Image Analysis and 3D Reconstruction Technique

Satinder Singh MD., FCCP
Professor of Radiology & Medicine (Div. of CV diseases)
Chief Cardiopulmonary Radiology
Director Cardiac CT
University of Alabama at Birmingham
Disclosure

- GE Imaging in Healthcare Advisory Board
Introduction

- Complexity of coronary anatomy, cardiac motion, calcium related artifacts and subtle nature of coronary lesions necessitate evaluation of coronary CTA on workstation capable of 2 & 3 dimensional display.
- The interpreting physician must know how to do the post processing & not just rely on processed images by technologist.
Objective

- Review the practical post processing techniques which are “must” for interpreting coronary CTA
- Discuss strengths and weaknesses of commonly used 3D reformatting methods
- Discuss coronary CTA image analysis in patients with
  - Suspected CAD
  - CABG/Stents
  - Coronary artery anomalies
Post Processing Cardiac CTA

Patient Preparation
- BMI, HR, Breath hold

Data Acquisition
- HR, Arrhythmia, Calcification, Contrast opacification, Prospective vs Retrospective gating

Data Reconstruction
- FOV, Slice thickness, Recon filter

Post-Processing
Common Reformation Techniques

- Multiplanar Reformation (MPR)
- Maximum-intensity projection (MIP)
- Shaded surface display (SSD)
- Direct volume rendering (DVR)
Transaxial Data

- Series of 2D images stacked in the longitudinal (Z-axis) direction of acquisition
- Proper W/L required for accurate interpretation
  - Ideally window level should be mean of the HU values of the ROI, window width should be 2.5 times the level
  - For a standard 120 kVp exam W/L of 800/300 are useful starting points, readjust for body habitus, extent of calcification & contrast intensity
Advantage:

- Minimum distortion or errors
- Maximum resolution and grey-scale rendering

Limitations:

- Tortuous vessels will move in and out of plane as the slice thickness is not variable
- Requires reader to mentally reconstruct the 3-D anatomic relationships of the vessels and other structures
Multi-Planar Reformat (MPR)

- A plane is defined inside the 3D volume
- Only data in this plane is displayed
- Performed by using either straight or curved planes
- Thickness is set to zero as default to optimize image quality, but can be changed (slab MPR)
**MPR**

- **Advantage:**
  - Ease of use and speed
  - Provide images containing all available information (all Hounsfield unit values retained)
  - Useful in delineating the morphology of the plaque and its effect on the lumen and adjacent vessel wall

- **Disadvantage:**
  - Operator dependence; prone to introduce false positive & negative stenosis
  - Viewing from multiple different view points is required (double oblique method)
  - Only one branch of a vessel is displayed at a time
Double Oblique Method
54 Y/M with chest pain and abnormal stress MPI
Curved MPR

- Allow to follow the course of a tortuous vessel for longer distances as it changes direction
- Requires the centerline to be tracked correctly (done manually or automatically)

**Advantage:**
- View of entire course of vessel in one image

**Disadvantage:**
- Inaccurate centerline tracking may cause artifactual lesions
Automated segmentation of centerline
Maximum Intensity Projection (MIP)

- Projection of highest attenuation voxel within volumetric data (all points below this value are ignored)
- Usually thicker sections to include vessel lumen & wall (usually 4-5 mm for coronary)
- Optimizes visualization & tracking of contrasted structures: especially useful for vessel depiction
MIP

- **Advantage:**
  - Fast & easy to configure
  - Visualization of long segment of vessel
  - Decreased perceived image noise
  - Good differentiation between vessel and background
  - Decrease artifacts from metal

- **Disadvantage:**
  - No in-depth information: Loss of lesion information within slab volume
  - Leads to overestimation of stenosis
  - Interference from overlapping structures
Switching back and forth between formats, toggling between MIP and MPR captures advantages of both when reading a particular vessel segment.
Volume Rendering

- Virtual light rays are cast from a viewing point through the tissue or tissues of interest.
- Create histogram of CT data to determine the number of voxels and range of H.U.
- Tissues are assigned a specific range of H.U and each tissue has assigned color, brightness, and degree of opacity (100%; most opaque, 0%; transparent).
- Cast rays to each point in volume and determine opacity value of all voxels in path of ray.
- Place sum of all opacity for each ray in final image.
- Clip planes and thinner slabs can be employed.
Volume Rendering

- **Advantage:**
  - Capacity to display multiple tissues and show their relationships to one another

- **Limitations:**
  - Labor intensive (not anymore!)
  - Operator dependent
  - Can be misleading especially for assessing vessel narrowing
Volume Rendering

- Useful for visualizing spatial relationship: defining course of coronary anomalies, presence and course of the bypass grafts
- Very useful in analysis of thoracic CV structures, congenital heart disease
- Impressive images for teaching and illustrating for patients
- Generally not useful for assessment of coronary artery stenosis
Coronary CTA Image Analysis

- **Coronary artery morphology:**
  - 2D axial
  - Curved MPR (double oblique method)
  - MIP
  - VR

