Cardiac Stent Imaging by CTA
Drug-Eluting Stents and Bare-Metal Stents

Stents and Bypass Grafts
Stents

Ref. (1)
Stents

Stent Images: When they’re good, they can be very good

Ref. (1)
Stents

Proximal LAD stent

Stent Images: When they’re good, they can be very good

Ref. (1)
Stents

Proximal LAD stent

LM calcium

Stent Images: When they’re good, they can be very good

Ref. (1)
Stents

Proximal LAD stent

LAD lesion

Stent Images: When they’re bad, they can be very good

Ref. (1)
Stents

Proximal LAD stent

Ref. (1)
Serial RCA stents with in-stent stenoses
Prox’l LAD diagonal stent with total occlusion

Ref. (1)
Stents  In-Stent High Grade Stenosis

Prox’l IMR branch stent with high grade stenosis

Ref. (1)
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Ref. (1)
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Prox’l IMR branch stent with high grade stenosis

Ref. (1)
Stents

Distal RCA stent

Stent Images: When they’re good, they can be very good

BUT:
More often than not, they are VERY difficult to read accurately

Ref. (1)
Stents

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Distal RCA < 60% in-stent stenosis

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Stents

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Ref. (1)
Stents

More often than not, they are VERY difficult to read accurately

Ref. (1)
More often than not, they are VERY difficult to read accurately.
Stents

Mid – LAD Stent

No Stenosis
Stents

Stent Images: When they’re good, they can be very good

Ref. (1)
Stents

BUT:
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Ref. (1)
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More often than not, they are VERY difficult to read accurately

Ref. (1)
Prox’l LAD diagonal stent with total occlusion

Ref. (1)
Stents: Optimizing Visualization

Tips and Tricks

A. Avoid motion - Find the best phase

Ref. (1)
Stents: Optimizing Visualization

Tips and Tricks

A. Avoid motion - Find the best phase

B. Minimize spatial resolution
   - thinnest slice thickness
   - sharp kernel

Ref. (1)
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Tips and Tricks

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   - sharp kernel

Grainy

Sharp Kernal

Ref. (1)
Stents: Optimizing Visualization
Tips and Tricks

A. Avoid motion - Find the best phase
B. Minimize spatial resolution - thin slice, sharp kernel
C. Get the stent in the imaging plane axis

- Get the whole stent in the line of the MPR reconstruction

Ref. (1)
Stents: Optimizing Visualization
Tips and Tricks

A. Avoid motion - Find the best phase
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C. Get the stent in the imaging plane axis

- Get the whole stent in the line of the MPR reconstruction
- Use thin slices with careful rotation

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Ref. (1)
Stents: Optimizing Visualization

Tips and Tricks

A. Avoid motion - Find the best phase
B. Minimize spatial resolution - thin slice, sharp kernel
C. Get the stent exactly in the imaging plane axis

Ref. (1)
Stents: Stent Lumen Visualization - Dependent factors

A. Stent type

- no data on ‘good’ vs. ‘bad’ stents

Maintz et al, Eur Radiol 2003
Stents: Stent Lumen Visualization - Dependent factors

A. Stent type

B. Stent size (diameter)

<table>
<thead>
<tr>
<th>Diameter</th>
<th>% Uninterpretable</th>
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<tbody>
<tr>
<td>≤ 3.0 mm</td>
<td>28%</td>
</tr>
<tr>
<td>&gt; 3.0 mm</td>
<td>11%</td>
</tr>
</tbody>
</table>

Schuijf et al, Eur Radiol 2003
Stents: Stent Lumen Visualization - Dependent factors

A. Stent type
B. Stent size (diameter) - 3 mm. cutoff point

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Evaluable (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥3.5 mm</td>
<td>32</td>
<td>35 (78)</td>
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<td>57</td>
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<td>&lt;3.0 mm</td>
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</table>

64 slice CT

Rixe et al, Eur Heart J 2006

Ref. (1)
Summary Points:

1. Stent visualization is very difficult
2. Stent diameter is the main predictor of evaluability
3. To optimize conditions for reading:
   - control heart rate
   - find the best phase
   - use thin slices / sharp kernel
   - use careful multiplanar reconstruction

Ref. (1)
For evaluating stent patency with cardiac CT which of the following is not a factor?

