Post-processing of CT and MRI

Dr. Ir. P.M.A. van Ooijen
Contents

• Post-processing
  – Coronary calcification
  – Coronary stenosis detection and measurement
  – Coronary plaque imaging
  – Heart chambers
  – Valves and Function
  – Late Enhancement
Post-processing
Coronary calcification

EBT Calcium Score (threshold >130HU)
Post-processing
Coronary calcification

- Agatston Score
- Volume Score
- MASS Score

- Different algorithms, but all based on the segmentation of calcified lesions with certain parameters:
  - Settings unknown
  - Sometimes (partly) configurable
  - Never recorded during evaluation
Post-processing

Coronary calcification

• Different software implementations for the quantification of coronary artery calcium load may display diagnostically relevant differences in spite of close direct correlation.

• If possible, record the parameters used with your scoring results

• Use both Agatston and volume results for the best analysis

• Do not compare results found in a patient with previous results without careful analysis

• Try to remain using the same workstation instead of switching between different workstations


Post-processing
Coronary stenosis detection and measurement

Basic steps in post-processing of the coronary arteries:

- segmentation of the heart,
- detection of the origins or locations of the coronary arteries
- segmentation of the coronary arteries and
- evaluation of stenotic lesions and/or stents.
Post-processing
Coronary stenosis detection and measurement

Fully automatic detection and measurement

Image courtesy: Vital Images

Image courtesy: TeraRecon, Inc.
Post-processing
Coronary stenosis detection and measurement

CT measurement validated against QCA and IVUS showing a close correlation

Ferencik et al. AJC 2003
Post-processing
Coronary stenosis detection and measurement

Vessel selective visualization is possible for most coronary datasets and requires approximately 1-3 minutes for full segmentation of all three major branches depending on the image quality of the acquisition.

Pitfalls are found in the apparent stenoses introduced by different artefacts.
Post-processing
Coronary stenosis detection and measurement

The algorithms used also have many difficulties with segmentation of stents and other high contrast structures (e.g. calcified plaques). Static instead of dynamic viewing of reconstructions could complicate correct interpretation. Overlapping veins can also cause incorrect segmentation.
Post-processing
Coronary stenosis detection and measurement

Image courtesy: Vital Images

University Medical Center Groningen, University of Groningen, Dept. of Radiology, The Netherlands
Post-processing
Coronary stenosis detection and measurement
Post-processing
Coronary stenosis detection and measurement
Post-processing
Coronary stenosis detection and measurement

Again apparent stenosis in automatic vessel segmentation (A), probably caused by the motion artefacts in the scan (yellow arrow in B).
Post-processing
Coronary stenosis detection and measurement

Contrast enhanced coronary CTA without saline chasing.
Streak artefact from dense contrast material in the right heart overlies the RCA and causes false positive stenosis of the proximal RCA.

Post-processing
Coronary stenosis detection and measurement

- Practical tips for post-processing:
  - Review different phase images to determine optimum reconstruction with least artefact; 3D volume rendering is helpful.
  - Late diastole (75% to 85% of R-R interval) is phase of least cardiac motion for most coronary artery segments.
  - 45% often best for right coronary artery.
  - Review axial data first, then optimize use of multiplanar reformation and vessel analysis software.
  - Functional information may require more phases.

Post-processing
Coronary stenosis detection and measurement

• Comparison of 40 patients (30 men, mean age 56 years +/- 8; mean heartrate 61 bpm +/- 6) using 16-MDCT analysed with:
  – exclusively transverse images,
  – free oblique multiplanar reconstructions (MPRs),
  – free oblique maximum intensity projections (MIPs, 5 mm thick),
  – Prerendered curved MPRs,
  – prerendered curved MIPs, or
  – Prerendered three-dimensional volume rendered reconstructions (VRTs).

• Accuracy was significantly higher for oblique MPR than for curved MPR ($P = .01$), curved MIP ($P = .03$), and VRT ($P < .001$).

Post-processing
Coronary stenosis detection and measurement

• “The evaluation of multi-detector CT coronary angiography with interactive image display methods, especially interactive oblique MPRs, permit higher diagnostic accuracy than evaluation of prerendered images (curved MPR, curved MIP, or VRT images)”
• “Interactive evaluation of multidetector CT coronary angiography data sets on a workstation should thus be the preferred way of interpretation”

Post-processing
Coronary plaque imaging
Post-processing
Coronary plaque imaging

• Total plaque burden, which would include vulnerable plaque, could provide a superior indicator for coronary risk assessment.

