Aortic valve evaluation by 128-DSCT prior to TAVI: Optimal time interval for AVA sizing in comparison with echocardiography

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Purpose

Aim of this study was to assess the diagnostic value of 128-DSCT for sizing of the aortic valve area (AVA). Therefore cardiac CT scans of patients with severe AS that were scheduled for TAVI were analyzed retrospectively, measuring AVA from different cardiac phases and comparing them to TTE results. Specifically, the best phases for sizing and image quality in different phases were analyzed.

Methods and Materials

Study population

44 patients (age 82.5 range: 69-92; 50% females) with severe aortic valve stenosis were examined with contrast enhanced ECG-gated 128-slice dual source CT (gantry rot. 0.28s) prior to transcatheter aortic valve implantation (TAVI) for procedure planning.

CT examination

Image acquisition was performed using 128-slice dual source CT (SomatomDefinition^{TM} Flash, Siemens Healthcare, Forchheim, Germany)

For contrast enhancement 70 to 110ml of iopromide (Ultravist 370™, Bayer Schering Pharma, Berlin, Germany) were injected via a cubital vein using an automatic injector at a flow rate between 4,5ml/sec and 5,5ml/sec followed by a saline chaser (40 ml).

The CT scan was triggered into the ascending aorta using a 'bolus tracking technique', after a CT-attenuation of 100 Hounsfield Units [HU]. Scan delay was 10 seconds after the threshold was reached.

The ECG was recorded simultaneously during scan and retrospective ECG-gating was performed. Images were reconstructed in 5% intervals over the cardiac cycle (5-45%) at 0.75mm width, increment 0.5 and a medium smooth convolution kernel [B 26 f].

Echographic examinations

TTE measurements were performed by experienced Cardiologists (Department of Internal medicine III: Cardiology; University hospital Innsbruck) using a standard ultrasound system (Acuson Sequoia 256, Acuson-Siemens Medical Systems, Malvern, Pennsylvania) equipped with a 3.5/1.75-MHz transducer. Especially Doppler flow rates from the left ventricular outflow tract (LVOT), peak transvalvular velocity and AV-gradients were measured. AVA was calculated using continuity equation approach.

CT image analysis

CT-Datasets were analyzed retrospectively using a syngo.via workstation (Siemens healthcare, Forchheim, Germany). Image quality was scored in a 4-point scale (1= excellent, no artifacts; 2=good, minor artifacts such as motion blurring, double contouring, stair-steps; 3= moderate, moderate artifacts still being diagnostic 4= poor/non-diagnostic) for each phase. AVA was measured during all phases from a multiplanar reformation (MPR) in the cross-sectional aortic valve plane.

Statistical analysis

The maximal AVA (AVA_{max}) and minimal AVA (AVA_{min}) of all systolic phases were selected.

The mean (AVA_{mean}) was calculated from all phases over 10-35%.

AVA by CT was compared to values from transthoracic echocardiography (TTE) calculated by Doppler continuity equation (VTI- integral).

The $AVA_{bestcorrel}$ *was defined.*

Statistical data analysis was performed using PASW statistics V 18 [SPSS Inc, Chicago, USA]. The correlations between AVA measured by CT and TTE were determined using linear regression analysis and the Pearson's correlation coefficient. A two-tailed probability value of less than 0.05 was considered statistically significant.

Images for this section:

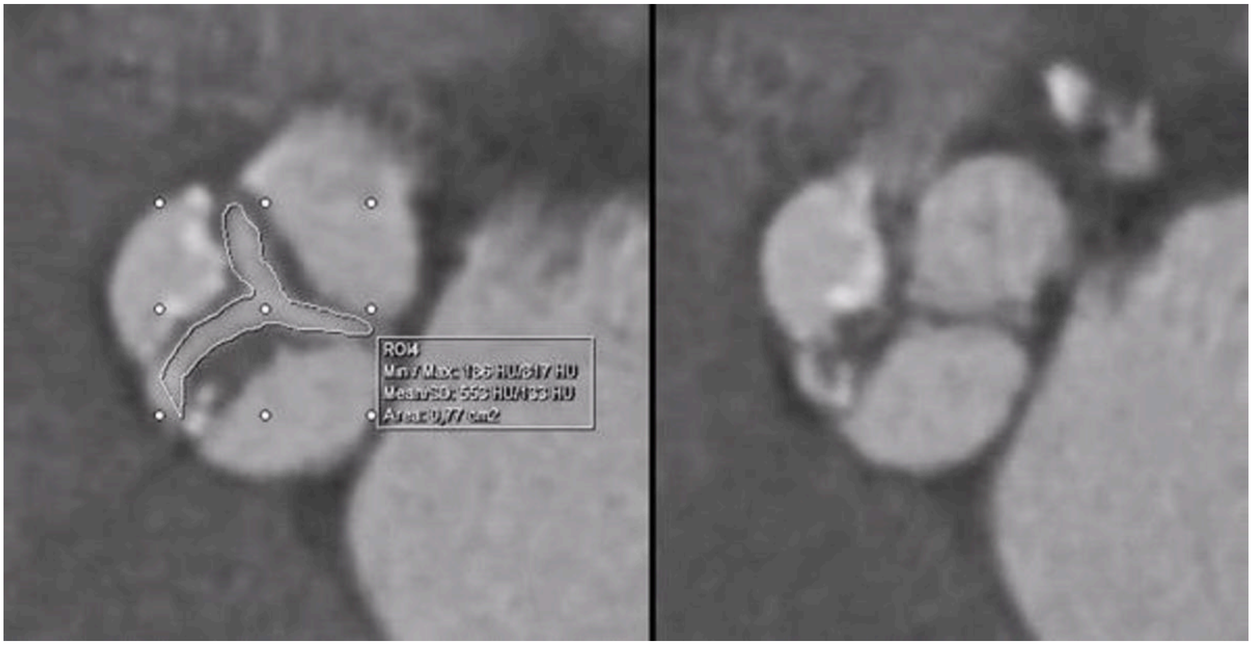

Fig. 1: SEVERE AORTIC STENOSIS OF A TRICUSPID VALVE. AVAmax MEASURES 0.77CM² AT 15% OF RR-INTERVAL (LEFT). AT 35% (RIGHT) AORTIC VALVE IS COMPLETELY CLOSED

