State-of-the-Art CTA
When Should We Use It Instead of MRI?

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State-of-the-Art CTA
When Should We Use It Instead of MRI?

Before we jump into that lets see what cardiac MRI can do first

Cardiac Magnetic Resonance Imaging (CMR)

- CMR - is not just one test, it is many tests rolled into one modality
- Similar to catheterization in some way but, non-invasive and without radiation exposure
- Similar to CT angiography but without radiation exposure
- Similar to echocardiogram but without acoustic window limitations

Cardiac Magnetic Resonance Imaging (CMR): Advantage

- Obtain morphologic data in any anatomic plane
- Volumetric and functional data
- Flow data-possible to obtain in any vessel
- Advance imaging techniques
  - Myocardial tissue characteristics
    - Late gadolinium enhancement – scar
    - Early gadolinium enhancement - inflammation
    - T1 mapping for diffuse fibrosis
    - T2 mapping for edema
    - T2* for iron deposition
    - First pass perfusion
  - Tagged imaging for myocardial strain
  - And more….

Cardiac Magnetic Resonance Imaging (CMR): Advantage

- Safer contrast agents with more options
- No radiation!

Estimated Risks of Radiation-Induced Fatal Cancer from Pediatric CT

David J. Brenner[1]
Carl D. Elliston[1]
Eric J. Hall[1]
Walter E. Berdon[2]

OBJECTIVE. In light of the rapidly increasing frequency of pediatric CT examinations, the purpose of our study was to assess the lifetime cancer mortality risks attributable to radiation from pediatric CT.

MATERIALS AND METHODS. Organ doses as a function of age-at-diagnosis were estimated for common CT examinations, and estimated attributable lifetime cancer mortality risks (per unit dose) for different organ sites were applied. Standard models that assume a linear extrapolation of risks from intermediate to low doses were applied. On the basis of current standard practice, the same exposures (milliampere-seconds) were assumed, independent of age.

RESULTS. The larger doses and increased lifetime radiation risks in children produce a sharp increase, relative to adults, in estimated risk from CT. Estimated lifetime cancer mortality risks attributable to the radiation exposure from a CT in a 1-year-old are 0.18% (abdominal) and 0.07% (head)—an order of magnitude higher than for adults—although those figures still represent a small increase in cancer mortality over the natrual background rate. In the United States, of approximately 600,000 abdominal and head CT examinations annually performed in children under the age of 15 years, a rough estimate is that 500 of these individuals might ultimately die from cancer attributable to the CT radiation.

CONCLUSION. The best available risk estimates suggest that pediatric CT will result in significantly increased lifetime radiation risk over adult CT, both because of the increased dose per milliampere-second, and the increased lifetime risk per unit dose. Lower milliampere-second settings can be used for children without significant loss of information. Although the risk–benefit balance is still strongly tilted toward benefit, because the frequency of pediatric CT examinations is rapidly increasing, estimates that quantitative lifetime radiation risks for children undergoing CT are not negligible may stimulate more active reduction of CT exposure settings in pediatric patients.

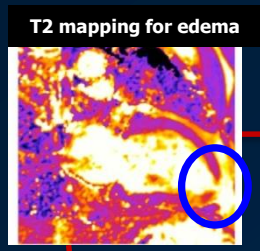
Cardiac Magnetic Resonance Imaging (CMR): Advantage

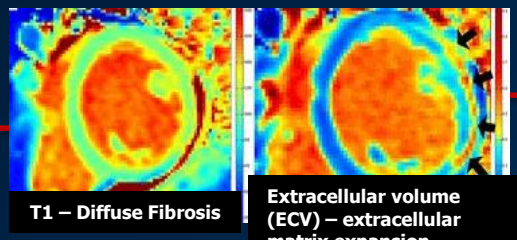
- Radiation and children do not mix
- Children are more sensitive to radiation
  - 10-fold greater risk than middle-aged adult
    - Dividing cells most susceptible
    - More time for genotoxic effects to be manifested
  - Predictions from Atomic bomb survivor data
    - Pediatric CT studies may cause eventual cancer-related death of 1/1000 children

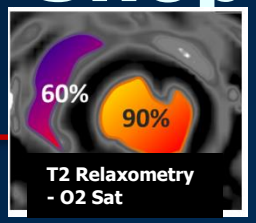
Brenner et al, AJR 2001, Brenner et al Ped Radiology 2002, Hall et al, Ped Radiology 2002, Pierce et al, Rad Res 2000, Benz et al Pediatrics 2004, Slovis et al, Ped Radiology 2002, Pearce et al, Lancet 2012, Chodick et al, Imaj 2007, Journey et al, J Rad Protection, 2016

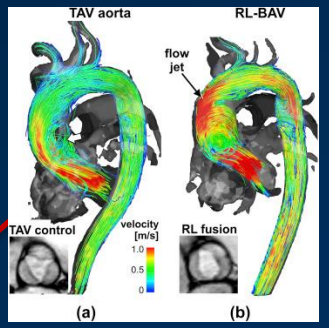
Lets see what cardiac MRI can do

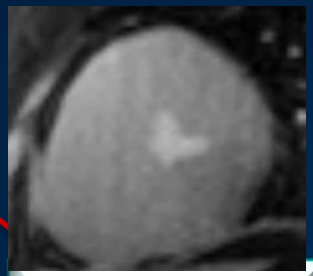
Cardiac Magnetic Resonance Imaging (CMR): One Stop Shop