A. Stent diameter
B. Stent length
C. Heart rate
D. Phase of reconstruction in the R-R interval
E. Reconstruction kernel

Ref. (1)
For evaluating stent patency with cardiac CT which of the following is not a factor

B. Stent length
### Accuracy for Determining In-Stent Stenosis

<table>
<thead>
<tr>
<th>Author</th>
<th>n</th>
<th>CT evaluable</th>
<th>Sens.</th>
<th>Spec.</th>
<th>Notes</th>
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<tr>
<td>Van Mieghem</td>
<td>74</td>
<td>16/64</td>
<td>100%</td>
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<td>Median: 4.0 mm</td>
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(data available from before the deadline)

Ref. (1)
### Accuracy for Determining In-Stent Stenosis

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Ref. (1)
# Stents:

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<td>93%</td>
<td>PPV 63%</td>
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Low PPV - due to Low Prevalence of Restenosis

Ref. (1)
QUESTION: The low Positive Predictive Value (PPV) for detecting in-stent restenosis in the available published studies is primarily due to which of the following factors:

A. High number of small stents (< 3.0 mm.)
B. High negative predictive value
C. High specificity of restenosis
D. Low prevalence of restenosis
E. Low number of false-positive results
QUESTION: The low Positive Predictive Value (PPV) for detecting in-stent restenosis in the available published studies is primarily due to which of the following factors:

ANSWER:

A. High number of small stents (< 3.0 mm.)
B. High negative predictive value
C. High specificity of restenosis
D. **Low prevalence of restenosis**
E. Low number of false-positive results
### Appropriateness Criteria - Stents

#### Table 7. Detection of CAD: Post-Revascularization (PCI or CABG)

<table>
<thead>
<tr>
<th>Indication</th>
<th>Applicateness Criteria (Median Score)</th>
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<tbody>
<tr>
<td>Evaluation of Chest Pain Syndrome (Use of CT Angiogram)</td>
<td></td>
</tr>
<tr>
<td>78.</td>
<td>Evaluation of bypass grafts and coronary anatomy</td>
</tr>
<tr>
<td>24.</td>
<td>History of percutaneous revascularization with stents</td>
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<tr>
<td>Asymptomatic (Use of CT Angiogram)</td>
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<tr>
<td>25.</td>
<td>Evaluation of bypass grafts and coronary anatomy</td>
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<tr>
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<td>Less than 5 years after CABG</td>
</tr>
<tr>
<td>26.</td>
<td>Evaluation of bypass grafts and coronary anatomy</td>
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<tr>
<td></td>
<td>Greater than or equal to 5 years after CABG</td>
</tr>
<tr>
<td>27.</td>
<td>Evaluation for in-stent restenosis and coronary anatomy after PCI</td>
</tr>
</tbody>
</table>

ACCF/ACR/SCCT/SCMR/
ASNC/NASCI/SCAI/SIR 2006 Appropriateness Criteria for Cardiac Computed Tomography and Cardiac Magnetic Resonance Imaging®

Ref. (1)
Appropriateness Criteria - CTA and Stents

27. **Inappropriate**: Asymptomatic patients
   For the evaluation for in-stent restenosis and coronary anatomy post PCI

24. **Uncertain**: Symptomatic patients
   History of percutaneous revascularization with stents
   In general, not appropriate except under exceptional circumstances -
   e.g., symptomatic patient with large stent who can’t be evaluated any other way

Ref. (1)
Summary Points: Stent Scanning

1. Coronary CTA for stents in NOT appropriate
2. Heterogeneous results in the published studies
3. More likely successful in
   a. low body weight patients
   b. low heart rates
   c. large stents
4. Low positive predictive value
   - many false-positive results

Ref. (1)
Question:
Evaluation for in-stent restenosis with CTA is most likely to be successful with which of the following?

A. Low body weight patients
B. Patients with low heart rates
C. Larger stents ( > 3.5 mm. )
D. **More proximally located stents**
E. All of the above
Question:
Evaluation for in-stent restenosis with CTA is most likely to be successful with which of the following?

