Management of aortic stenosis

Usefulness of other imaging techniques

CT and MRI

David Messika-Zeitoun
Usefulness of CT and MRI

- Assessment of AS severity
- AS anatomy
- Complete workup of the heart, coronary arteries and ascending aorta
- Prognostic information
- Guide clinical management and surgical indications
Aortic Valve Area

Planimetry
Scanner
Aortic Valve Area

TEE
Computed Tomography Planimetry

- CT scan
- Iodine contrast agent
- ECG-gating
- Mid-late systolic image reconstruction
Computed Tomography Planimetry

Laissy, Heart 2007
Planimetry of Aortic Valve Area

Laissy, Heart 2007
Computed Tomography Planimetry

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>AVA echo (cm²)</th>
<th>AVA CT (cm²)</th>
<th>Correlation Coefficient</th>
<th>SD of the difference (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feuchtner</td>
<td>30</td>
<td>0.90±0.22</td>
<td>0.94±0.27</td>
<td>0.89</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6 – 1.7</td>
<td>0.6 – 1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bouvier</td>
<td>30</td>
<td>0.80±0.27</td>
<td>0.87±0.33</td>
<td>-</td>
<td>0.16</td>
</tr>
<tr>
<td>Alkadhi</td>
<td>20</td>
<td>0.83±0.33</td>
<td>0.89±0.35</td>
<td>0.95</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.4 – 1.6</td>
<td>0.44 – 1.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laissy</td>
<td>40</td>
<td>0.81±0.20</td>
<td>0.87±0.23</td>
<td>0.77</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.35 - 1.2</td>
<td>0.40 - 1.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pouleur</td>
<td>48</td>
<td>2.0±1.5</td>
<td>2.5±1.7</td>
<td>0.96</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5 – 6.1</td>
<td>0.5 – 6.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MRI Planimetry

Echo
AVA planimetry = 0.8 cm²

Echo
AVA planimetry = 1.8 cm²

cMR
AVA planimetry = 0.9 cm²

cMR
AVA planimetry = 1.7 cm²

47 patients
Avant chirurgie valvulaire
ETT – ETO – IRM
31 RAC

Aortic Valve Area

Continuity Equation
MRI
Continuity Equation

Caruthers, Circulation 2003
Aortic Valve Dimension

\[ y = 0.90x + 0.19 \]
\[ r = 0.83 \]

Bland-Altman Analysis for Aortic Valve Dimension

Caruthers, Circulation 2003
Aortic Valve Calcification
Aortic Valve Calcification

The Leading process to Aortic Stenosis
Aortic Valve Calcification (AVC)

CT is ideally suited to objectively and quantitatively assessed calcifications.
CT scanner - Acquisition

- Forty 3-mm-thick contiguous transverse slices with 3-mm table incrementation
- Covering the ascending aorta to the apex
- Acquisition triggered by electrocardiography at 80% of the RR interval (prospective ECG-gating)
- 2 independent runs
- No contrast agent
Aortic valve calcium is defined as calcification within valve leaflets, aortic annulus, or aortic wall immediately adjacent to leaflet or annular calcification.
CT Scanner – Measurements of Calcifications

- Automated operator-independent image-processing software
- Calcification are defined as 4 adjacent pixels with density 130 Hounsfield units
- Radiologist affect the selected area to the coronary arteries, the aortic valve....
The Agatston Score

For each region of interest, score = density score * area

Total score: sum of score of each region of interest in all slices

Peak density score

<table>
<thead>
<tr>
<th>Hn</th>
<th>X Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>130-199</td>
<td>1</td>
</tr>
<tr>
<td>200-299</td>
<td>2</td>
</tr>
<tr>
<td>300-399</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 400</td>
<td>4</td>
</tr>
</tbody>
</table>

Area 1 = 15 mm²
Peak CT = 350 Hn
Region 1. Score = 15 * 3 = 45

Area 1 = 30 mm²
Peak CT = 500 Hn
Region 2. Score = 30 * 4 = 120
Examples of degree of AVC

Mild AVC. Score = 200 AU

Moderate AVC. score = 800

Severe AVC. Score = 2000
(A) Mild calcification of the left coronary cusp (Volume 74 mm³, aortic valve area 2.4 cm²).