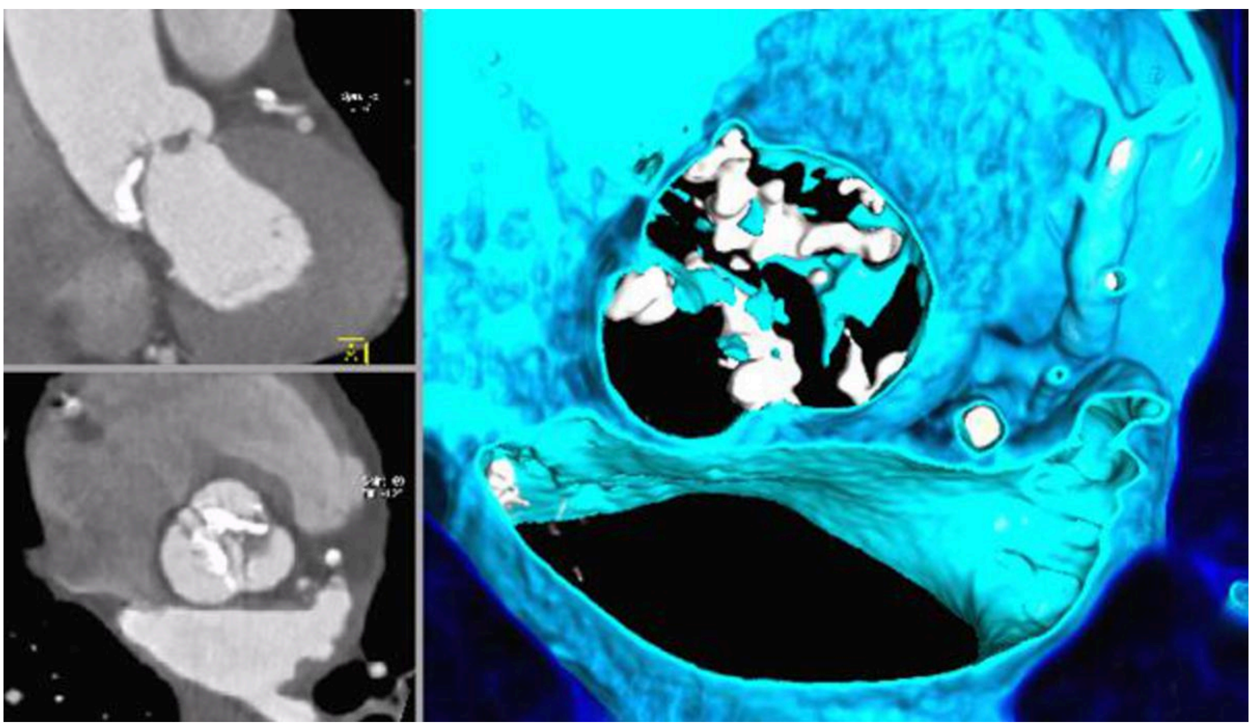

Fig. 2: AORTIC STENOSIS OF A CONGENITAL BICUSPID VALVE. RIGHT- AND LEFT VALVULAR CUSP ARE FUSIONED WITH A CALCIFIED RAPHE. LEFT IMAGES SHOW MPRS IN A CORONAL PLANE (ABOVE) AND IN CROSS-SECTIONAL PLANE (BELOW). THE RIGHT IMAGE SHOWS A VRT-RECONSTRUCTION THAT VISUALIZES VALVULAR CALCIFICATIONS (RED ARROWS)

Results

Among the 44 patients 32 Patients were in Sinus rhythm, the remaining 12 had atrial fibrillation. Mean heart rate was 73 bpm (range 49-101).

Phase of best correlation

For the best correlation between CT and TTE (AVAbestcorr; r=0.94, p=0.001), the most frequently chosen phase was 35% of the RR-interval. (11/44, 19%) as shown in Table1.

Phase of largest Aortic valve area

The largest AVA (AVA_{max}) was most likely to be found at 25% (17/44; 39%) of cardiac cycle in early to mid systole and far less often in late systole as shown in Table2.

The maximal AVA (AVA max) correlated significantly (r=0.64, p<0.001); with an overestimation of + 0.12 (limits of agreement: -0.09-0.33) by CT.

Image quality

Image quality of the aortic valve was sufficient for diagnosis in all patients. It was most frequently excellent or good at 25%, 30% and 35% of RR-interval.

There was a relationship between phases offering excellent image quality and heart rate. For slow heart rates (<70bpm) image quality was most frequently excellent in early systole. In patients with fast heart rates (>80) image quality was more often excellent in late diastole. Peak prevalences of image quality graded as excellent was 15-25% for < 70 bpm, 20-30% for 70-80 bpm and 25-40% for >80 bpm.

Bicuspid valves

Functional bicuspid valves were found in 9/44 (20%). (5NC/RC, 3LC/RC, 1 NC/LC). Two congenital bicuspid valves (both RC/LC, with calcified Raphe) were diagnosed.

Images for this section:

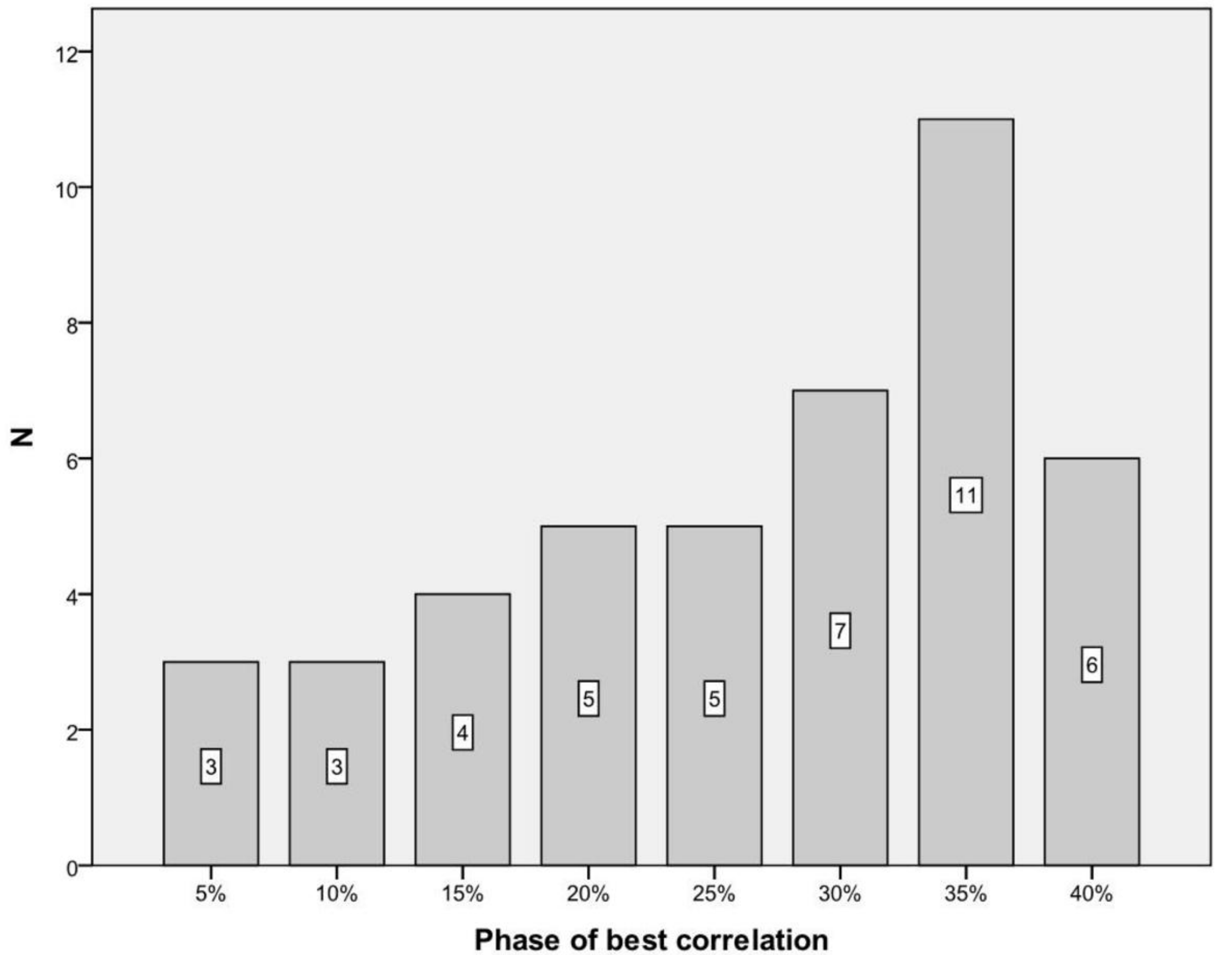

Table 1

