ACVP’s RCIS Review Course:
Coronary and Vascular Anatomy, Physiology, Imaging

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18th Annual Conference
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THE PERIPHERAL EVENT OF THE YEAR
## Disclosures

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Coronary and Vascular Anatomy, Physiology and Imaging: Topics

- Identify Vessel Structures
- Describe Vascular Physiology
- Identify Coronary Vessel Anatomy
- Discuss Methods of Coronary Imaging
- Identify Major Peripheral Vascular Anatomy
- Discuss Methods of Selected Peripheral Vascular Imaging
Vessel Structure and Physiology
Vessel Types:

• Blood Vessels are closed conduits that move blood through the body, controlling distribution of blood and nutrients to organs and tissues.

• There are three general categories of blood vessels:
  1. Arteries: Conduit vessels that move blood away from the heart towards tissues and organs. Three sub categories of arteries:
    1. Aorta and Elastic Arteries
    2. Muscular Arteries
    3. Arterioles
  2. Veins: Capacitant vessels that move blood towards the heart, and store blood for the cardiovascular reserves. Three sub categories of veins:
    1. Venules
    2. Veins
    3. Greater Veins (vena cava)
Vessel Types

- **LARGE VEIN**
  - Tunica externa
  - Tunica media
  - Tunica intima
  - Endothelium

- **ELASTIC ARTERY**
  - Internal elastic layer
  - Endothelium
  - Tunica media
  - Tunica intima

- **MUSCULAR ARTERY**
  - Tunica externa
  - Tunica media
  - Tunica intima
  - Endothelium

- **MEDIUM-SIZED VEIN**
  - Tunica externa
  - Tunica media
  - Tunica intima
  - Endothelium

- **VENULE**
  - Tunica externa
  - Tunica media
  - Endothelium

- **FENESTRATED CAPILLARY**
  - Pores
  - Endothelial cells
  - Basal lamina

- **CONTINUOUS CAPILLARY**
  - Endothelial cells
  - Basal lamina

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Vessel of Resistance

• In the circulatory system it is the arteriole vessels that act as the point of resistance to vascular flow
  • Primarily due to their number and vessel structure
• The pressure produced by the heart, causing blood circulation, is primarily determined by arteriole vasoconstriction
Vascular System Anatomy

• The vascular system is divided into two separate circuits:
  
  • Systemic system: Originates at LV, delivers oxygenated blood to body tissues. Deoxygenated blood returns to RA.
  
  • Pulmonic system: Originates at RV, delivers deoxygenated blood to lungs for reconditioning. Oxygenated blood returns to LA.
Vessel Wall Structure

- Artery and Venous wall structures are similar, and are composed of three basic layers (tunicas)
  - Tunica Intima
  - Tunica Media
  - Tunica Adventitia (Externae)

- Each tunica has a role to play in vascular physiology

- Each tunica is separated by elastic laminae that allows for the vessel to dilate and constrict

- Veins have valves to control the passive motion of blood, decreasing backflow risk
Capillary Wall Structure

• Capillary structure is significantly different than arteries and veins
• Capillaries are composed of a single layer of endothelial cells bound to a basement membrane
• Capillary flow through an organ is controlled by tiny precapillary sphincters
Coronary Vessel Anatomy
Coronary Arteries

- Typically originate from the left and right anterior (coronary) cusps of the aorta
  - Ostia are protected by the sinus of Valsalva during ventricular contraction
- Travel along the epicardial surface
  - Intramural branches penetrate the deep myocardium
- Flow through coronaries is greatest during diastole
Coronary Arteries: Left Coronary Tree

- The left coronary tree has 3 major branches, and 3 sets of sub-branches

  - Left Main: Origin off of Left Coronary Cusp of Aorta, bifurcates to LAD and Circumflex

  - Left Anterior Descending: Bifurcates from LM, travels anteriorly across LV towards apex. Two sub-branches
    1. Diagonals
    2. Septal Perforators

  - Circumflex: Bifurcates from LM, travels around AV groove, towards inferior/posterior LV. One major sub-branch
    • Obtuse marginal
    • PDA MAY originate from distal circumflex (left dominant in 12% of patients, codominant in 2%)
Coronary Arteries: Right Coronary Tree

- The Right coronary artery originates from the right coronary cusp of the Aorta and continues posteriorly along right AV groove. It has several branches:
  - Conus Branch: typically first branch off RCA, feeds RV outflow tract
  - SA Nodal Branch: MOST commonly originates from proximal RCA
  - RV Branch: Originates from RCA and travels over lateral/anterior RV
  - Acute Marginal Branch: Feeds inferior RV
  - PDA: MOST often originates from RCA (right dominant 86%, 2% codominant)
  - Posterior Lateral Branches: Distal RCA past PDA, feeds inferior LV
Invasive Coronary Angiography
Invasive Coronary Angiography