(B) Severe calcification (Volume 5044 mm³, aortic valve area 0.4 cm²)
Echocardiographic Assessment

- 100 patients prospectively evaluated by EBCT
- Aortic valve area (cm²): 1.8±0.9 (range 0.5-4.1)
- Peak aortic valve velocity (m/sec): 2.8±1.4 (range 1-6)
Relationship between AVC and Hemodynamic Severity

Aortic valve area, cm$^2$

EBCT Score

Relationship between AVC and Hemodynamic Severity

Peak aortic valve velocity, m/sec

EBCT Score

R=-0.79, p<0.0001

R=0.86, p<0.0001

Messika-Zeitoun Circulation 2004
Scanner EBCT Thresholds

Sensibilité

1 - Spécificité

Score = 500
Score = 1100
Score = 2000

AUC = 0.89
### Scanner EBCT Thresholds

<table>
<thead>
<tr>
<th>Calcium Score</th>
<th>Sensibility, %</th>
<th>Specificity, %</th>
<th>PPV, %</th>
<th>NPV, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>100</td>
<td>69</td>
<td>57</td>
<td>100</td>
</tr>
<tr>
<td>1000</td>
<td>93</td>
<td>77</td>
<td>63</td>
<td>96</td>
</tr>
<tr>
<td>1100</td>
<td>93</td>
<td>82</td>
<td>68</td>
<td>97</td>
</tr>
<tr>
<td>1200</td>
<td>86</td>
<td>82</td>
<td>66</td>
<td>94</td>
</tr>
<tr>
<td>1500</td>
<td>72</td>
<td>85</td>
<td>66</td>
<td>88</td>
</tr>
<tr>
<td>2000</td>
<td>55</td>
<td>92</td>
<td>73</td>
<td>83</td>
</tr>
</tbody>
</table>
EBCT = MSCT ?
Measurement of aortic valve calcification using multislice computed tomography: correlation with haemodynamic severity of aortic stenosis and clinical implication for patients with low ejection fraction

Caroline Cueff, Jean-Michel Serfaty, Claire Cimadevilla, Jean-Pierre Laissy, Dominique Himbert, Florence Tubach, Xavier Duval, Bernard Iung, Maurice Enriquez-Sarano, Alec Vahanian, David Messika-Zeitoun

ABSTRACT

Background Measurement of the degree of aortic valve calcification (AVC) using electron beam computed tomography (EBCT) is an accurate and complementary method to transthoracic echocardiography (TTE) for assessment of the severity of aortic stenosis (AS). Whether threshold values of AVC obtained with EBCT could be extrapolated to multislice computed tomography (MSCT) was unclear and AVC diagnostic value in patients with low ejection fraction (EF) has never been specifically evaluated.

Methods Patients with mild to severe AS underwent prospectively within 1 week MSCT and TTE. Severe AS was defined as an aortic valve area (AVA) of less than 1 cm². In 179 patients with EF greater than 40% (validation set), the relationship between AVC and AVA was evaluated. The best threshold of AVC for the diagnosis of severe AS was then evaluated in a second subset (testing set) of 49 patients with low EF (≤40%). In this subgroup, AS severity was defined based on mean gradient, natural history or dobutamine stress echocardiography.

Results Aortic valve calcification (AVC) using electron beam computed tomography (EBCT) has previously been validated as a complementary method for the evaluation of AS severity. However, whether thresholds defined

continuity equation. According to current recommendations, severe AS is defined as an AVA less than 1 cm² (or 0.6 cm²/m² of body surface area), an MPC greater than 40 or 50 mm Hg and a peak aortic velocity greater than 4.0 m/s. However, echocardiographic evaluation of AS severity may be technically challenging in patients with poor echocardiographic windows such as obese patients or patients with severe chronic obstructive pulmonary disease. Furthermore, in patients with depressed EF and low-flow/low-gradient (LF/LG) AS, transthoracic echocardiography (TTE) at rest is not conclusive requiring additional testing such as dobutamine stress echocardiography (DSE) to differentiate severe from pseudo-severe AS.