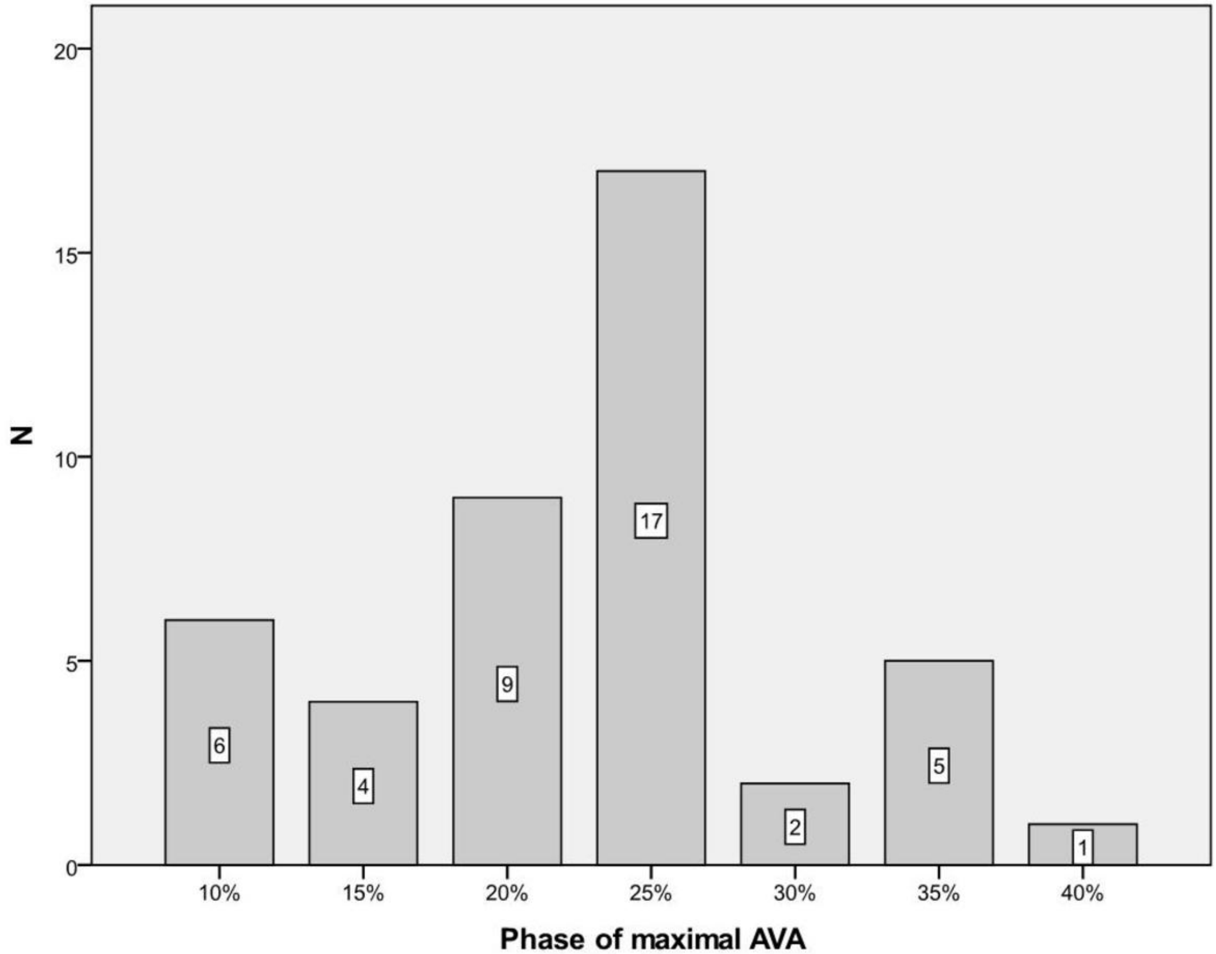

Table 2