• Purpose:
  • Coronary anatomy
    • Vessel dominance
    • Vascular distribution
    • Anomalous vessels
    • Collateral circulation
  • Coronary luminal obstruction
    • Guide revascularization decisions
    • Coronary blood flow

• Limitations:
  • Invasive
  • May underestimate severity of stenosis
    • Diffuse disease, compensatory artery enlargement, eccentric plaque, vessel tortuosity and branch points
  • Does not provide physiologic flow limitations
    • Fractional flow reserve measures physiological significance of the stenosis
  • Does not provide vascular anatomical detail
    • IVUS provides detail of plaque composition and wall structure
Invasive Procedure Complications and Predictors

- Death
- AMI
- Emergency CABG
- Dysrhythmia
- Stroke
- Bleeding
- **Hematoma**
- Vascular Injury
- Contrast Toxicity
- Allergic reactions
- Pulmonary Edema
- Air/clot embolism
- Renal Failure (CIN)
- Vasovagal reaction

- Age < 1 year or > 65 years old
- Left main disease
- Severe LV dysfunction low EF%
- Valve disease- Aortic stenosis
- Class IV heart failure
- Comorbidities:
  - Diabetes, renal failure, COPD, PVD,

Clinical Note: Hematoma remains the most common complication of percutaneous invasive cardiovascular procedures
Invasive Coronary Angiography: What View Am I In?

• General Rules:
  
  • RAO
    • spine is on the left, apex point to the right
  
  • AP
    • spine bisects the screen
  
  • LAO
    • spine is on the right, apex points to the left

• When Spine Is Not In View:
  
  • The Aorta lies on the left side of the spine
    • The Catheter will be visible in the Aorta, thus catheter position indicates side that spine should be on
  
  • The Ribs will slope down away from the spine
Invasive Coronary Angiography: Coronary Rules

• LCA General Rules
  • The Circumflex will be closest to the spine
  • The LAD will be away from the spine
  • The LAD should be the longest artery
  • In LAO the LAD will be to the left
  • In RAO the LAD will be to the right

• RCA Special Rules:
  • In LAO the RCA will form a “C” shape
  • In RAO 45 the RCA will form an “L” shape
Spine is on the Left

Ribs point down from Spine
Projection is LAO

Spine is on the Right

RCA forms a “C”
Projection is RAO

Spine is on the Left

RCA forms an “L”
Common Images

• Left Coronary Arteries:
  • LAO-Caudal view: Best for visualizing left main, proximal LAD and proximal Circumflex.
  • RAO-Caudal view: Best for visualizing left main bifurcation, proximal LAD and the proximal to mid Circumflex.
  • Shallow RAO-Cranial view: Best for visualizing mid and distal LAD and the distal Circumflex. This view also separates out the septals from the diagonals.
  • LAO-Cranial view: Best for visualizing mid and distal LAD, and the distal Circumflex in a left dominant system. Also separates out the septals from the diagonals.
  • PA projection: Best for visualizing ostium of the left main.
  • PA-Caudal view: Best for visualizing distal left main bifurcation as well as the proximal LAD and the proximal to mid Circumflex.
  • PA-Cranial view: Best for visualizing proximal and mid LAD.
  • Left lateral view: Best for visualizing proximal Circumflex, proximal and distal LAD.
Common Images

• Right Coronary Arteries:

  • LAO 30: Best for visualizing ostial and proximal RCA, SA Nodal, Conus
  • RAO 30: Best for visualizing mid RCA and PDA, Right Ventricular Branches
  • PA Cranial: Best for visualizing distal RCA bifurcation and the PDA, Acute Marginal, Posterior Lateral Branches
Intravascular Ultrasound (IVUS)

• Utilizing ultrasound to visualize plaque formation
• Purpose:
  • Detailed information of plaque formation and composition
  • Structural integrity of plaque
  • Evaluate % stenosis
  • Observe stent deployment
Vascular Optical Coherence Tomography (OCT)

• OCT uses light emission close to Infrared EMR
• Due to its smaller waveform profile, it interacts with the vessel at a smaller level, creating amazing detail.
• The trade-off is a lower penetration and axial resolution

Peripheral Angiography
Aortic Arch Angiography

• Purpose:
  • Identify anatomy (especially for carotid and subclavian procedures) and arch type
  • Identify structural competency of aortic arch (rule out aneurysm/dissection)

