BOARD REVIEW
Non-Coronary, Extracardiac Findings Protocols – Triple Rule Out
PART I

The Triple-Rule-Out

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Chest Pain

Non cardiac

Vascular
- Aortic dissection, aneurysm, laceration
- PE
- Vasculitis
- Vascular Anomalies

MSK/Soft Tissue
- Fractures (rib, spine)
- Muscle Sprain
- Arthritis
- Costochondritis
- Rheumatoid Arthritis
- Hematoma

Visceral
- Infection (TB, pneumonia, etc)
- Hernia (diaphragm, hiatal)
- Others (bronchogenic cyst, sequestration, etc)

Cardiac

Pericardium

Valvular

Myocardium

Vascular

Neoplasms (Primary and metastatic)

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Background

- Patients presenting to ER with chest pain need an efficacious study to exclude: pulmonary embolism, coronary stenosis, thoracic aortic dissection!

- High sensitivity and specificity of CT angiography to rule out disease!

- HYPOTHESIS:
  CT angiography protocol which would allow for consistent evaluation of all three conditions with just one CT acquisition – Triple-Rule-Out Protocol.
TRIPLE RULE OUT !
The Case Against It !

A good Physical examination is needed – Not TRO !

Object to SHOTGUN imaging approach !

Radiation to high with TRO !

Compromises in contrast enhancement is obligatory !

Guidelines say it is not an appropriate indication !
320 - 370 mgI/ml
Injection @ 5 (6) cc/s
20 cc test bolus
30 cc saline flush
Trigger at bolus peak
Volume = scan time x 5 (6)
50 cc 30% / 70% DualFlow – contrast / saline mixture
30 cc saline flush
Contrast Enhancement
The Triple Rule Out CT Protocol

Volume = Scan Time x 5 (6)

50 cc Dual Flow
30% / 70% Mix

30 cc NaCl

PA enhancement

Syst. arterial enhancement

64 SLICE SCAN OR HIGHER

20 s breathhold
Dual - Flow Technique
DEDICATED CORONARY
‘monophasic injection’

TRIPPLE-RULE-OUT
‘triphaseic injection’

LA

AORTA

RV
Regular heart rate < 80 bpm CTA

- Testbolus low dose: ROI at the ascending aorta
- Ultravist 370 mg Iodine!
- Dual Head Injector 5 ml/sec / 20 cc contrast
- 5 ml/sec / 50 cc saline

Evaluate bolus timing!
- Start at delay for Coronary CTA: add 4-5 sec!
- CTA
- Dual Head Injector 5 ml/sec / 80 cc
- 5 ml/sec / 50 cc saline

- 120 kv
- 850 mAs
- 64 x 0.6 collimation
- Pitch 0.2
- Rotation Time 0.33 sec
- Reconstruction
- 65% axial slice 0.75 increment 0.5 B25f
- 25% axial slice 0.75 increment 0.5 B25f
- 45% axial slice 0.75 increment 0.5 B25f
- Argus left ventricle 0–90% slice 8 increment 8
- Postprocessing, MIP LAO, RAO, LAO cranial, CX, VRT, EF
- Calcium score
CTA monitoring/testbolus
Dynamic Evaluation
Avoid ‘Breath-holding’ Heart Rate Variations!
“Triple-Rule-Out Protocol”
Evaluate PA, Coronaries, Thoracic Aorta, PV Pre-Ablation

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Chest Pain/Triple Rule Out

- Ultravist 370 (Schering, Berlin, Germany), 18G, A.C. vein
- Dual Head Injector (Stellant D, MEDRAD, Pennsylvania, USA)

<table>
<thead>
<tr>
<th>Injection</th>
<th>Rate</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5 ml/sec</td>
<td>80 cc contrast</td>
</tr>
<tr>
<td>A + B</td>
<td>5 ml/sec</td>
<td>50 cc</td>
</tr>
<tr>
<td>B</td>
<td>5 ml/sec</td>
<td>50 % cc Contrast</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 % ml Saline</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>50 cc saline flush</td>
</tr>
</tbody>
</table>

- Scan mid inspiration whole chest cranio–caudal, 12-17 sec
- Automatic Bolus Tracking!
  ROI: Left atrium autoscan start delay 6 sec!
- Threshold: 120 HU
- 64 x 0.6 collimation
- 120 kv
- CareDose4D 500-600 mAs
  (optimize for patient habitus and scan length!)
- Pitch 0.3
- Rotation time 0.33 sec
- Reconstruction
  65%, 25%, 45% axial 0.75/0.5 B25f only heart
  65% axial for PE whole chest and FOV 400!
  MIP for cardiac vessels LAO, RAO, LAO cranial, MIP for PE right and left pulmonary separate, MIP for dissection candy cane
Contrast Injection Protocol

- Iopromide (Ultravist 370, Schering, Berlin, Germany) using a dual syringe injector (Stellant D, MEDRAD, Indianola, Pennsylvania, USA) via 18G needle in the antecubital vein.

