MSCT)	
Volume	0.82*
Mass	0.80*
Agatston	0.83*
Aortic leaflet calcium (contrast MSCT)	
Volume	0.81
Mass	0.81
Annulus diameter	
Mean	0.68
Minimum	0.68
Maximum	0.69
Prosthesis to annulus area	0.36
Prosthesis to annulus diameter	0.36
* As determined in the subset of 98 patients with a non-contrast MSCT of which nine underwent PDP.	

Discussion

This study shows firstly that quantification of mass and volume of dense calcium of the aortic leaflets on contrast MSCT is feasible and, secondly, that it allows the detection of dense calcifications that increase the risk of needing post-dilatation after TAVI. Dense calcium was a predictor of PDP in the present study and others²⁵. Less dense calcification did not affect this procedural outcome. This concept is supported by the observation in the present study that calcifications measured on both contrast and non-contrast MSCT discriminated the need for PDP equally, despite the fact that spots of calcium with mild to moderate density (<450 HU) are not detectable on contrast MSCT.

Although semi-quantitative estimation of calcification burden on the aortic leaflets on echocardiography has been described², the measurement of calcium on non-contrast MSCT (Agatston score, volume, mass) has to be considered the gold standard^{26,27}. We report that calcium volume is underestimated on contrast when compared to non-contrast MSCT, and the degree of underestimation increases with increasing levels of root Ca volume. In comparison, the mass measurement did not show a similar increasing bias. This may be explained by the fact that less dense calcium that will not be detected on contrast scans (<450 HU) may have a substantial volume but relatively little mass. These data indicate measurement of calcium on contrast MSCT may lead to significant misclassification when small amounts of calcification have prognostic implications for example in the coronary arteries¹³. Yet only dense aortic leaflet calcification (Agatston score >3000 on non-contrast MSCT, mass ≥ 800 , volume ≥ 1200 on contrast MSCT) was a risk marker for PDP during TAVI in this and another study²⁵. The ability to easily measure dense aortic root calcification contrast MSCT may eliminate the need for an additional non-contrast MSCT before TAVI. This would reduce the radiation dose of a pre-TAVI MSCT scan by approximately 1-2 mSv on average, depending on the scanning protocol used.

PAR is common post-TAVI, but is mostly mild whereas haemodynamically significant AR (grade 3 to 4) is reported in approximately 1 to 5% of patients^{8,25}. This is in part because haemodynamically significant PAR is not well tolerated in elderly patients with stiff ventricles. Consequently it is almost always ameliorated by additional measures during the implantation procedure, even when it does not lead to acute haemodynamic compromise. Treatment options include PDP in order to improve apposition of the sealing skirt at the inflow of the frame to surrounding tissues, or, if a too deep implantation is the principle cause, a second prosthesis may be deployed (valve-in-valve). We observed haemodynamically significant AR (grade ≥ 3) in 15 patients (14%) after TAVI, of which 10% was first treated with PDP and 4% were treated with implantation of a second valve. The reported incidence of PDP after implantation of a MCS ranges between 9 and 34%^{8,25}. Another study of similar size reported PAR grade ≥ 3 in 9% of patients of which 3% were treated with implantation of a second valve after PDP failed to improve the AR²⁵. In that study, PDP was performed in a larger proportion, i.e., 34% of patients, because the threshold was lower, i.e., patients with PAR grade 2 also underwent PDP. In our study, PAR grade ≥ 3 was seen in only one patient on follow up echocardiography one week after TAVI. It is thought that the nitinol frame of the MCS continues to expand up until 48 hours after device release. Consequently PAR may be expected to reduce further within this period without PDP. The additional instrumentation during PDP may carry an incremental risk of complications such as aortic root rupture, although the risk may be small and substantially lower than for predilatation of the native valve (PABV) that is not followed immediately by TAVI^{25,28}. A case report suggested that caution may be warranted when post-dilatation is performed in patients with a ventricular membranous septum that extends a relatively long way below the aortic annulus²⁴. However, as there is currently no technique to eliminate the calcium during TAVI, and the current frame technology does not fully accommodate the surrounding anatomy, additional PDP is integral part of TAVI, fortunately a low risk. It is conceivable that more aggressive predilatation of the native valve in patients with very dense aortic leaflet calcification may reduce PAR and the need for post-dilatation, yet this may come at a greater risk of root rupture and needs further study. In patients who receive a surgical aortic valve prosthesis, aortic calcification is a marker of adverse procedural outcome. There is currently no evidence that this calcification predicts an adverse outcome after TAVI, although the case series have been relatively small.

We report that aortic annulus dimensions and the ratio of nominal prosthesis to annulus size were higher in patients who required PDP when compared to those who did not. Two studies of respectively 74 and 53 patients reported similar findings based on 2D echocardiographic measurements^{5,29}. In the present study there was substantial overlap between the two groups. However, annulus dimensions discriminated less well the need for PDP than did quantification of calcifications. These data suggest that relative undersizing, if not too extreme, may exacerbate the effects of dense calcification rather than being the primary cause of haemodynamically

significant AR requiring PDP. Furthermore, the availability of larger prosthesis sizes in combination with sizing based on mean annulus dimensions from a 3D imaging modality such as MSCT, 3DTEE or CMRI may reduce the need for PDP, although this would require further study.

LIMITATIONS

This is a relatively small study and should be viewed as hypothesis generating. Since the analysis method for the quantification of calcium on the contrast and non-contrast scans are different and non-contrast scans do not allow appreciation of fine anatomical detail, it is not possible to exactly match the regions of interest on the two types of scan. Other factors that may affect the detection of calcium between contrast and non-contrast scans include differences in scanner type, body habitus, the radiation dose, slice thickness, reconstruction increment in addition to the presence or absence of contrast^{17,30-32}. Despite the fact that these differences can not be adjusted, the ability to discriminate the need for PDP was similar for calcium measured on both contrast and non-contrast MSCT. This study included only patients who received an MCS, and we cannot comment on the implications for the Edwards system.

Conclusions

Dense aortic leaflet calcification can be quantified sufficiently on contrast MSCT to allow prediction of haemodynamically significant PAR during TAVI requiring PDP release of the MCS. On contrast MSCT, an aortic leaflet calcium mass >800 , a calcium volume >1200 , larger annulus dimensions and nominal prosthesis inflow to annulus ratio were associated with PDP during TAVI. Aortic root or aortic leaflet calcium on respectively non-contrast and contrast MSCT showed excellent discrimination for the requirement of PDP, whereas the discriminatory value of aortic annulus dimensions was moderate.

Conflict of interest statement

The authors have no conflicts of interest to declare in relation to this paper.

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