Aortic valve calcification (AVC) is the leading process to aortic valve stenosis. Measurement of the degree of AVC using electron beam computed tomography (EBCT) has previously been validated as a complementary method for the evaluation of AS severity. However, whether thresholds defined
AVA : AUC=0.86

MPG: AUC=0.92

AVAi : AUC=0.9

MPV : AUC=0.9
## Scanner MSCT Thresholds

<table>
<thead>
<tr>
<th>Calcium score</th>
<th>Sensibility, %</th>
<th>Specificity, %</th>
<th>PPV, %</th>
<th>NPV, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>100</td>
<td>31</td>
<td>46</td>
<td>100</td>
</tr>
<tr>
<td>700</td>
<td>98</td>
<td>49</td>
<td>49</td>
<td>98</td>
</tr>
<tr>
<td>1000</td>
<td>94</td>
<td>65</td>
<td>55</td>
<td>94</td>
</tr>
<tr>
<td>1200</td>
<td>91</td>
<td>65</td>
<td>59</td>
<td>92</td>
</tr>
<tr>
<td><strong>1651</strong></td>
<td><strong>82</strong></td>
<td><strong>80</strong></td>
<td><strong>70</strong></td>
<td><strong>88</strong></td>
</tr>
<tr>
<td>2000</td>
<td>62</td>
<td>86</td>
<td>72</td>
<td>79</td>
</tr>
<tr>
<td>3000</td>
<td>57</td>
<td>91</td>
<td>74</td>
<td>72</td>
</tr>
</tbody>
</table>
Clinical Implications

- Discrepancies between symptoms and echocardiographic measurements
- Poor echogenicity
- Low gradient – low output
Dobutamine up to 20 μg/kg/min

- **Contractile reserve**
  - Final AVA < 1 cm²
  - AVA increase < 0.3 cm²
    - Severe AS

- **Contractile reserve**
  - Final AVA > 1 cm²
  - AVA increase ≥ 0.3 cm²
    - Pseudo-severe AS

- **No contractile reserve**
  - (SV increase < 20%)
    - Non conclusive test

---

Monin Circulation; 108: 319-324
47 patients with Low EF

EF ≤ 40%
47 patients

MG > 40 mmHg
AVA < 1 cm²
Severe AS
24 patients

MG ≤ 40 mmHg
AVA < 1 cm²
Low gradient / Low Output
20 patients

MG ≤ 40mmHg
AVA ≥ 1 cm²
Non Severe AS
5 patients

Severe AS
14 patients

Non Conclusive AS
2 patient

Pseudo Severe AS
4 patients

Cueff Heart 2011
Case 1

- 72 years old lady
- Weight 80 kg
- Length 160 cm
- BSA 1.8 m²

Symptoms
- NYHA class III
- No Angina

Medical history
- Coronary artery disease with 70% lesion on RCA
- Chronic atrial fibrillation
TTE

- Normal EF with LVH
- LVOT diameter 22 mm
- CO 2.5 l/min
- Mean gradient 30 mm Hg
- Peak velocity 3.4 m/sec
- AVA 0.70 cm²
- SPAP 35 mm hg
Aortic Valve Calcification

Calcium score = 4300
Severe AS with paradoxical low flow
Case 2

- 86 years old lady
- Weight 50 kg
- Length 155 cm
- BSA 1.4 m²
- Symptoms
  - NYHA class III but COPD
  - No Angina
- Sinus rhythm
TTE

- Normal EF with LVH
- LVOT diameter 19 mm
- CO 4.1 l/min
- Mean gradient 40 mm Hg
- Peak velocity 4.0 m/sec
- AVA 0.75 cm$^2$ / 0.53 cm$^2$/m$^2$
- SPAP 45 mm hg
Small Aorta

23 mm

ELI 0.90 cm² / 0.65 cm²/m²
Aortic Valve Calcification

Calcium score = 410
Moderate AS
Overestimation of the gradient due to pressure recovery phenomenon
Prognostic value of AVC
Echocardiographic assessment

Event free survival (%)

No or mild calcification

Moderate or severe calcification

P<0.0001

Rosenhek NEJM 2000
Echocardiographic Evaluation of Aortic Valve Calcification

- None
- Mild: isolated spots
- Moderate: Multiples spots
- Severe: Large and diffuse calcifications

Classification
Subjective and inaccurate

\[ \kappa = 0.60 \]

-1 class
Identical
+1 class

%
Prognostic value of AVC EBCT assessment

AVC and hemodynamic severity provide complementary prognostic information

Messika-Zeitoun Circulation 2004
AVC and Hemodynamic Severity are Not Equivalent

Aortic valve area, cm$^2$

EBCT Score

Peak aortic valve velocity, m/sec

R=-0.79, p<0.0001

R=0.86, p<0.0001

Messika-Zeitoun Circulation 2004
Other Information
Bicuspid vs. Tricuspid aortic valve
Coronary Arteries