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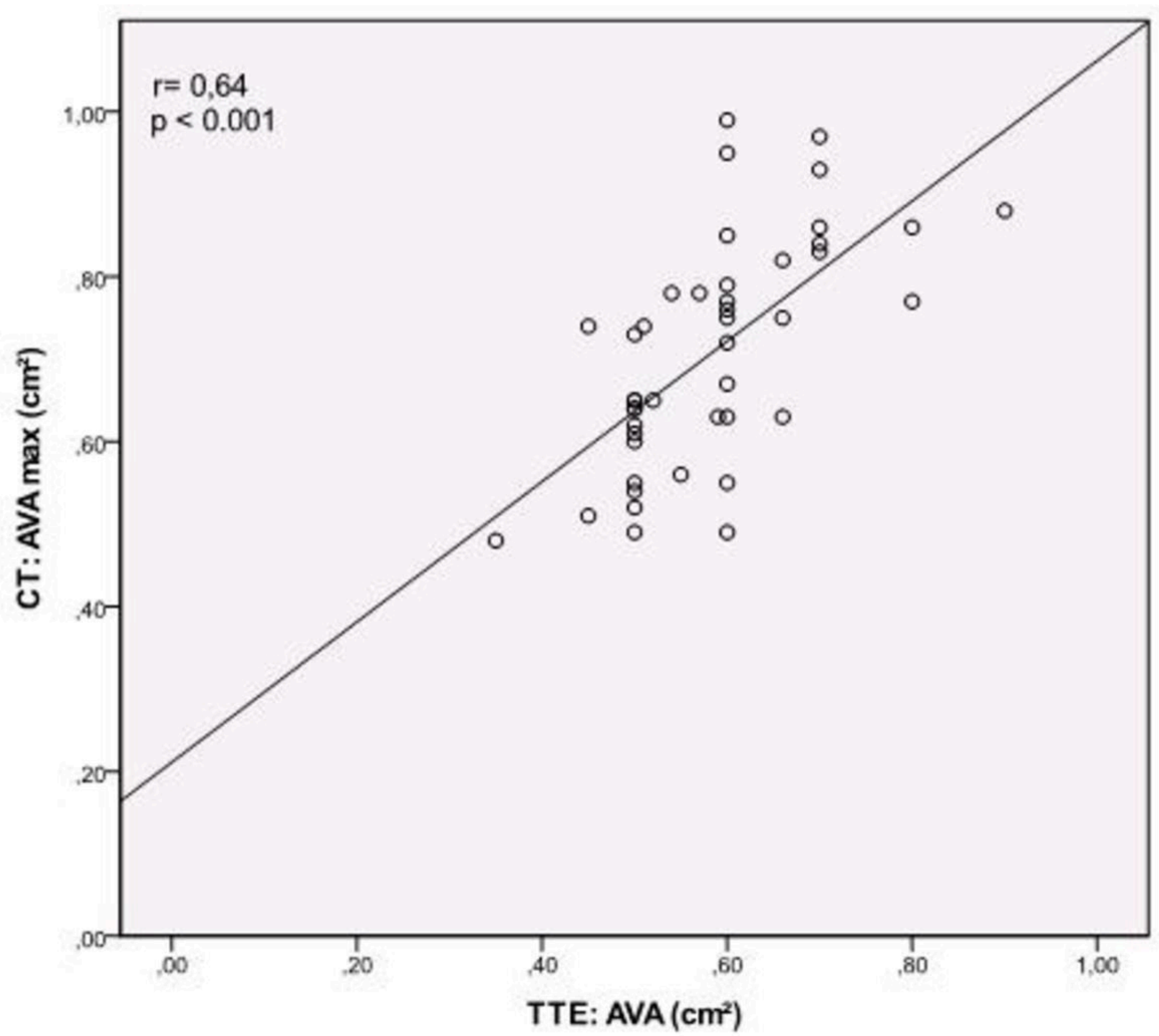