• Procedure:
  • 15-30 degree RAO separates out the common origins
  • Pigtail catheter positioned in ascending Aorta

• Evaluate:
  • Innominate (brachiocephalic) with right subclavian/carotid bifurcation
  • Left common carotid
  • Left Subclavian
Alternate Aortic Arch Anatomy

- Aortic Arch Types
- Anomalous Anatomy
Carotid Angiography

- **Purpose:**
  - Landmark Mapping/definition for Surgery (not common)
  - Preparation for Internal Carotid Artery Stenting

- **Procedure:**
  - Three images are common
    - 30-45 degree ipsilateral view
    - Left Lateral
    - Townes View to evaluate cerebral flow (Circle of Willis)
  - 8CC per view suggested, bilateral evaluation when appropriate
  - Catheters: JR4, Vitek, Simmons
  - Digital subtraction
  - Spin Angiography?

- **Evaluate:**
  - Carotid Bifurcation (majority of occlusions occur here)
  - Internal Carotid Segments (Cervical/Petrous/Cavernous/Supraclinoid)
  - Circle of Willis
Carotid Angiography: Townes View

- AP Cranial view
  - Approximately 30 degrees cranial
Upper Extremity Angiography

• Purpose
  • Identify anatomical structure
  • Evaluate subclavian, axillary, brachial, ulnar, radial, and interosseous flow and abnormalities

• Procedure:
  • Usually step angiography
  • Begin with Aortic Arch Angiography, followed by sub selecting subclavian vessel, axillary, and brachial vessels (in sequence)
  • Step images down arm until upper extremity evaluation is completed
  • 5-10 cc bolus per section is typically adequate
  • AP view suggested (slight ipsilateral angulation may be helpful for radial/ulnar separation)
  • Digital Subtraction
  • Catheters: JR4, Vitek, Simmons, Headhunter, Cobra
Renal Angiography

• Anatomy:
  • Renal arteries bifurcate laterally and posteriorly from abdominal aorta at the region of the 1st or 2nd lumbar vertebrae (right side often slightly superior to the left)
  • Most patients have one hilar artery to each kidney, though other variations (such as two Hilar, or Hilar and Polar arteries are possible)
Alternate Renal Artery Anatomy
Renal Angiography

• Purpose
  • Demonstrate Renal Vascular Anatomy for Procedures
  • Assess Renal Artery Stenosis
  • Evaluate for Renal Artery Fibromuscular Dysplasia

• Procedure:
  • Abdominal Aortic Angiography through pigtail catheter placed at region of T12 vertebrae (30-40 CC) to demonstrate renal artery anatomy
  • Sub-select renal arteries with JR4, renal Double Curve (RDC), SOS, Cobra
  • 10 CC injection in AP and ipsilateral view (bilateral angiography when appropriate, digital subtraction)
  • Continue angiogram until ureter is seen (if possible)
Iliac Angiography

• Purpose:
  • Define Iliac Anatomy
  • Identify femoral vascular access
  • Evaluate flow and abnormalities in the iliac/femoral vessels

• Procedure (simultaneous bilateral angiography):
  • Pigtail catheter positioned at 4th lumbar vertebrae, AP position
  • 20 – 30 ml contrast injection with digital subtraction angiography

• Evaluate:
  • Abdominal Aorta
  • Internal and External Iliac Vessels
  • Common Femoral Arteries
  • Superficial Femoral Arteries
  • Profunda Femoris (deep femoral arteries)
Femoral / Lower Limb Runoff

• **Purpose:**
  - Evaluate the vascular anatomy of the legs
  - Identify flow and vascular abnormalities of the lower limbs
  - Prepare for lower limb vascular procedures

• **Evaluate:**
  - Superficial femoral, Popliteal, Anterior Tibial Artery, Posterior Tibial artery, Peroneal artery, Dorsalis Pedis
Lower Limb Runoff / Bolus Chase

• Procedure:
  • A runoff (or bolus chase) is a procedure in which one bolus of contrast is used to evaluate the limb vasculature as the patient is moved under the x-ray gantry. A recorded image is produced
  • May be performed on an ipsilateral accessed vessel through the sheath, or a contralateral approach by which a long sheath or catheter is advanced across the iliac vessel arch (Omni SOS of Flush catheter)
  • Bilateral runoffs are possible, but very difficult due to unilateral disease
  • 45 cc contrast for selected runoff, AP gantry position, Digital Subtraction
  • Stepped Angiography may be performed, but typically increases the contrast dose
Lower Limb Bolus Chase Angiography
Discussion:

• Questions / Comments / Quemments

• Obligatory Family Photo
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