Cardiac CT
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Why Do Cardiac CT/CTA
- Evaluate coronary artery stenosis
- Alternative for assessment of patient risk factors with Calcium Scoring
- Assessment of calcified and non calcified plaque burden
- Visualization of cardiac and coronary venous anatomy
- Establish patency of bypass grafts and stented arteries
- Diagnosis of cardiac pathology:
  - Myocardial ischemia/infarction
  - Cardiomyopathy
  - Myocardial masses
  - Cardiac valve and perivalvular regions
- Evaluate congenital heart disease

Benefits
- Noninvasive
- Decreased Cost with decreased invasive interventions
  - Over 2,000,000 catheter based coronary angiograms done per year with only 33% having direct intervention. Therefore 67% are purely diagnostic
Cardiac CTA

- Compared with ICAG the sensitivity of CTA to diagnose significant stenosis (defined as diameter reduction >50%) was 90%, specificity 94%, PPV 89% and NPV 95%
  - Diagnostic accuracy of 64 slice CT for detecting angiographically significant coronary artery stenosis in an unselected consecutive patient population comparison with conventional invasive angiography
  - Ehara M et al, Circ J 2006 May; 70(5):564-571

Cardiac CTA

- Current recommended indications
  - Unexplained chest pain in the ER or clinicians office
  - Atypical CP
  - Screening of patient at risk due to family history or elevated cholesterol
  - Unexplained CP that maybe due to an aberrant vessel

Contraindications

- Contraindications
  - Arrhythmias, relative CI
  - Target heart rate < 65 BPM or < 60 in individuals with arrhythmias, therefore usually requires administration of beta blockers
  - Patient must be able to tolerate meds
  - Breath hold of 10 sec, = patient cooperation
  - CI in extensive coronary artery calcification > 1000 Agaston units
  - Renal failure, iodine allergy
  - Appropriate technology and technique
Technical factors

- The slower the heart rate the longer the diastolic phase = better CT data acquisition
  - Beta blockers used in patients with HR >65 BPM of in patients with irregular rhythm and HR > 60 BPM
  - 50 mg metaprolol one hour prior to study
    - (unless CI ie sinus bradia, allergy, active bronchospasm, decompensated cardiac failure)
    - Alternatives: NTG and calcium channel blockers
  - Usually works within 30 minutes, if not by one hour than IV beta blockers

Cardiac CTA

- Delivery of contrast
  - Bolus Tracking Technique
    - 20 cc of contrast, with trigger for 100 HU in ascending aorta and then add 4 sec for breath hold
  - Test bolus
    - 20 cc contrast (rate of 4 cc/sec) and 40 cc saline are injected sequentially
      - Start scanning at 10 sec post start of injection and at 3 sec intervals for 10 scans
      - Select scan where contrast is brightest in ascending aorta and add 6 secs
  - Preset timing (25-28 sec)
  - Computer assisted triggering

Cardiac CTA

- 80 ml of contrast at 5cc/s followed by 50 ml (25 ml visipaque and 25 ml saline) than a 50 ml Saline flush
- Saline flush
  - Eliminates excess contrast in tubing
  - Flushes contrast from peripheral veins into central veins
  - Permits reduction in contrast volume by 20-40%
  - Reduces beam hardening artifact in RCA
Cardiac CTA - Gating

- Retrospective Gating
  - Acquire continuous acquisition with recording of the ECG therefore data can be reconstructed at any point in the R-R interval
  - Cine loops can be generated
  - Higher radiation dose

- Prospective
  - Maximum mA used only during portion of the R-R interval
  - Usual focus is 70-80% of R-R interval
  - Up to 70% dose reduction compared with retrospective gated CTA
  - Limitations
    - Images acquired during select phase of R-R interval, in patients with high heart rates or irregular beats this technique should not be used

Coronary artery anatomy

Define coronary artery anatomy and dominance
- Anomalies present in 1%
  - Aberrant origins
  - Aberrant coarse
  - Congenital stenosis of ostia
  - Coronary artery aneurysms
  - Anomalies of termination
  - Dominance – Artery that supplies the diaphragmatic aspect of the IVS and LV – 85%
    - Right sided
Normal Coronary Anatomy

Right Coronary Artery

Right Dominance - origin PDA
Anomalies of origin

- High take off above sinotubular junction
- Multiple ostia–RCA/Conus
- Anomalous origin from the opposite coronary sinus
- Anomalous origin of coronary artery from the pulmonary artery
Anomalous Origins

- Goal: Differentiate malignant (interarterial course) vs nomalignant - patients are at increased risk for sudden death if a major coronary branch crosses between the pulmonary artery and the aorta.