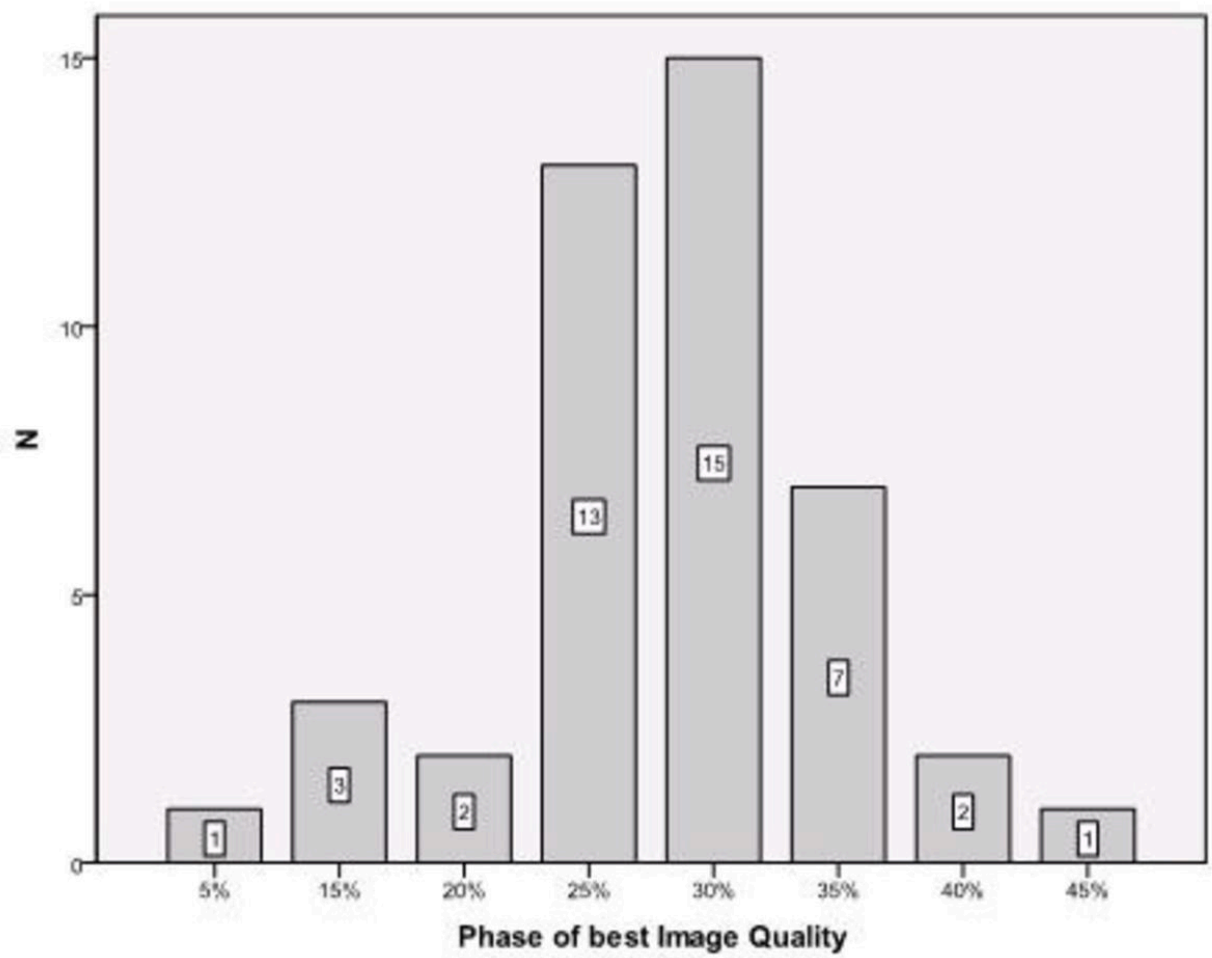