• MDCT plaque appearances are mainly compared with IVUS or pathology and characterized using attenuation values:

• Overlap between predominantly lipid-containing lesions and fibrous coronary lesions exists.
Post-processing
Coronary plaque imaging

• Evaluation of presence or absence of atherosclerotic disease is best performed initially using the axial images.
• Wide CT window settings are required (width 1500 HU, centre 300 HU) as narrow windowing increases image noise and grey scale differentiation of fine detail structures may be lost.
• Dynamic Curved MPR useful for illustrating stenotic plaques

Figure 2. Curved vessel reformation showing: (1) soft plaque, (2) calcified plaque, (3) mixed morphology plaque (predominantly soft). There is evidence of positive arterial remodelling (preserving of lumen diameter).

Post-processing
Coronary plaque imaging

Image courtesy: Vital Images

Vessel Area: 11.3mm²
Wall/Lumen Ratio (Area): 317.3%
Plaque burden: 76.0%

<table>
<thead>
<tr>
<th>Plaque1</th>
<th>Plaque2</th>
<th>Calcium</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>50:49</td>
<td>50:149</td>
<td>150:1500</td>
<td></td>
</tr>
</tbody>
</table>

| Area (mm²) | 2.6 | 5.1 | 0.9 | 8.5 |
| Area (%)   | 30.4| 59.5| 10.1| 100 |
| Mean (HU)  | 34  | 92  | 150 |     |
| SD (HU)    | 10  | 28  | 9   |     |

Cardiac: 51.64 T
VITAL15110SFO2: C.3600
Age: 36
M

Image courtesy: Vital Images
Post-processing
Coronary plaque imaging

• Different publications provide different subdivisions of soft plaque, intermediate plaque and calcified plaque making it difficult to determine which subdivision to use.

• No real clinical application possible yet.
Post-processing

Valves
Post-processing
Valves
Post-processing
Global ventricular function

• Volumetric dimensions of the ventricle
  – End-systolic and end-diastolic volume
• Stroke volume, ejection fraction
  \[ E_f = \frac{SV}{EDV} = \frac{EDV - ESV}{EDV} \]

• LV mass
• Filling/ejection parameters
LV functional parameter assessment

- Consecutive SA slices
- Cine SSFP
- Base to apex
- No geometrical assumptions
- Post-processing software for quantification
- Epi-and endocontours in ES and ED
Post-processing
Global function assessment – Area-length method

- Quantitative assessment

Area - length method: fast, but geometrical assumptions

\[ V = \frac{\pi}{6} LD^2 \]
Post-processing
Global function assessment - Long-axis approach

- Fast
- Clear visualization of base and apex
- Volume calculation based on assumption of an elliptical geometry
- Needs accurate image planning
- Highly automated
Post-processing
Global function assessment - Long-axis approach

- 3 landmarks defined manually
- Endo contour detected automatically

→ EF: 20%
Post-processing
Volume assessment from multi-slice short-axis MRI

- Simpson’s method: “cutting” object into thin slices

\[ LV_{Vol} = \sum A_N \times S. \]

- No geometrical assumptions needed
- Relative insensitive to slice orientation
- Volume obtained by slice summation
- Many images to process/review
Post-processing
Volume assessment from multi-slice short-axis MRI
Post-processing
Automated contour detection MR

• Needed to reduce post-processing time
• Various approaches
• Based on gray values and edges in the images
• Modeling required to deal with complexity of the problem: variation in image/patient characteristics
• Manual contour tracing is still the ‘gold’ standard
Post-processing
Automated contour detection CT

- **Threshold-based volumetric method: sum of voxels exceeding a predefined attenuation threshold**
Semi-automated Segmentation

- Manually determine ED and ES phases
- Automatic segmentation of left ventricle (HU)
- Some cases manual setting mitral valve & localising LV needed
- Endo-epicardial contours automatically drawn
Automatic Segmentation

- Fully automatic
- Manual adjustments:
  - mitral valve & apex plane
  - LV axis
  - endo- and epicardial contours
- Automatic segmentation of LV bloodpool (HU)
# Results