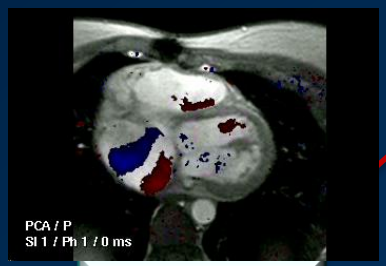


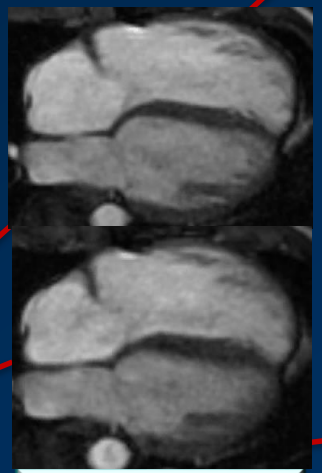






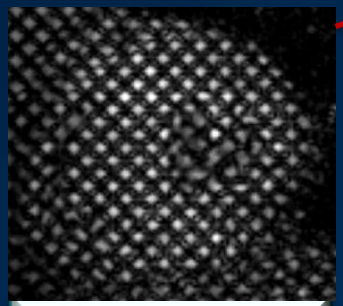


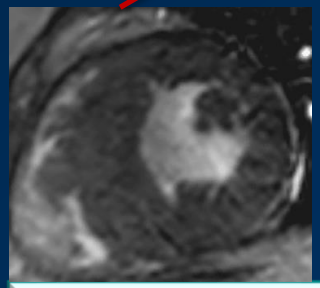


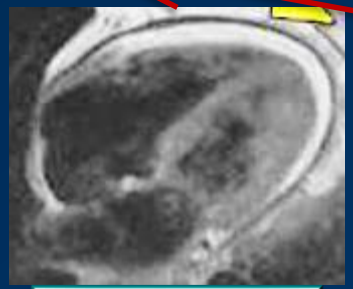


Myocardial Tissue Characteristic

Cardiac MRI







When to use Cardiac CT

- Cardiac MRI – comprehensive diagnostic test
- But there are times when we should consider a CT instead:
  - Risk of heating up
  - Risk of movement
  - Interruption of device function
  - Artifacts from device, stents or coils
  - Sedation issues/risk

Horwood t al, Europace, 2016, Russo et al, Circ 2014, Langman et al, Pacing Clin Electrophy 2011, Langman et al, JMRI 2011, Higgins et al, Pacing Clin Electrophy 2014, mrisafety.com,

When to use Cardiac CT

- Absolute contraindications to MRI
  - Pacemaker*, defibrillators, wires (conductance)
    - **Basis**: unclear but includes heating, malfunction and movement
    - *Exception: MR conditional pacemaker
  - Metallic foreign body in eye (metal workers)
    - **Basis**: movement and heating
  - Deep brain stimulator/other stimulators
    - **Basis**: heating along wire, malfunction
  - Swan-Ganz catheters
    - **Basis**: wires causes melting of adjacent catheter

Horwood t al, Europace, 2016, Russo et al, Circ 2014, Langman et al, Pacing Clin Electrophy 2011, Langman et al, JMRI 2011, Higgins et al, Pacing Clin Electrophy 2014, mrisafety.com, Ferreira et al, Med Dev, 2014

When to use Cardiac CT

- Absolute contraindications to MRI Cont'
  - Bullets or gunshot pellets
    - **Basis**: movement and heating especially risk to adjacent vital organs
  - Cerebral aneurysmal clips
    - **Basis**: if magnetic, will move and risk tearing of aneurysm and bleeding
  - Cochlear implants/drug infusion devices
    - **Basis**: temporary or permanent malfunction

Horwood t al, Europace, 2016, Russo et al, Circ 2014, Langman et al, Pacing Clin Electrophy 2011, Langman et al, JMRI 2011, Higgins et al, Pacing Clin Electrophy 2014, mrisafety.com, Ferreira et al, Med Dev, 2014

When to use Cardiac CT

- Absolute contraindications to MRI Cont'
  - Implantable Pediatric Sternal Device (Magnetic Mini-mover) - Pectus
    - **Basis**: loss of magnetization
  - "Triggerfish" Contact lens (records intra-ocular pressure)
    - **Basis**: heating causing severe burn
  - Temporary or abandoned pacemaker wires
    - **Basis**: conductive material causing heating
  - More Information on MRI Safety (mrisafety.com)

Horwood t al, Europace, 2016, Russo et al, Circ 2014, Langman et al, Pacing Clin Electrophy 2011, Langman et al, JMRI 2011, Higgins et al, Pacing Clin Electrophy 2014, mrisafety.com, Ferreira et al, Med Dev, 2014

