Quantification of abdominal aortic calcification: inherent measurement errors in current computed tomography imaging

Clark Zeebregts

Professor of Vascular Surgery
University Medical Center Groningen
Department of Surgery
Division of Vascular Surgery
Groningen, The Netherlands
Disclosure of Interest

Speaker name: Clark Zeebregts

• I have the following potential conflicts of interest to report:
  – Consulting: Terumo Aortic (Vascutek)
  – Other(s): Received research grants from W.L. Gore & Associates, LeMaitre Vascular, Atrium Maquet Getinge Group, and Cook Medical
Coronary calcification

B

Coronary-artery calcium score

- >300
- 101–300
- 1–100
- 0

Cumulative Incidence of Coronary Events (%)

Years to Event

Coronary calcification as a predictor of coronary events in four racial or ethnic groups. N Engl J Med 2008; 358: 1336-45.
Abdominal aortic calcification (AAC)

- Burden of aortic calcification correlates with the degree of atherosclerosis in other arteries.

- AAC is an independent predictor for cardiovascular disease.

- AAC can be detected by conventional x-ray, CT, but also with DEXA technique.

Clearly visible entity on CTA
Calcification and cardiovascular risk

Calcification in the AAA wall

Protection  Degeneration
Population & methods

• Population:
  – Elective AAA; n = 129
  – Symptomatic, non-ruptured AAA; n = 28
  – Ruptured AAA; n = 73

• Calcification measurements:
  – AAC-8 score
  – Visual calcification grading tool
Results: 95%-CI error bar

Diameter

Calcification score
## Results: multivariate analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>P-value</th>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (♀)</td>
<td>0.02</td>
<td>4.12</td>
<td>1.25 - 13.57</td>
</tr>
<tr>
<td>Diameter</td>
<td>&lt; 0.001</td>
<td>1.05</td>
<td>1.03 - 1.08</td>
</tr>
<tr>
<td>AAC-8 score</td>
<td>&lt; 0.001</td>
<td>1.38</td>
<td>1.18 - 1.61</td>
</tr>
</tbody>
</table>
Calcification quantification

• Semi-quantitative
  – AAC-8/24 score
  – Agatston score
  – % of aortic circumference

• Fully quantitative
  – Volume
  – Mass

• No clinical research on reliability of quantification tools
Phantom analysis - study design

- Two scanning protocols
  - Cardiac
  - Abdominal

- Two endpoints
  - Mass
  - Volume

- Five CT scans/protocol
  - 2-5 mm random movement between scans

- Two measurement tools
  - Aquarius iNtuition
  - 3Mensio Structural Heart

- Nine different calcium elements
  - Pre-established mass and volumes
Phantom analysis - results

• Abdominal versus cardiac protocol (mass):
  – Actual calcium mass:
    • 0.16 mg
  – Measured calcium mass:
    • $0.84 \pm 1.02$ versus $1.24 \pm 1.38$ mg, $p < .05$

• Mass measurements:
  – Between 39% underestimation and 1538% overestimation.

• Volume measurements:
  – Between 30% and 316% overestimation.

• Smaller calcium spots, higher error margin
Influence of contrast - study design

- Multi-phase CT scans
  - 50 clinical patients
  - Random selection
  - >65 years old
  - No implants in scanning area

- Non-enhanced versus contrast-enhanced
  - Subsequent scans within 30 minutes
  - Calcium volume and mass measurements
  - Three HU thresholds for calcium
    - 130, 299 & patient-dependent
Influence of contrast - results

- Non-enhanced versus contrast-enhanced calcium quantification:
  - Volume ($\text{mm}^3$): $1640 \pm 1917$ versus $2022 \pm 2469$, $p < .05$)
  - Mass (mg): $1174 \pm 1288$ versus $1005 \pm 1337$, $p < .05$)
Calcium measurements tools: summary

- Aortic calcium volume and mass measurements are grossly erroneous and highly variable.

- Further worsening of the error margin for:
  - Smaller, lower weight calcium spots
  - In the presence of contrast

- Calcification measurement tools based on cardiac protocol measurements are non-representative.

- Measuring calcifications under contrast-enhanced conditions greatly impacts reliability.

- Not one currently used scoring tool for aortic calcification is demonstrably unaffected by the abovementioned issues.
Conclusions

• AAA diameter: insufficient

• Role of calcification: ambiguous

• Clinical value: promising

• Before further implementation harmonize scanning protocols and software packages
Acknowledgements

Ruben Buys
Reza Golestani
Eva Leemans
Tineke Willems
Hendrikus Boersma
Riemer Slart
Maarten van der Laan
Ben Saleem
Paul van Schaik
Jean-Paul de Vries
Bas Wallis de Vries
Ignace Tiellieu

Thank you for your attention and welcome to ESCVS 22-25 May 2019 in Groningen!