Interarterial Course - Malignant
Single Coronary Artery from Left Coronary Sinus

- Proximal stenosis of a single coronary artery may be devastating if there is an inability to develop collateral channels.

ALCAPA

- Most serious congenital coronary anomaly
- Anomalous origin of coronary artery from pulmonary artery
- 1:300,000 of live births
- Symptoms in infancy and early childhood
- 90% of untreated infants die in the 1st year of life
- Most common form - LCA originating from the Pulmonary artery “Bland White Garland Syndrome”
- Collateral circulation between RCA and LCA goes to PA resulting in “Coronary Steal Phenomenon”
ALCAPA

- Anomalous origin of the left coronary artery from the pulmonary artery with multiple collaterals in the interventricular septum and dilated right coronary artery

ALCAPA post surgical repair

- Ligation of LCA os
- Creation of anastamosis between the Internal mammary and LCA
- Subsequent diminished collaterals and RCA size

Myocardial Bridge

- Band of myocardial muscle overlying a segment of coronary artery
- Most commonly involving the middle segment of the LAD
- Maybe asymptomatic versus symptomatic (arrhythmia, angina, infarction)
- If a myocardial bridge is suspected reconstructed images should be done in both diastole and systole
  - Evaluating for luminal narrowing in systole
Myocardial Bridge

Myocardial Bridge-Diastole

Myocardial Bridge-Systole
Coronary artery aneurysms

- Most commonly involves RCA and 2nd LAD
- Coronary aneurysms - diameter dilatation by 50%
  - Kawasaki's, atherosclerosis, trauma, cocaine, SLE, rheumatic fever

Anomalies of Termination

- Coronary fistula - communication exists between one or two coronary arteries and
  - cardiac chamber
  - coronary sinus
  - superior vena cava
  - pulmonary artery
- Coronary arcade -
  - Large, angiographic identifiable communication between LCA and RCA (in absence or CAD)
- Extra cardiac termination
  - Connections between coronary arteries and extra cardiac vessels, i.e. bronchial arteries (usually associated with CAD)

Anomalies of Termination

Coronary fistula

- Myocardial perfusion may be diminished resulting in "Steal Phenomenon"
- Involved artery is dilated tortuous
- Common site of drainage
  - RV 45%, RA 25%, PA 15%
  - When connected with left sided chamber: Aortic Insufficiency
  - When connected to right sided chamber: left to right shunt
Coronary artery fistula

- Multiple tortuous communicating vessels originating from the RCA and draining into the main pulmonary trunk

Calcium Scoring

- Useful in assessing the risk in an individual patient of developing clinical coronary artery disease
- Coronary artery calcification is an atherosclerosis marker indicating intimal atheroma, often before there is a reduction of luminal diameter > 50%, after which they become detectable by other modalities i.e. SPECT and stress ECG
- Rapid progression of atherosclerotic plaque as assessed by coronary calcium detection using EBCT has been associated strongly with cardiovascular events
- A negative/zero calcium score is associated with a high negative predictive value (nearly 100%) for excluding hemodynamically relevant CAD

Calcium Scoring

- The greater the amount of calcium, the greater the likelihood of occlusive CAD, but there is not a 1:1 relationship
- Total amount of calcium correlates best with the total amount of atherosclerotic plaque, although the true burden is underestimated
- Total burden of atherosclerotic disease rather than severity of focal stenoses may be a more significant prognostic indicator of subsequent cardiac events
Calcium Scoring

- The Framingham risk estimation serves as the basis for identifying asymptomatic adults that should be treated with ASA and lipid lowering therapy in primary prevention
- The traditional risk factor assessment might fail to identify certain populations with significant subclinical atherosclerosis
  - Women (Hx + sibling with CAD) were classified as low risk by FRE but a third had significant subclinical atherosclerosis
    - Michos ED et al., AM heart J 2005; 150(6):1276-81

Calcium Score

- Agatston Analysis - HU weights, are assigned numbers (1 for 130-200 HU, 2 for 201-299 HU, 3 for 300-399 HU, 4 for 400HU) and multiplied by the area of each lesion to obtain individual lesion score, which are then summed throughout the coronary tree to obtain a total calcium score
  - Minimal 1-10
  - Mild 11-100
  - Moderate 101-399
  - Severe >400

