Fundamentals, Techniques, Pitfalls, and Limitations of MDCT Interpretation and Measurement

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Traditional helical CT lacks sufficient temporal resolution to image the heart.

Traditional recon algorithms **average** all of the acquired data (do not temporize the data).
ECG Gating Permits Visualization of the Moving Heart

Selected Phase

Retrospective ECG-Gated Reconstruction
Prospective Cardiac CT: X-Ray Tube Mostly Off

Prospective ECG-Triggered Acquisition
Pitfalls & Limitations

• Limitations
  • Noise
  • Motion Artifacts
  • Gating Artifacts
  • Beam Hardening
  • Volume Averaging

• Pitfalls
  • MIP pitfall
  • cMPR pitfalls
  • VR pitfalls
Limitations

Noise
“Thin Slice” scanning is required for coronary CTA...
...but increases image noise

- Standard CT slice thickness = 5 mm
- Cardiac CT slice thickness = 0.5-0.75 mm
- Why?
  - Thin collimation = Better resolution of small structures (coronary arteries)
Axial Recons: Thin Slice = High Resolution

1x5.0mm image

8x0.67mm MIP
Coronal & Oblique Recons
Thin slice CT = preservation of z-axis resolution

1x5.0mm image

8x0.67mm MIP
“Thin Slice” scanning is required for coronary CTA... ...but increases image noise

• Case Example
  • 37 yo woman
  • History of hypertension, diabetes
  • Symptom: palpitations during exercise
  • Treadmill stress test:
    • Palpitations during exercise = PVC’s
    • But also: mild ischemia, anterior wall → artifact?
CT Scan

- 5’2” (1.57 m) tall and 272 lbs (124 kg)
- BMI = 50 kg/m²
- Pulse 71 bpm (sinus rhythm)
  - 15 mg metoprolol i.v. → 55 bpm
- Tube settings:
  - 140 kVp, 425 mAs
- 85 mL contrast @ 5 mL/sec
- X-ray dose: 553 mGy (9.4 mSv)
Obesity Creates Excessive Image Noise

- Signal - to - noise problem
- Morbid obesity = ↑↑↑↑ Image Noise
- + Weak “signal” = ↓↓↓ SNR
- Poor SNR = Decreased test accuracy
Contrast-to-Noise Ratio

Patient → Detector

Contrast

Noise

hi con
lo noise
Noise

With optimal HR reduction and use of Dose Modulation, it is possible to obtain adequate image quality by using higher tube current...

58yo F
6’ 250 lb BMI 36

59yo F
5’3”’ 240 lb BMI 42
But only at the cost of significantly higher radiation exposure...

990 mGy
17 mSv

1229 mGy
21 mSv
The Obese Patient

Do Cardiac CT

- Cath undesirable
- Pulse < 65 bpm
- Regular rhythm
- Good IV access
- Normal renal function
- Older (>70)
- Men
- BMI < 40

Do Not Do Cardiac CT

- Weak indication
- High heart rate
- Irregular rhythm
- Elevated Cr
- CABG / Stent
- Younger (<50)
- Women
- BMI > 45
Limitations

Motion
Motion Artifact: Concepts

- Temporal resolution is like shutterspeed
- It takes time to acquire the image
  - Time required = temporal resolution
  - In CCT the time is 80-200 ms
  - In cineangiography the time is 10 ms
- Motion during acquisition creates artifacts which may be misinterpreted as pathology
- To prevent distortion:
  - (a) Breath-hold
  - (b) Heart rate modulation
Respiratory Motion
Respiratory motion
Respiratory motion

- $\text{CACS} = 0$
- Breathing during scan
Respiratory motion: pseudostenosis
Respiratory Motion

- Avoid at all costs!
- Nurses & Techs should very carefully explain to patient
- ** Practice breath holding**

*Note: The asterisks in the bullet points indicate important instructions.*
Cardiac Motion (phase specific)

Always review coronary CT angiograms in multiple phases (usually 3)

75% 70%
(50ms earlier)
Cardiac Motion (phase specific)

75% phase

80% phase
Non-Coronary Motion Artifact
Heart Rate Modulation for Cardiac CT

- Heart rate & rhythm significantly influence CCT image quality *
- High quality requires aggressive heart rate modulation
- Target heart rate << 65 bpm
- Nitroglycerin (800 ug)
- Review quality before discharging pt

Noninvasive coronary angiography with 16-detector row CT: Effect of heart rate
Limitations

Gating Artifacts
Gating Artifact Concepts

- Actually a form of motion artifact
- Entire cardiac CT is performed during one, single, brief acquisition
- Images are reconstructed after the fact, using the ECG time-stamp
  - Motion-free axial images are reconstructed from the data obtained during the end-diastolic portion of the cardiac cycle, as defined by the ECG
    - Usually 75% of the length of the cardiac cycle
Example of Gating Artifact: PVC
CCTA: Chest Pain
CCTA Chest Pain
CCTA Chest Pain
Limitations

Beam Hardening
Beam Hardening (Metal Lead)
Streak Artifact (also associated with metal)
Beam Hardening
Limitations

Volume Averaging ("blooming artifact")
Volume Averaging
Pitfalls

MIP Pitfall
MIP Pitfall

5 mm MIP

0.67 mm image
MIP Pitfall
Pitfalls

CMPR Pitfall
(Curved Multi-planar Reformation)
cMPR Pitfall
cMPR Pitfall: pseudostenosis
Pitfalls

VR Pitfall
(Volume Rendering)
VR Pitfall

Lesion “severity” can be increased or decreased!
Volume rendered images are **not** reliable for evaluating stenosis severity.
## Common Limitations and Pitfalls in Cardiac CT

<table>
<thead>
<tr>
<th>Limitation or Pitfall</th>
<th>Result</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inadequate HRM</td>
<td>Non-dx study</td>
<td>Re-medicate &amp; repeat</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>Incomplete study</td>
<td>Edit ECG</td>
</tr>
<tr>
<td>Morbidly obese patient</td>
<td>Non-dx study</td>
<td>Adjust parameters, or do not scan</td>
</tr>
<tr>
<td>Heavy Calcification</td>
<td>Incomplete study</td>
<td>Do not scan</td>
</tr>
<tr>
<td>Stairstep artifact</td>
<td>Overcall</td>
<td>Recognize artifact</td>
</tr>
<tr>
<td>MIP pitfall</td>
<td>Undercall</td>
<td>Never use only axial images for diagnosis</td>
</tr>
<tr>
<td>MPR pitfall</td>
<td>Overcall</td>
<td>Use multiple MPR projections</td>
</tr>
<tr>
<td>3D Volume pitfall</td>
<td>Over or Undercall</td>
<td>Never use only 3D volume for diagnosis</td>
</tr>
</tbody>
</table>
Conclusions

Careful attention to patient preparation & image acquisition will help avoid artifacts.

A systematic approach to case interpretation will help avoid pitfalls.