- **Cardiac Function:**
  - 2D method: Area length, Simpson’s method
  - 3D method: Threshold method

- **Valves** (retrospective gated)

- **Myocardial Perfusion**
Coronary Artery Analysis

- AHA 17 segment evaluation
- Remodelling: positive, negative
- Stenosis: location, degree, number, quantification, factors affecting evaluation
- Plaque evaluation: size, density, ulceration
Proper cardiac phase selection
Padding in Prospective gating

64% 74% 84%
Window/Level

W/L: 800/100  W/L: 800/350
Evaluation of Calcified Lesions
Effect of Window/Level on Calcification

W/L: 800/350

W/L: 1000/500

W/L: 1650/750
Plaque Characterization
Plaque Quantification
Coronary Stent Evaluation

Stent factors:
Size
Design
Material
Adequate dilatation
SVG to OM1
Occluded
Rabbit Iliac artery 3 mm Nitinol Stent: Effect of image thickness
Rabbit Aorta Stents: Standard vs Sharp filter
Improving Stent evaluation

- High mAs to improve contrast resolution
- High intravascular attenuation (high CM iodine/flow rate)
- Low HR
- Iterative reconstruction: less blooming
- Use sharp kernel for reconstruction
- Thin section images, MPR, double oblique
CABG

- VR shows the grafts course
- MIP/MPR for patency
- Must look at anastamosis sites
- Re-do: relation to sternum
Coronary Artery Anomaly

- In a younger age: restrict FOV
- For inter arterial course show pulmonary valve relation (good to have some contrast in right circulation)
- VR images show spatial relationship nicely
- MPR/Thin MIP images needed to document intramural course & oblique narrow takeoff of the anomalous vessel
Inter-arterial vs Intra-septal

Axial CT image the anomalous LM (Red arrows) is clearly arising from right cusp above the level of pulmonary valve (Yellow arrow) and courses between aorta and pulmonary trunk.

Coronal oblique CT image shows LM arising from the right coronary artery and passes through the infundibular septum (red arrows) below the pulmonary valve level (green arrows). No vessel is seen between Ao and PA on coronal.
Cardiac Function: Global

- **2D methods:**
  - Area length method
    - \( \text{LV volume} = \frac{8}{3} \times \frac{\text{area}^2}{\pi} \times \text{length} \)
  - Simpson method
    - \( \text{LV volume} = \sum \text{area} \times S \)

- **3D methods**
  - Volume segmentation is based on H.U. using threshold

\[
\text{LVEF} = \left[ \frac{(\text{LVEDV} - \text{LVESV})}{\text{LVEDV}} \right] \times 100\%
\]
Cardiac Function

- Date of Birth: 1968-08-32
- Age: 37
- Height: 177.8 cm
- Weight: 92.2 kg
- Body Surface Area: 2.087 m²
- Heart Rate: 80 bpm

- Ventricular End Diastolic Volume: 400.49 ml
- Ventricular End Systolic Volume: 232.75 ml
- Ejection Fraction: 35.16
- Stroke Volume: 76.64 ml
- Cardiac Output: 4529 ml/min
- Stroke Index: 30.7
- Epi-diastolic Myocardial Volume: 129.13 cm³

- Prisms:
  - Volume (ml): 396.26, 282.10, 340.00, 324.09, 321.75, 329.63
  - % / %: 86.0%, 50.0%, 74.0%, 60.0%, 40.0%, 50.0%

- Prisms:
  - Volume (ml): 358.31, 274.72, 468.40, 372.66
  - % / %: 40.0%, 70.0%, 80.0%, 90.0%

- Wall Thickness

- Wall Density

- Segments Ejection Fraction

- Segments Wall Thickness

- Segments Wall Density
Cardiac Function: Global
Cardiac Function: Regional wall motion

- 53 Y/M S/P GSW to chest, Serial Cardiac enzymes abnormal
- Gated CCTA: HR 94, Ventilator, mid-distal LAD occlusion, LAD distribution infarct, wall motion abnormality, no delayed enhancement
- MPI: Reversible ischemia in distal septum, apex and ant wall
- Cath: Total occlusion mid-distal LAD, could not pass guide wire, PCI failed
Myocardial Perfusion

- MinIP and Thin MPR better than thick MIP: due to greater contrast to noise ratio
- Use narrow W/L (200/100) maximizes contrast between normal and abnormal myocardium
- Persistence of suspected defect across multiple phases
- Look for regional wall motion abnormality
Conclusions

- Coronary CTA assessment requires real-time interaction with the volumetric data and the interpreting physician must become proficient with workstation and post-processing techniques.
- Always assess each vessel in multiple views and toggle between MPR and MIP without changing position to capture advantages of both methods.
- Change W/L for calcified lesions.
Conclusions

- Stents: Use sharper kernel, thin sections & iterative reconstruction
- Retrospective gated CTA: valve and cardiac function evaluation possible
- Myocardial Perfusion: Use narrow W/L, minIP and thin MPR more helpful, look for regional wall motion abnormality