Bad News for Calcium Scoring

- Patients can have a large plaque burden with little calcium
- Vulnerable plaques tend to have thin fibrous cap and large lipid core
Calcium Scoring

- Detection of coronary artery calcification has utility in:
  - Early detection of calcification in asymptomatic persons in whom risk-factor modification may be indicated
  - Evaluation of the progression of calcification as an indicator of the activity of the atherosclerotic process
  - Demonstration of absence of calcification, to rule out significant stenoses

Coronary CTA

- Coronary risk factors by CT
  - Calcium scoring
  - Diameter stenosis
  - Total plaque burden
  - Plaque distribution and character
    - Vessel may be modestly stenotic and invisible to angiography but prone to rupture
  - Artery wall remodeling
  - All of which need to be integrated with patients risk features

Myocardial Infarction

- Acute
  - Hypoperfusion
  - Impaired function
  - Evaluation of viability/ischemia

- Chronic
  - Myocardial thinning
  - Calcification or fatty metaplasia
  - Hypo/akinesis
Acute Myocardial Infarction

Ventricular aneurysm
- True – Contains myocardial elements in the wall
  - Only likely to rupture in the early postinfarction period
  - Managed medically unless associated CHF or arrhythmia
  - Anterolateral/Apical

Ventricular Pseudoaneurysm
- False - rupture of the myocardium that is contained by pericardial adhesions
  - High risk of rupture therefore require surgical repair
  - Posterolateral wall
  - Neck is small compared to aneurysm
Cardiac masses

- Nonmalignant – 80% of cardiac masses
  - Thrombus
  - Myxoma – Most common tumor 25%
  - Lipoma/Lipomatous hypertrophy of the atrial septum
  - Hemangioma
  - Teratoma
  - Pheochromocytoma
  - Papillary fibroelastoma

- Children
  - Rhabdomyoma – 40% cardiac tumors,
    - 30-50% in patients with TS
  - Fibroma – 2nd most common, may cause arrhythmias

Benign Cardiac Tumors

- Myxoma - 75% left atrium pedunculated, prolapsing through valve
  - Goal of imaging is to define site of attachment-usually from septa at fossa ovalis

Lipoma

- Homogeneous, low-attenuation masses either in a cardiac chamber or in the pericardial space
Lipomatous Hypertrophy of the Interatrial Septum
- Deposit of fat in the atrial septum, which exceeds 2 cm in transverse dimension
  - Not encapsulated and not a true neoplasm
  - Associated with advanced age and obesity
  - More common than cardiac lipoma

Papillary Fibroelastoma
- Attached to valves by a short pedicle in 90%
- Second most common benign tumor
- 29% Aortic valve
- Symptoms are related to embolization of thrombi; therefore right-sided tumors usually are asymptomatic

Cardiac Fibroma
- Cardiac fibromas are often associated with arrhythmias
- Second most common primary cardiac tumor associated with sudden death
- Increased prevalence of cardiac fibromas in Gorlin syndrome
- Homogeneous masses with soft-tissue attenuation that may be either sharply marginated or infiltrative
  - Little or no contrast material enhancement
  - Calcification is often seen
Malignant Cardiac Masses

- Malignant
  - Metastatic disease
  - Primary malignant
  - Lymphoma, lung, breast and melanoma
  - Carcinoid
  - Rhabdomyosarcoma
  - Sarcomas
  - Pericardial Mesothelioma

Pericardium

- Normal thickness < 2 mm, triangular shape, lateral and posterior walls of left ventricle usually not visible

Pericardial Disease

- Pericarditis
- Pericardial Effusion
- Cyst - most common mass
- Hematoma
- Primary Neoplasm
  - Lipoma, teratoma, fibroma, hemangioma
  - Mesothelioma, lymphoma, sarcoma
- Metastatic neoplasm
  - Lung, breast, lymphoma, melanoma
Constrictive Pericarditis

- +/- Calcifications, presence of calcifications does not mean constrictive
- Focal or diffuse thickening, >4mm
- Etiologies:
  - Prior cardiac surgery
  - IRX to the chest (can occur up to 10 years later)
  - TB #1 cause in some parts of the world
  - prior pericarditis (viral, uremic)
- Evaluate for secondary signs of constrictive disease
  - Increased right sided pressures
    - Septum is deviated (to the left) or straightened interventricular septum
    - Dilated IVC
    - JVP
    - Ascites, pleural effusions