A. Low body weight patients
B. Patients with low heart rates
C. Larger stents ( > 3.5 mm. )
D. More proximally located stents
E. All of the above
Bypass grafts and Preoperative Assessment
Ref (2)
3-D, Volume Rendered images easily identify the location, size and likely patentcy of bypass grafts

Ref (1)
Imaging of bypass grafts.  
(A) Transaxial slice: The aortic anastomosis of a venous graft can be seen (large arrow). In addition, two cross-sections of the venous grafts to the left anterior descending coronary artery and diagonal branch are depicted (small arrows).  
(B) Curved multiplanar reconstruction of the bypass graft to the left anterior descending coronary artery. Large arrows indicate bypass graft; small arrows, native left anterior descending coronary artery; asterisk, bypass graft anastomosis.  
Ref (1)
Patient with four venous bypass grafts

(A) Three-dimensional reconstruction shows occlusions of the bypass grafts to the left circumflex and right coronary artery (large arrows) as well as a high-grade proximal stenosis of the venous graft to the left anterior descending coronary artery (small arrow). Calcification is present in the stenosis. The venous graft to a diagonal branch is patent and has no high-grade stenoses.

Ref (1)
Patient with four venous bypass grafts

(B) Curved multiplanar reconstruction of the bypass graft to the left anterior descending coronary artery (double arrows indicate calcified stenosis).
Patient with four venous bypass grafts.

C) Invasive angiogram of the bypass graft to the left anterior descending coronary artery showing high-grade stenosis of the proximal bypass graft.

Ref (1)
Bypass Graft Analysis:
- Origin of the graft
- Main body of the graft
- Insertion Site
- ? Multiple anastomoses
- Variant course

Identify:
- Rings, clips, stents,
- Plaque - homogeneous, moxed
- Thrombus
- Patency and degree of stenosis

Ref (1)
• Also very important to always identify the internal mammary arteries
  – ? Used already
  – ? Usable in the future
  – Course, size, patency

Ref (1)
• Systematic analysis –
  – Finding the grafts – which order are they in?
  – Identify usual graft locations – proximal to distal, right to left, distal insertion sites, distal vv. filling
  – Don’t assume anything will be normal
    Look for variants
      - ? Why
      - Look at the distal vessels
  – Use all the tools 3-D, MPR, thick and thin MIP, CPR, Cut 3-D
• The occluded graft – identify characteristics
  – Look for soft tissue traces and remnants of the course, clips, etc.
  – Look at the native vessel – ? patent and still stenosed
• What a graft stenosis looks like:
  Very similar to native vessels only larger

Ref (1)
• Using 3-D to get an idea of the patency of a BPG and its course and possible stenosis,
• And then use mpr and other thinner imaging modalities to define it more accurately.
• How accurate are we at analyzing graft patency and stenosis?

  Extremely accurate -
  - hard to get it wrong with CTA
  - large vessels that move less than native arteries with good border definition

Ref (1)
Extremely accurate –
Very high Sensitivity and Specificity for:
Occlusion - near 100%
Occl. or Stenosis – both over 95%

Ref (1)
• However, there can be problems with graft analysis
  – Metal clips usually around the mammary arteries
    Rings, stents, partial volume effects with possible skip grafts
  – Anastomosis imaging and native arteries analysis

Ref (1)
• Anastomotic sites can be very difficult to analyze

Ref (1)
• The native arteries change after bypass surgery

• - Proximal vessels progress with accelerated atherosclerosis and heavier calcification, possibly due to changing flow dynamics.

Analysis of the post bypass patient MUST always include assessment of the proximal and distal segments of the bypassed arteries. This is difficult and limits the usefulness of CTA in this population.

Ref (1)
Low Specificity and PPVs in the native arteries post CABG is due to this heavier, accelerated calcification and disease.

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
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<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nieman [42]</td>
<td>79-89%</td>
<td>72-75%</td>
<td>73-80%</td>
<td>79-86%</td>
</tr>
<tr>
<td>Malagutti [79]</td>
<td>97%</td>
<td>98%</td>
<td>86%</td>
<td>99%</td>
</tr>
<tr>
<td>Hopers [83]</td>
<td>96%</td>
<td>76%</td>
<td>44%</td>
<td>96%</td>
</tr>
<tr>
<td>Onuma [128]</td>
<td>78%</td>
<td>92%</td>
<td>79%</td>
<td>97%</td>
</tr>
</tbody>
</table>