- 80cc contrast at 5cc/s followed by...

- 50cc equal mixture of contrast and saline at 5cc/s followed by...

- 50cc saline flush at 5cc/s.
Methods

- Acute Chest Pain. TIMI Score $> 3$ !
- **55-65/min Heart rate** achieved in 9 out 11 pts.
- Two pt with a HR of 68, 79.
- 30 mg IV Metroprolol as needed.
- 64-MDCT Angiography (SENSATION 64, SIEMENS) using the new “triple-rule-out” protocol.
- Exclusion criteria: allergic reaction to iodine contrast media, renal insufficiency (Creatinine $> 1.6$ mg/dL), pregnancy, unstable clinical status, arrhythmia, or marked heart failure.

Triple-Rule-Out = No Contrast Enhancement Compromise!

Wilke, Nguyen, Ayala et al., RSNA 2006
SCAN PROTOCOL

• 64-slice MDCT Aquillion Toshiba

• Scan range: apices of the lungs to the costophrenic angle. Scan time of 10-12 sec.

• Gantry rotation time 0.40 sec; tube voltage 120kv with effective exposure 500mAs; approx pitch 0.3; acquisition-collimation 64x0.5mm; and scan direction cranio-caudal.

• Region of interest for bolus monitoring at left atrial cavity. Threshold of 150 Hounsfield Units (HU) with 8 sec positioning and patient breathhold.

Ayala, Qualitas Imaging Center. Wellington, FL.
Contrast Injection Protocol

- Visipaque 320 using a dual syringe injector (Stellant D, MEDRAD, Indianola, Pennsylvania, USA) via 18G needle in the antecubital vein.

- 80 cc contrast at 5cc/s followed by...

- 50 cc equal mixture of contrast and saline at 5 cc/s followed by...

- 50 cc saline flush at 5 cc/s.

Courtesy Dr. Ivan Ayala, Qualitas Imaging Center. Wellington, FL.
TRIPLE R/O PROTOCOL

SCAN FROM ARCH THROUGH BOTTOM OF HEART

TRIPLE R/O INJECTION

CONTRAST
1) 80 ml IV CONTRAST, 5 ml/sec
2) 50 ml (60%) SALINE (40% = 30 cc) CONTRAST MIX, 5 ml/sec
3) 50 ml SALINE @ 5 ml/sec
SNAPSHOT SEGMENT (HELICAL)

- 0.35 ROTATION TIME
- 40 mm DETECTOR COVERAGE,
- 0.625 mm THICKNESS
- 0.35 SEC. ROTATION, USING CARDIAC SFOV,
- 120 kV
- ECG MODULATED MA, MIN 250 MAX 800
- RECON SNAPSHOT SEGMENT SCAN
Radiation Concerns

- Mean dose length product (DLP)

  **Triple-Rule-Out:** 1049
  **Coronary CT angiography:** 1004
  **PE Protocol only:** 400

  **NOTE:** Longer scan range and radiation
  - Lower effective exposure setting (500-600 mAs) of new protocol as comparable to that of the coronary CTA (800-900 mAs).
  - Increased Radiation due to the much lower pitch needed for coronary artery imaging.

- Chest pain patients who received multiple separate studies for the evaluation of acute chest pain ending up with more radiation!
Effective Dose: CTA vs Cath

- Coronary CTA: 14 mSv
- Coronary cath: 5.6 mSv

Coles, JACC 2006
- Cardiac Cath = 3-30 mSv.
- RG-CCTA = 7-20 mSv.
- RG-Triple R/O = 20-30 mSv.
- SPECT Thallium = 25.3 mSv.*
- SPECT Sestamibi = 17-20 mSv.*
- PG-CCTA = 2-8 mSv.
- PG, 100 kvp CCTA = 1-5 mSv
- PG-Triple R/O = 12 mSv.


Dowe et al., 2008
Pitch Settings

Scan time for a given scan range vs. adequate data acquisition

- Pitch of 0.3 allows for scan time of 12-17 s for scan range from lung apices to costophrenic angles.
- Limits reconstruction options for very fast and very slow heart rates.
  - Not enough data acquisition for multi-segment reconstruction
  - Pitch may be too high for heart rates <50 causing regular skip line artifacts.
  - Decreasing pitch will increase scan time (more breathing artifact) and also increase radiation.
The Future is here!

Higher temporal resolution

- Higher pitch (less overlap)
- Shorter period of nominal tube current for ECG pulsing (e.g. 100 vs 400 msec)

→ Dose reduction by 50%

McCollough CH (personal communication)
The Future is here!

