To Tell the Truth: “Will the Real Measurement Please Stand Up?”

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Disclosures

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Speaking Bureau / Teaching
Asked for Clarification of the Topic

- “Is measuring off of 3D reconstruction accurate or do we need to use MPRs?”
- “Do we need 2D angio also to get pulsatility?”
- “Which is the "real" measurement?”
- ‘Is 3D "good enough” ’
Cardiovascular Quantification
3-DRA Reconstruction

Is This Real

Quick Measurement 1: 9.30 mm
Quick Measurement 2: 12.42 mm
Quick Measurement 3: 8.80 mm
Is This Real

Cardiovascular Quantification
3-DRA Reconstruction
Cardiovascular Imaging
Quantitative Analysis

• QA: “Examination of measurable and verifiable data”

• Requirements in CV QA
  – Clear visualization of structures of interest
    • Spatial resolution
    • Temporal resolution
  – Impact of 2D vs. 3D datasets
  – Measurement tools
    • Accurate
    • Reproducible
    • Simple to use
Cardiovascular Imaging

- **Spatial resolution**: “Ability of the imaging modality to differentiate between two objects”
- **Temporal resolution**: ”Duration of time for acquisition of a single frame of a dynamic process”

### Table 1

<table>
<thead>
<tr>
<th>Imaging Method</th>
<th>Spatial resolution (FWHM), mm</th>
<th>Contrast resolution</th>
<th>Temporal resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>0.5-0.625</td>
<td>Low to moderate</td>
<td>83-135 ms</td>
</tr>
<tr>
<td>MRI</td>
<td>1-2</td>
<td>High</td>
<td>20-50 ms</td>
</tr>
<tr>
<td>Catheter angiography</td>
<td>0.16</td>
<td>Moderate</td>
<td>1-10 ms</td>
</tr>
<tr>
<td>PET</td>
<td>4-10</td>
<td>Very high, varies†</td>
<td>5 s to 5 min</td>
</tr>
<tr>
<td>SPECT</td>
<td>4-15</td>
<td>Very high, varies†</td>
<td>15 min</td>
</tr>
<tr>
<td>Echocardiography</td>
<td>~0.5-2†</td>
<td>Low to moderate</td>
<td>&gt;200 frames/s (&lt;5 ms)</td>
</tr>
</tbody>
</table>

*Radiopaedia.org*  
Cardiovascular Imaging
Quantitative Analysis

• 2-Dimensional datasets
Cardiovascular Imaging
Quantitative Analysis

• 2-Dimensional datasets
Cardiovascular Imaging
Quantitative Analysis

• 3-Dimensional datasets (Not 3-D reconstruction)

Courtesy of Brian Fonseca, MD
Cardiovascular Quantification
“For The Interventionalist”

• Interventionalist’s perspective
  – Standards for measurement derived from stationary projection angiography
  – Management decisions based on largest dimension of the cardiovascular structure of interest
    • Systole for arteries and valves
    • Diastole for VSD
Cardiovascular Quantification
“For The Interventionalist”

• Echocardiography
  – Advantages
    • Very high temporal and reasonable spatial resolution
    • Readily obtainable
    • Measurement tools facile and accurate
  – Disadvantages
    • 2-Dimensional imaging
Cardiovascular Quantification
“For The Interventionalist”

• cMR / CT
  – Advantages
    • High spatial and acceptable temporal resolution
    • 3-Dimensional dataset imaging
    • Measurement tools facile and accurate
  – Disadvantages
    • Non-gated or gated to diastole
Cardiovascular Quantification
“For The Interventionalist”

• Static projection digital cineangiography ("Planimetry")
  – Advantages
    • It is our “gold standard”
    • Extremely high spatial resolution and high temporal resolution
    • Can choose specific point in cardiac cycle
    • Measurement tools facile and accurate (Auto-calibration*)
  – Disadvantages
    • 2-Dimensional quantification*
    • Area obscured by other contrast filled structures
    • Calibration (object of known dimension) may be required
Cardiovascular Quantification
Static Projection Angiography

- 2-Dimensional Quantification
Cardiovascular Quantification
3DRA Reconstruction

- 3-Dimensional image dataset
- High spatial resolution but low temporal resolution
- Overcomes some limitations of static angiography

- Tetralogy of Fallot with RPA Stenosis

Cardiovascular Quantification
3-DRA Reconstruction

• Signal averaged image dataset

• Window leveling
Commandment of Imaging
Quantification

Thou shalt not make measurements from 3-dimensional reconstructions!
Commandment of Imaging
Quantification

Thou shalt not make measurements from 3-dimensional reconstructions!
Cardiovascular Quantification
3DRA Multiplanar Reformat