Sp = 80-85% ave.  PPV = 50-75% ave.
• There is a high percentage of unevaluable arteries - 15 to 35%
• But the percentages are getting better, with better imaging
• Typical patient with chest pain post CABG – questions is not just of graft patentcy, but very much the status of the native arteries plus the unbypassed, proximal vessels
• This is a major limitiaton of CTA imaging
<table>
<thead>
<tr>
<th>Indication</th>
<th>Evaluation of Chest Pain Syndrome (Use of CT Angiogram)</th>
<th>Appropriateness Criteria (Median Score)</th>
</tr>
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<tr>
<td>23.</td>
<td>• Evaluation of bypass grafts and coronary anatomy</td>
<td>U (6)</td>
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<td>• History of percutaneous revascularization with stents</td>
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<td>• Evaluation of bypass grafts and coronary anatomy</td>
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<tr>
<td>27.</td>
<td>• Evaluation for in-stent restenosis and coronary anatomy after PCI</td>
<td>I (2)</td>
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</table>
### Table 7. Detection of CAD: Post-Revascularization (PCT or CABG)

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</table>

- **Appropriateness criteria - reflect these limitations**
  - CP and hx CABG - **UNCERTAIN** usefulness
  - Asx’ic pt – **INAPPROPRIATE** - Can’t use “just to check”
    - Either < 5 yrs or >5yr. Post bypass

Ref (1,3)
Post Bypass Unusual Findings - Graft Anuerysms
Preoperative Assessment in the Post CABG Patient

- Localization of grafts relative to the chest wall
- Surgeons become big advocates for CTA preop.
Other useful CTA identifiable preop information

• Calcification of ascending aorta
• Position of BPGs and target vessels
• Intramyocardial course/calcification of native arteries
• Internal mammary arteries
• Incidental findings – hernias, nodules, congenital findings

Ref (1)
BYPASS GRAFTS

Modification of Surgical Planning Based on Cardiac Multidetector Computed Tomography in Reoperative Heart Surgery

Galit Aviram, MD, Ram Sharony, MD, Amir Kramer, MD, Nahum Nesher, MD, Dan Loberman, MD, Yanai Ben-Gal, MD, Moshe Graif, MD, Gideon Uretzky, MD, and Rephael Mohr, MD

Departments of Radiology and Cardiothoracic Surgery, Tel Aviv Sourasky Medical Center, Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel.

PERIOPERATIVE CROSS-SECTIONAL IMAGING

Multisection CT Evaluation of the Reoperative Cardiac Surgery Patient

Robert C. Gilkeson, MD • Alan H. Markowitz, MD • Leslie Ciancibello, RT
• Appropriateness Criteria:  **Appropriate for**

Noninvasive coronary mapping
prior to repeat surgical revascularization

Ref (3)
Summary Points

A. Bypass graft occlusion / stenosis – easy and accurate by CTA
B. Potential problems – clip / anasomosis
C. Native arteries post bypass: difficult to visualize (Ca+. Small diameters)
D. CTA “not appropriate” routinely post CABG
E. Only “appropriate’ exeception; “mapping” prior to redo surgery

Ref (1)
Question:
What structure is identified by the arrow?

A. Accessory internal mammary branch
B. Saphenous vein bypass graft
C. Radial artery bypass graft
D. Phrenic nerve bundle
E. Bronchial artery

Ref (1)
Question:
What structure is identified by the arrow?

Answer
A. Accessory internal mammary branch
B. Saphenous vein bypass graft
C. Radial artery bypass graft
D. **Phrenic nerve bundle**
E. Bronchial artery
Question:
In assessing bypass grafts for stenosis, which is the best processing tool to utilize?

A. Thin slice multiplanar reconstruction
B. Maximum intensity projection
C. Minimum intensity projection
D. Fly-through endoscopic rendering
E. 3-D volume rendering technique.
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ANSWER

A. Thin slice multiplanar reconstruction
B. Maximum intensity projection
C. Minimum intensity projection
D. Fly-through endoscopic rendering
E. 3-D volume rendering technique.
Question: What is the most significant finding in this image?

A. LAD occlusion with retrograde filling of the distal segment
B. Moderate 50% mid LAD stenosis
C. Misalignment artifact
D. Anomalous LAD arising from the right sinus of Valsalva with trans-septal (subpulmonic) course
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QUESTION

According to the appropriateness criteria, a 55 yo man who is ten years post 4 vessel bypass, who continues to smoke and who has asthmatic bronchitis, diabetes, and who cannot undergo standard nuclear stress imaging, CTA would be considered appropriate. True or False?

A. True
B. False
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