- Changes of kVp affect radiation dose more than changes of mAs
- Radiation dose can be limited by “common sense” and high-tech approaches
- Design of future scanners reduce patient dose!
Practical Limitations

- Not everywhere available 24 hours a day (lack of experienced technologists, readers, and physician supervision)
- Increased contrast volume (>100 mL)
- Obesity and calcifications limit interpretation
- Patient exclusion criteria:
  - Rapid heart rate
  - Arrhythmias
  - Renal dysfunction
  - Contrast allergies
Conclusion

‘Triple-Rule-Rule Out’

• Protocol of choice for Acute Chest Pain

• Optimal enhancement of the pulmonary arteries, coronary arteries, and thoracic aorta

• Radiation dose comparable to that of a dedicated coronary CTA

• Future improvement in CT technology

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Methods

• 11 patients (age 55±18, 63% male, BMI 30.6±7.4).

• 55 < Heart rate <65 achieved in 9 out 11 pts. The other two pt HR were 68, 79. This is achieved with up to 30 mg IV Metoprolol as needed.

• All pt underwent CT angiography using the new protocol.

• Exclusion criteria: allergic reaction to iodine contrast media, renal insufficiency (Creatinine > 1.6 mg/dL), pregnancy, unstable clinical status, arrhythmia, or marked heart failure.
# Effective Dose (E)

## Radiation dosage of cardiovascular radionuclide studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Total body effective dose (mSv)</th>
</tr>
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<tbody>
<tr>
<td>Tc-99m tetrofosmin rest-stress (10 mCi + 30 mCi)</td>
<td>10.6</td>
</tr>
<tr>
<td>Tc-99m sestamibi 1-day rest-stress (10 mCi + 30 mCi)</td>
<td>12</td>
</tr>
<tr>
<td>Tc-99m sestamibi 2-day stress-rest (30 mCi + 30 mCi)</td>
<td>17.3</td>
</tr>
<tr>
<td>TI-201 stress and reinjection (3.0 mCi + 1.0 mCi)</td>
<td>25.1†</td>
</tr>
<tr>
<td>Dual-isotope (3.0 mCi TI-201 + 30 mCi Tc-99m)</td>
<td>27.3</td>
</tr>
<tr>
<td>Rb-82 PET myocardial perfusion (45 mCi + 45 mCi)</td>
<td>16.1†</td>
</tr>
<tr>
<td>Ce-68 transmission for PET</td>
<td>0.08</td>
</tr>
<tr>
<td>Gd-153 transmission for SPECT</td>
<td>0.05</td>
</tr>
<tr>
<td>Cs-137 transmission for PET</td>
<td>0.01</td>
</tr>
<tr>
<td>CT transmission source for PET (low-dose CT protocol)</td>
<td>0.8</td>
</tr>
<tr>
<td>Fluorine 18 fluorodeoxyglucose PET viability (10 mCi)</td>
<td>7†</td>
</tr>
<tr>
<td>Radionuclide angiogram, Tc-99m-labeled red blood cells (20 mCi Tc-99m)</td>
<td>5.2</td>
</tr>
<tr>
<td>Iodine 123 MIBG myocardial imaging (10 mCi)</td>
<td>4.8</td>
</tr>
<tr>
<td>Iodine 123 BMIPP myocardial imaging (5 mCi)</td>
<td>4.7</td>
</tr>
<tr>
<td>Ventilation/perfusion lung (200 MBq Tc-99m MAA + 70 MBq Tc-99m aerosol)</td>
<td>2.8</td>
</tr>
</tbody>
</table>

*Note: Values are approximate and may vary depending on specific conditions.*
Coronary CTA Effective Dose

- Background radiation ~ 3.6 mSv
- PA + lat chest x-ray 0.04 – 0.06 mSv
- Coronary cath 3 - 10 mSv

4-slice MDCT
- 120 kVp, 300 mA, 500 msec
- Hunold P, Radiology 2003

64-slice MDCT
- 120 kVp, 900 mA, 333 msec
- Mollet N, Circulation 2005
Type Aortic Dissection
Aortic Intramural Hematoma

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Takayasu Arteritis
Pulmonary Thromboembolism
Retroesophageal Right Subclavian Artery s/p closure of ASD
Sarcoidosis with Multiple Pulmonary Nodules and Hilar Nodes
Apical Cavitation and Scarring from TB
Prominent Right Heart Border

Breathless Cyst
Pericardial Cyst
RA Diverticulum
Compression Fractures and Vertebral Hemangioma

Hemangioma
(salt pepper appearance)

Compression frx

Old Rib Fracture
Hiatal Hernia

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Eventration (up-ward bowel displacement) simulating Cavitary Pneumonia
Multiple mildly prominent mediastinal nodes post CABG
Bulky Multiple Mediastinal Nodes (NHL)
Anterior Mediastinal Mass (Thymoma)
Breast CA - Retroareolar and Pulmonary Nodule
Pulmonary Metastases from Thyroid CA
Hepatic Tumor Tracking up IVC into RA

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Thank you