Constrictive Pericarditis

Congenital Anomalies of the Pericardium

- Absence of the pericardium
  - Complete
    - Heart is shifted to the left
    - Benign
    - Associated defects
      - ASD, defects in parietal pleura, TOF, PDA, bronchogenic cysts
      - Pulmonary sequestration 30%
      - Pectus Excavatum 80%
  - Partial absence, usually on the left
    - Chest pain, syncope and sudden death
Partial absence
- Protrusion and compression of ventricles through defect

Congenital absence
- Interposition of lung tissue between the aorta and the main segment of the pulmonary artery

Complete Absence
Myocardium

Myocardial thickness
- End diastole 10-12mm, Systole 20-24 mm
- Cardiomyopathy
  - Dilated
  - Hypertrophic
  - Restrictive - Need to differentiate from constrictive pericarditis
    - Both have similar hemodynamic features
    - Differential essential- constrictive pericarditis can be treated with surgical resection whereas restrictive cardiomyopathy is usually fatal
- Arrhythmogenic Right Ventricular Dysplasia

ARVD
- Fat in free wall of right ventricle
  - Classical description but least reliable sign
  - Thinning of the RV wall - difficult to differentiate from normal
  - Dilatation of the right ventricle
  - Enlargement of the trabeculae
  - Scalloped appearance, sacculations, aneurysms of the right ventricular wall
  - Regional or global RV contractile dysfunction
  - RV myocardial delayed enhancement
  - Endomyocardial biopsy has low sensitivity due to location of disease versus location of biopsy

ARVD
- Finding fat in the right ventricular myocardium alone does not suggest a diagnosis of ARVD
- Evaluate for associated findings
- DDX of fat in the ventricular wall -
  - Healthy patients
  - Dilated cardiomyopathy
  - Hypertrophic cardiomyopathy
  - Kawasaki disease
  - Old myocardial infarction
ARVD
- Slight bulging of the anterior wall of the right ventricle and fatty tissue is seen in the right ventricular aspect of the subendocardial portion of the ventricular septum

ARVD
- Fatty tissue is noted in the trabeculae of the anterior wall and the right ventricular aspect of the ventricular septum

CABG Patency
Stent Patency

Left Atrial and Pulmonary Vein Mapping

- Indications
  - Ablation for atrial fibrillation-Ectopic foci of electrical activity in ostia or muscular sleeves of pulmonary veins
  - Pre evaluation - anatomy
  - Post procedure - complications

Pulmonary Vein Ablation
- Pulmonary veins
- Accessory pulmonary veins
- Diameter and location of ostia
- Left Atrial size
- +/- thrombus (CI to procedure)
Valve Morphology and Anatomy

- **Aortic Stenosis**
  - Supravalvular – Congenital/Williams Syndrome
  - Valvular – Congenital or Acquired
    - Usually associated with poststenotic dilatation of ascending aorta
    - Degenerative Aortic Stenosis
      - #1 cause of calcific aortic stenosis in adults
      - Congenital – Usually related to bicuspid valve and is the most common congenital heart anomaly
      - Rheumatic valvular stenosis
  - Subvalvular

Aortic Stenosis

- Normal aortic valve opening area of 3–4 cm²
- A decrease to approximately one-fourth of the normal area results in a hemodynamically significant stenosis
  - Mild aortic stenosis = valve area of 1.5 cm²
  - Moderate aortic stenosis = valve area between 1.0 and 1.5 cm²
  - Severe aortic stenosis = valve area of 1.0 cm² or less
  - Critical aortic stenosis = valve area of 0.7 cm² or less
Aortic Stenosis

- Presence of a bicuspid aortic valve
- Evaluation for extensive valve calcification
  - associated with a higher prevalence of surgical difficulties with
  - placement and fixation of the valve prosthesis into the annulus

Aortic Stenosis

- Slight calcification of aortic cusps
  - decreased $AVA = 1.46 \text{ cm}^2$, mild stenosis

Aortic Stenosis

- Moderate Aortic Stenosis = $AVA = 1.10 \text{ cm}^2$, which indicated
- Severe Aortic Stenosis = $AVA = 0.93 \text{ cm}^2$
Pulmonic Stenosis

- Pulmonic stenosis manifests as dilatation of the main and left pulmonary arteries with a relatively normal caliber right pulmonary artery
- RVH due to right ventricular outflow obstruction