Cardiac Catheterization Basics for Thoracic Radiologists

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Objectives:
- For our discussion, we will mainly focus on diagnostic left heart catheterization and evaluation of the coronary arteries.
- Learn approved indications for left heart catheterization.
- Become familiar with routine views used in a standard examination.
- Understand what fractional flow reserve (FFR) is and why it is important.
- View a variety of basic cases involving angiography and ventriculography.
- Recognize that familiarity with cath images will help improve correlation with cardiac CTA examinations.

Background

Diagnostic LH Cath - 3 components:
- Anatomic evaluation
- Hemodynamic evaluation
- Ventriculography

Class I* Indications for Left Heart Catheterization:
- Unstable coronary syndromes/angina
  - Which is refractory to medical therapy or recurrent symptoms following initial medical therapy
- Class III or IV angina
  - defined as (1) marked limitation of ordinary physical activity and (2) inability to carry on any activity without discomfort, respectively
  - This is based on CCS (Canadian Cardiovascular Society classification of angina)
- Acute MI
  - Intended intervention in STEMI or new LBBB MI (within 12 hours of onset of symptoms)
  - Non-ST elevation MI with persistent symptoms on medical therapy or with elevated troponin, D-dimer, or other high risk features
- Perioperative risk stratification prior to Noncardiac surgery
- Many other scenarios exist in practice, the risk/benefits of cardiac catheterization should be weighed on an individual basis.

Hardware:
- Just like in interventional radiology, a similar system of guidewires, dilators, sheaths, and catheters are used.
- Common catheter types
  - Judkins (left and right subtypes called JR and JL, respectively) [4, 5] are most commonly used
  - Amplatz
- Catheter selection depends on:
  - Approach: groin vs upper extremity
  - Shape of the aortic arch (for example, a more horizontal arch may require a JL5 or JL6)
  - Whether or not CABG grafts are present

Radial access used in patients with
1. Morbid obesity
2. Severe peripheral vascular disease
3. Aortic dissection

* where evidence and/or general agreement that cath is beneficial
Coronary Artery Anatomy:

**RCA:**
1. Arises from the right sinus and travels in the right AV groove.
2. In 80% of people, gives rise to the Right Obtuse Marginal (ROM) artery.
3. The part of the RCA that continues after the PDA is given off is called the PLV or posterolateral ventricular branch.

**LCX:**
1. Normally is a branch of the Left Main, which arises from the Left sinus of Valsalva.
2. Runs in the left AV groove.
3. Branches of the LCX are called Obtuse Marginal (OM) branches.

**LAD:**
1. Normally is a branch of the Left Main, which arises from the Left sinus of Valsalva.
2. Runs in the left anterior interventricular groove to the apex.
3. Branches of the LAD are called Diagonal. (D is for Diagonal)

Angiographic views

Routine views - Basic concept: View all vessels in orthogonal planes without overlap

Two dimensions:

- **Left/Right:** AP, LAO, RAO - just like in regular fluoroscopy
- **Cranial/Caudal:**

How do I know what view I am looking at?

Pearl 1: Look at the spine:

- If spine is to the left of EPT of the catheter, you are looking at an LAO view.
- If spine is right of catheter, you are looking at an RAO view.
How do I know what view I am looking at?

Pearl 2: Look at the Catheter...

- If the catheter crosses over itself → RAO view.
- If the catheter loops like a candy cane or is an "open loop" → LAO view.