r= 0,64
p < 0.001
CT: AVA max (cm²)
TTE: AVA (cm²)
1,00
,80
,60
,40
,20
,00
,00
,20
,40
,60
,80
1,00

Table 4



15
10
5
0
N
1
3
2
13
15
7
2
1
5%
15%
20%
25%
30%
35%
40%
45%
Phase of best Image Quality

Table 3

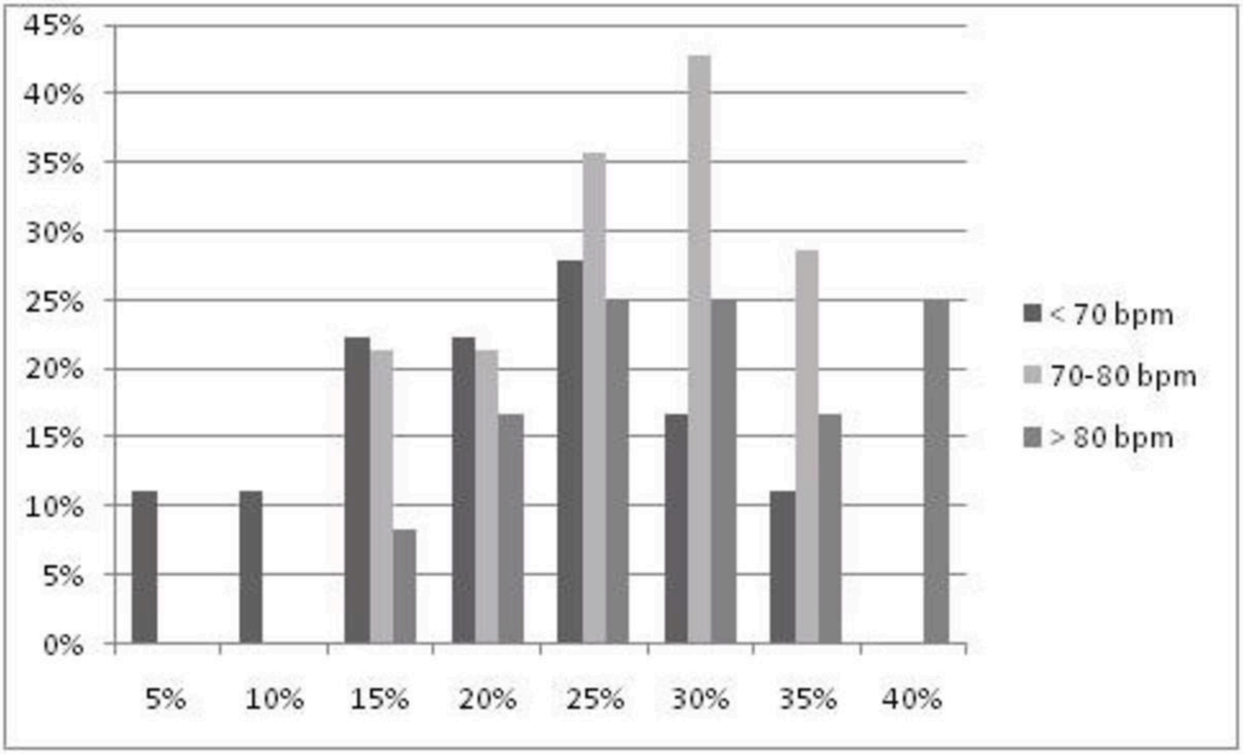


Table 5: HEART RATE DEPENDENCY OF IMAGE QUALITY IN DIFFERENT PHASES

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Conclusion

The phase with widest opening of the aortic valve was most likely to be found in early-to-mid systole at 20-25% of RR interval. This was also the interval of the cardiac cycle, where best image quality was achieved and is therefore the interval most suitable for AVA planimetry. That accords to data previously published for 16- and 64-slice CT, where 20-30% [1], 20-25% [2], 5-20% [3] and 12% [4] were suggested to be the phases of widest opening of aortic valve.

AVA_{max} showed a good correlation with AVA_{TTE} with a slight overestimation of AVA by CT. An overestimation of planimetry compared to TTE estimation was also described by several other studies and is result of a meta-analysis by Shah et al. [5] that included 437 patients from 9 studies.

The phase of best correlation between AVA measured by CT and AVA estimated by TTE was found most often at 35% of RR-interval (11/44 [25%]), which is later than the phase of maximal AVA. Thus an explanation for the systematic overestimation of AVA_{max} compared to AVA_{TTE} could be, that the flow-dependent AVA_{TTE} corresponds to a cardiac phase, later than the one used for CT-planimetry when the aortic valve is already partially closed.

Shah et al. supposed the systematic overestimation to be caused by two different aortic valve orifices, measured by CT and TTE respectively. Through the continuity equation, the "effective" orifice area is measured which is always smaller than the actual anatomic orifice because blood flow tends tostream centrally from the anatomic orifice. [5]

A limitation of this study is the fact, that AVA measurement by CT could not be compared to catheter based calculation, because not all patients included had received invasive coronary angiography. Moreover it would have been interesting, but not practicable to compare AVA measured by CT to cardiac MRI. Furthermore a lot of patients scheduled for TAVI had renal insufficiency so that they had to be excluded from CT-study.

128-slice DSCT allows direct measurement of the anatomic aortic valve area, independent from hemodynamics. Results correlate good with TTE calculations. However, cardiac CT causes a radiation exposure for the patients and requires administration of contrast medium. TTE should therefore remain diagnostic standard for AVA-quantification. However, as a cardiac CT scan is performed anyway if TAVI intervention is planned, AVA should be measured by CT in these patient additionally to TTE calculation.

References

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