- 3-Dimensional image dataset

- Signal averaged imaging
Cardiovascular Quantification
3DRA Multiplanar Reformat

- Window leveling
Cardiovascular Quantification
3DRA Multiplanar Reformat

- Found correlation MPR and static angiograms (n= 33 studies)
  - RPA: correlation coefficient 0.94 (P <0.001)
  - LPA: correlation coefficient 0.97 (P < 0.001)
- Alignment of MPR vessels with angio projections not performed*
- CPCs; non-pulsatile vessels and some paced
  - Expect to correlate better than in pulsatile vessels

*3DRA …oblique angulations that best profiled the vessel of interest
• Studied correlation MPR and static angiograms (n= 25 studies)
  – Branch PA measurements correlated well
  – SVC and prox RPA: poor to moderate correlation
• Alignment of MPR vessels with angio projections not specified*
• CPCs; non-pulsatile vessels
  – Expect to correlate better than in pulsatile vessels

* using two-dimensional tomographic slices created by the intersection of the parallel and perpendicular planes at each reference point.
Cardiovascular Quantification
3DRA Multiplanar Reformat

Table 2 Correlation between measurements on 3DRA-derived tomographic images and 2D angiography

<table>
<thead>
<tr>
<th>Vessel</th>
<th>2D angiography (mm)</th>
<th>3DRA (mm)</th>
<th>Correlation coefficient (r)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal LPA</td>
<td>9.6 ± 2.3</td>
<td>9.6 ± 1.7</td>
<td>0.81</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Narrowest LPA</td>
<td>7.7 ± 2.5</td>
<td>8.0 ± 2.1</td>
<td>0.89</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Distal LPA</td>
<td>7.7 ± 2.5</td>
<td>7.8 ± 2.0</td>
<td>0.83</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Proximal RPA</td>
<td>10.0 ± 1.8</td>
<td>10.2 ± 1.7</td>
<td>0.28</td>
<td>0.30</td>
</tr>
<tr>
<td>Distal RPA</td>
<td>8.7 ± 1.4</td>
<td>8.5 ± 1.6</td>
<td>0.75</td>
<td>0.001</td>
</tr>
<tr>
<td>SVC</td>
<td>11.4 ± 2.1</td>
<td>12.4 ± 1.9</td>
<td>0.50</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Measurements listed as mean ± standard deviation

Abbreviations as in Table 1: RPA right pulmonary artery, SVC superior vena cava

Borik, Pediatr Cardiol. 2015 Jun;36(5):1083-9
Cardiovascular Quantification
3DRA Multiplanar Reformat

- Pulsatile vessels:
  - Image blur may represent systolic dimensions
  - Alignment of vessels with control imaging cumbersome
Assessed correlation of static projection angiograms to MIP (n=60 pts)
- Location of aortic measurement
- Correlated angulation of MIP to the aortic arch projection
- Both systolic and diastolic angio aortic diameters
- Controlled window leveling of the MIP images
Cardiovascular Quantification
3DRA Maximal Intensity Projections

• Window leveling
Cardiovascular Quantification
3DRA Maximal Intensity Projections

Stenger, Pediatr Cardiol. 2016 37; 528-36
Correlation of measurements (n = 60)

\[(r = 0.99 \text{ after Pearson, } p < 0.0001)\]

Stenger, *Pediatr Cardiol*. 2016 37; 528-36
“Our optimized measurement methodology is likely to be a reason for (the high correlation) result. Also the variation in vessel diameter between systole and diastole of about 6% appears clinically not relevant.”

“Thus, we assume that quantitative 3D vessel measurements are of at least similar precision as measurements taken with conventional 2D angiographies.”

Stenger, Pediatr Cardiol. 2016 37; 528-36
Cardiovascular Quantification
3DRA – Original Question

• Is quantification from 3DRA reconstructions “accurate”?
  – Reliability questionable!

• Is quantification from 3DRA “adequate”?
  – We need further study
  – Reasonable studies can be undertaken; esp. MPR and MIP
Cardiovascular Quantification
3-DRA Reconstruction
Cardiovascular Quantification
3-Dimensional Rotational Angiography
A Current Strategy

- 3DRA performed
- Use 3DRA reconstruction and MPR
  - Anatomical diagnostics*
  - Define optimal projection for further work
- QA performed on rotational angiogram if adequate projection (calibration)
- If RA not adequate, QA performed on “optimized” angiogram

Aldoss, Pediatr Cardiol. 2016 Oct;37(7):1211-21
Quantification can be performed on rotational angiograms if calibration adequate

MPR and MIP may be useful but requires further investigation and different clinical settings

There may be a potential roll for quantification of 3DRA reconstructions, but there are significant hurdles to overcome
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tfagan1@uthsc.edu
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