Cranial and Caudal

- Diaphragm is domed – caudal
- If flat or not seen – cranial
- LCX "follows the II". i.e. if II goes cranial, the LCX will rise on the image

Left System Views

<table>
<thead>
<tr>
<th>Left System Views</th>
<th>Segments Visualized</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAO LCA view</td>
<td>Left main, proximal LCX</td>
</tr>
<tr>
<td>RAO CCA view</td>
<td>Central LCA</td>
</tr>
<tr>
<td>RAO RCA view</td>
<td>Right coronary artery</td>
</tr>
<tr>
<td>AP view</td>
<td>Proximal, mid and distal LAD</td>
</tr>
<tr>
<td>LAO view</td>
<td>Proximal, mid and distal LAD</td>
</tr>
<tr>
<td>LAO balloon view</td>
<td>Left main, proximal and distal LAD</td>
</tr>
<tr>
<td>RCA views</td>
<td>Segments visualized</td>
</tr>
<tr>
<td>LAO</td>
<td>Proximal and distal RCA with distinguishing of RV and PCA</td>
</tr>
<tr>
<td>LD</td>
<td>Mid and distal RCA</td>
</tr>
<tr>
<td>AOS</td>
<td>Mid and distal RCA</td>
</tr>
<tr>
<td>LAD</td>
<td>Mid and distal RCA</td>
</tr>
<tr>
<td>LAD balloon view</td>
<td>Left main and proximal and distal LAD</td>
</tr>
</tbody>
</table>

RAO view of the RCA

- Best shows the mid RCA and obtuse marginal.

LAO view:
Better visualization of ostium and PLV
Notice how the RCA has been foreshortened and is less conspicuous.

Left System

- Several views are made from the combination of RAO/LAO rotation and cranial/caudal angulation. For example:
  - RAO caudal - for LCX and OM, ostium, distal Left main...BUT this foreshortens the mid LAD and obscures origins of diagonals.
  - RAO cranial view is done which shows the mid LAD and origins of diagonals better.
  - Bottom line: two orthogonal views for the LAD and two for the LCX is the minimum.
Stenoses in the LAD, RCA, and LCX are considered significant when they cause >70% luminal narrowing.

In the left main coronary artery, a stenosis is considered critical if it narrows >50% of the lumen.

This is based on studies which monitor myocardial blood flow as a function of percent stenosis.

In order to describe the flow of contrast in a particular coronary vessel, a description system is used called the TIMI grade system.

This is as follows:
- TIMI 3 - Normal distal runoff (spreads distally in less than 3 heartbeats)
- TIMI 2 - Good distal runoff (longer than 3 beats)
- TIMI 1 - Poor distal runoff (does not completely spread distally)
- TIMI 0 - Absence of distal runoff (no flow)

Vessel narrowing is based on ratio of width of stenosed vessel to normal vessel in long axis. This is usually done as a visual estimate. However, quantitative methods are available if needed.
63 year old male with persistent exertional chest pain.

- What view is this?
- What vessel is diseased?
- How would you grade the stenosis?

LAO view of the RCA shows 99% stenosis in the proximal RCA.

77 year old male with persistent exertional chest pain.

- What view is this?
- What vessel is stenosed?
- How would you grade the stenosis?

Shallow RAO view of the left system shows >95% stenosis in the mid LAD (blue arrow).

A stent was placed across the lesion.

77 year old male with persistent exertional chest pain.

- What view is this?
- What vessel is diseased?
- How would you grade the stenosis?

RAO Caudal (Lcx down) view shows >95% narrowing at the ostial LAD.

In this case, stenting is NOT a good option, as the proximal part of the stent would "stick out" into the Left Main. The patient was referred for bypass.

63 year old male with persistant exertional chest pain.

- What view is this?
- What vessel is diseased?
- How would you grade the stenosis?

LAO view of the RCA shows 99% stenosis in the proximal RCA.

77 year old female presents with ST elevation MI (STEMI)

- What view is this?
- What vessel is occluded?

RAO view showing truncated LAD (blue arrow), normal LCX (red arrow), normal Diagonal (green arrow).

After thrombectomy:
LAD normal (blue arrow) - (note how it goes to apex)
LCX with mild luminal irregularities (red arrow).
Normal Diagonal (green arrow).

Hemodynamics
“Dampening” is defined as a drop in catheter tip systolic pressure which usually occurs when there is a bubble in the catheter-transducer system.