<table>
<thead>
<tr>
<th>MRI</th>
<th>Mean EF ± SD</th>
<th>Mean difference ± SD</th>
<th>Limits of agreement</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens</td>
<td>63 ± 10</td>
<td>5 ± 5%</td>
<td>± 9.9%</td>
<td>0.88</td>
</tr>
<tr>
<td>Vitrea</td>
<td>64 ± 10</td>
<td>7 ± 5%</td>
<td>± 9.1%</td>
<td>0.90</td>
</tr>
<tr>
<td>TeraRecon</td>
<td>61 ± 10</td>
<td>3 ± 5%</td>
<td>± 13.0%</td>
<td>0.80</td>
</tr>
</tbody>
</table>
Post-processing
Factors influencing accuracy, precision and reproducibility

- Image quality
- Slice position
- Slice thickness and gap
- Image segmentation, papillary muscles
- Basal slice level
Post-processing
Factors influencing accuracy, precision and reproducibility

Volume of papillary muscles ~6.5% ±1.3 % of EDV
When included in LV blood pool (I):
• EDV ↑, ESV ↑, SV =, LV Mass ↓
• Accurate regional wall thickness measurements
• Better observer agreement
• Analysis time ↓
Post-processing
Factors influencing accuracy, precision and reproducibility

Through-plane motion: 1 - 2 cm in normal ventricles
Contribution basal slice ~ 10-15% of total volume
Post-processing
Quantification of regional myocardial function

• Detection and quantification of regional wall motion abnormalities
• Assessment of regional response to stress/exercise
Post-processing
Quantification of regional myocardial function

• Cine-MRI
  – wall motion
  – thickening / thinning
• Tagging
  – Myocardial strain
• Velocity-encoded cine MRI
Post-processing
Quantification of regional myocardial function

Centerline method
Method to compute displacement of points between two contours
Used for:
• Regional wall motion
  – Compare ED-ENDO and ES-ENDO
• Regional wall thickness/thickening
  – Compare ENDO and EPI for ED and ES
Post-processing
Quantification of regional myocardial function

Radial versus centerline method
Post-processing
Wall thickening quantification from cine-MRI using the Centerline method

Patient with septal-anterior myocardial infarction
Post-processing
Wall thickening quantification from cine-MRI using the Centerline method
Post-processing
Delayed Contrast Enhanced (DCE) MRI

• DCE MRI provides information about the size and localization of myocardial infarction at high image resolution
• Infarct size and transmurality derived from DCE MRI is related to functional recovery after a revascularization intervention
• Manual contour delineation is time consuming and often difficult due to the heterogeneous distribution of areas of hyper enhancement.
Post-processing
Delayed Contrast Enhanced (DCE) MRI

Quantification of:
• Total size of infarction
  – Absolute (g)
  – Relative to LV size
• Transmural extent
• Characterization of core vs border zone
Post-processing
Delayed Contrast Enhanced (DCE) MRI

LE-MRI manual image analysis

• Definition of endocardial and epicardial boundaries in order to quantify total LV mass

• Manual delineation of enhanced myocardium
  – Often multiple regions per image

• Infarct size expressed as:
  % of total LV mass
Post-processing
Delayed Contrast Enhanced (DCE) MRI

Epi-endo Transmurality

Centerline method - 100 wall thickness chords

Transmurality (T) for each chord:

\[ T_{\text{chord}} = \frac{\text{Enhanced length}}{\text{Chord length}} \]

For each segment:

\[ T_{\text{segment}} = \frac{\text{Sum of } T_{\text{chord}}}{\text{Number of chords}} \]
Post-processing
Take Home Messages

• Advanced post-processing methods are needed to extract relevant information from the huge 3D and 4D image data sets.
• Manual tools provide a high level of user intervention, are less reproducible and can be very time-consuming.
• Automated segmentation tools are adequate in many cases. However, one should be aware of the possible pitfalls and evaluate the data dynamically to obtain a correct diagnosis based on these visualizations.
Conclusion

Advanced visualization is required in cardiac MR and CT workup, but quantitative software should be used with care and results should not be accepted blindly.
EDUCATIONAL SESSIONS
PROFFERED PAPER SESSIONS
HIGHLIGHTED LECTURES
CASE DISCUSSIONS
POST PROCESSING SESSIONS
INDUSTRY SYMPOSIA

PRAGUE 2010-SPECIALS:
- ESCR meets
- Educational Sessions for Technologists

ANNUAL SCIENTIFIC MEETING
OCTOBER 28–30

Organised by ESCR in cooperation with the University Hospital in Motol, Prague and the Medical University Graz.
www.escr.org