Mollet JACC 2004
<table>
<thead>
<tr>
<th></th>
<th>Gilard</th>
<th>Reant</th>
<th>Laissy</th>
</tr>
</thead>
<tbody>
<tr>
<td>N of patients</td>
<td>55</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Prevalence of coronary stenosis (coronary angiogram)</td>
<td>20</td>
<td>32.5</td>
<td>33</td>
</tr>
<tr>
<td>Sensibility, %</td>
<td>100</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Specificity, %</td>
<td>80</td>
<td>78</td>
<td>93</td>
</tr>
<tr>
<td>Positive predictive value, %</td>
<td>55</td>
<td>67</td>
<td>85</td>
</tr>
<tr>
<td>Negative predictive value, %</td>
<td>100</td>
<td>96</td>
<td>93</td>
</tr>
</tbody>
</table>
LV Volumes and Ejection Fraction

CT

MRI

![Graphs showing correlations between CT and MRI measurements of LV volumes and ejection fraction](image)

Juergens Radiology 2004
TAVI Measurement of the Aortic Annulus
TTE vs. TEE vs. CT

Messika-Zeitoun JACC 2010
Aorte Ascendante
Impact of Myocardial Fibrosis in Patients With Symptomatic Severe Aortic Stenosis

Frank Weidemann, MD*; Sebastian Herrmann*; Stefan Störk, MD; Markus Niemann, MD; Stefan Frantz, MD; Volkmar Lange, MD; Meinrad Beer, MD; Stefan Gattenlöchner, MD; Wolfram Voelker, MD; Georg Ertl, MD; Jörg M. Strotmann, MD

Background—In this prospective follow-up study, the effect of myocardial fibrosis on myocardial performance in the clinical outcome, they may prove valuable for preoperative risk assessment in patients with aortic stenosis. (Circulation. 2009;120:577-584.)
Impact of Myocardial Fibrosis in Patients With Symptomatic Severe Aortic Stenosis

Frank Weidemann, MD; Sebastian Herrmann; Stefan Störk, MD; Markus Niemann, MD; Stefan Frantz, MD; Volkmar Lange, MD; Meinrad Beer, MD; Stefan Gattenlöhrner, MD; Wolfram Voelker, MD; Georg Ertl, MD; Jörg M. Strotmann, MD

Background
In symptomatic patients with severe aortic valve stenosis, symptoms may improve after aortic valve replacement (AVR).

Methods
We performed extensive transthoracic and transesophageal echocardiography, magnetic resonance imaging, and computed tomography in 22 patients who underwent AVR. NYHA functional classes were assessed at baseline and 9 months after AVR.

Conclusion
Symptomatic improvement was noted in patients with severe NYHA Class III fibrosis and died in patients with severe NYHA Class IV fibrosis. Circulation. 2009;120;1415-1421.
Midwall Fibrosis Is an Independent Predictor of Mortality in Patients With Aortic Stenosis

Marc R. Dweck, MD,*† Sanjiv Joshi, MD,* Timothy Murigu, BSc,* Francisco Alpendurada, MD,* Andrew Jabbour, MD,* Giovanni Melina, MD,* Winston Banya, MSc,* Ankur Gulati, MD,*‡ Isabelle Roussin, MD,* Sadaf Raza,* Nishant A. Prasad,* Rick Wage, BSc,* Cesare Quarto, MD,* Emiliano Angeloni, MD,* Simone Refice, MD,* Mary Sheppard, MD,* Stuart A. Cook, MD, PhD,* Philip J. Kilner, MD, PriD,*‡ Dudley J. Pennell, MD,*‡ David E. Newby, MD, DSc,*† Raad H. Mohiaddin, MD,*‡ John Pepper, MD,* Sanjay K. Prasad, MD*‡

London and Edinburgh, United Kingdom
Conclusion

- CT and MRI are complementary but second lines methods for the assessment of AS severity (planimetry or continuity equation)
- Measurement of the degree of aortic valve calcification is useful in difficult situations such as
  - Patients with depressed ejection fraction and low gradient
  - Paradoxical low flow low gradient AS
  - Pressure recovery
Conclusion

- Degree of aortic valve calcification provides independent prognostic information but prognostic thresholds need to be defined
- CT and MRI provides a complete evaluation of the heart, coronary arteries and ascending aorta
- Prognostic value of myocardial fibrosis seems promising
Thank you