“Ventricularization” is defined as a coronary pressure being visualized similar to left ventricular chamber pressure in the setting of a critical stenosis. This results in a substantial drop in diastolic pressure (4) (see figure 17).

Ventricularization can be seen with ostial lesions or when the catheter tip is against the wall of the vessel. Readjustment should be made prior to injection to make sure the latter is not the case.

What to do with this lesion?

Fractional Flow Reserve (FFR)…

Let’s say we see 50% stenosis within a vessel...does that matter? We will want to know if the stenosis is hemodynamically significant or not. I.e. Does an intermediate stenosis without ischemia warrant intervention? How do we decide?

→ Measure Fractional Flow Reserve (FFR)

A wire is introduced through the catheter and pressure recordings are made. Adenosine is administered for vasodilation (simulates physiologic increase in flow).

After adenosine, the proximal and distal segments will dilate, but the stenosed segment will not dilate as much. As a result, the pressure gradient across the lesion will be exaggerated.

\[ FFR = \frac{P_{distal}}{P_{proximal}} \]

An FFR of 0.8 or less is considered a significant lesion.

LAD lesion (a) with corresponding FFR: (b) baseline measurements, and (c) after infusion of 90 micrograms of intracoronary adenosine. FFR: 0.75, meaning this lesion is hemodynamically significant.
FFR, why it is important:

- FFR < 0.75 is considered significant (changed to 0.8 in FAME II).

FAME trial - Patients with multivessel coronary disease underwent revascularization via stenting or CABG.

Determination for PCI was via an FFR-guided strategy or angiography strategy.

FAME showed that FFR-guided strategy led to significantly lower MI and need for repeat stenting or bypass.

DEFER trial - Five year outcome after deferral of PCI of an intermediate coronary stenosis based on FFR > 0.75 is excellent. The risk of death or MI related to this stenosis is <1% per year and not decreased by stenting.

Ventriculography

Common indications for ventriculography are (6). Some of these are now routinely performed with MRI:

1. Estimation of LV function in patients with coronary artery disease, myopathy, or valvular disease.
2. Detection of ventricular septal defect (VSD)
3. Mitral regurgitation quantification

Miscellaneous
Intravascular ultrasound (IVUS). This is useful for borderline lesions (50-70%) and ostial lesions.

IVUS images from a diseased coronary artery in a 77-year-old male with associated schematic representations of the lumen and vessel walls. Note the calcified plaque (white) deposited in the intimia (gray). (Plaque characterization).

Complications:

<table>
<thead>
<tr>
<th>Complication</th>
<th>Risk (%)</th>
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<tbody>
<tr>
<td>Death</td>
<td>0.11</td>
</tr>
<tr>
<td>MI</td>
<td>0.16</td>
</tr>
<tr>
<td>Stroke/CVA</td>
<td>0.07</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>0.30</td>
</tr>
<tr>
<td>Contrast reaction</td>
<td>0.39</td>
</tr>
<tr>
<td>Vascular complication</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Complications associated with cardiac catheterization (2). *59,792 patients were studied.

Noncontrast computed tomography was requested on post cath day 1 for falling hematocrit.

A small retroperitoneal hematoma (red arrows) is noted. Patient was stable after transfusion.

Vascular complication - Linear defect (green arrow) in the PLV is consistent with a dissection.

Summary:

- Cardiac Catheterization is the "gold standard" for imaging the coronary arteries to assess for stenosis. Different views are used to assess for atherosclerotic plaque.

- Fractional Flow Reserve (FFR) uses pressure measurements to determine if a plaque is hemodynamically significant.

- Familiarity with conventional angiography may provide improved cross correlation while interpreting cardiac CT and MRI.

- This is a very brief introduction into a complex area of study. We encourage further reading to supplement this presentation.

References:

- Askari, Arman. ‘Introductory Guide to Cardiac Catheterization’. 2nd Ed. 2011 Lippincott Williams & Wilkins