Cardiac Assessment: CT Versus MRI

- CT Scan
  - Radiation exposure: 2-10 mSv = 3-5 yr back ground radiation
  - Cost $1200-3000
  - Time = < seconds
  - Application: vascular, bone and lungs
  - Better spatial resolution
  - Scan in systole HR >90, diastole HR < 90 or whole cardiac cycle
- MRI
  - None - MRI does not emit ionizing radiation
  - Cost $1200-5500
  - Time = minutes to hours
  - Application: vascular and soft tissue
  - Better temporal resolution
  - MRA is collected over many heart beats and average of systole and diastole

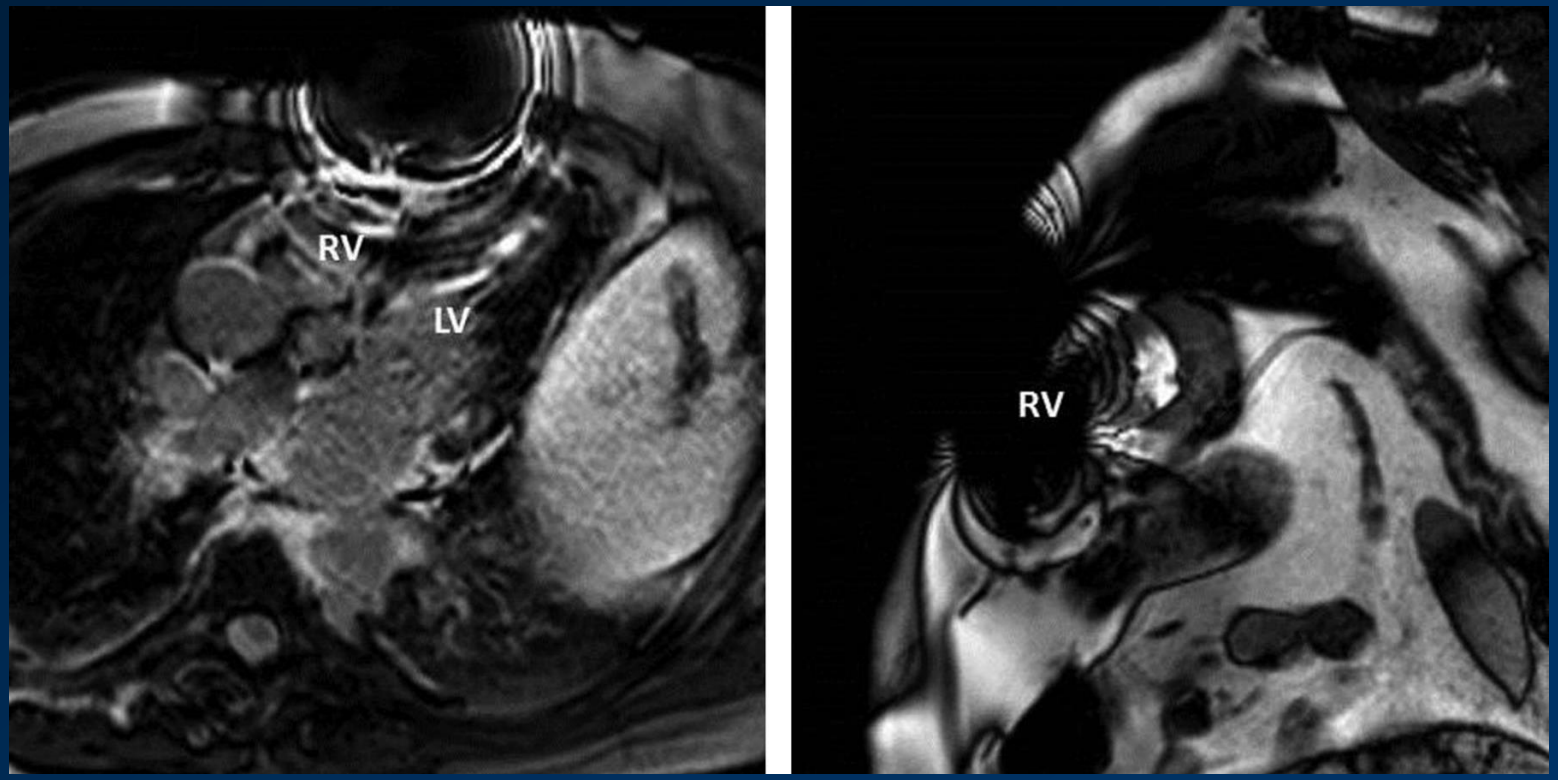
When to use Cardiac CT

- When CT can provide what MRI cannot or is better
  - The need for speed
    - CTA takes 0.35 to 0.5 seconds
    - MRA 15-20 seconds per dynamic
    - 3D Whole Heart can take 5-10 minutes depending on multiple factors
  - Avoid or minimize sedation
    - **Basis:** in some patients initiation of anesthesia adds significant risk (Williams Syndrome, pulmonary hypertension, unstable patients)

Han et al, JCCT, 2013

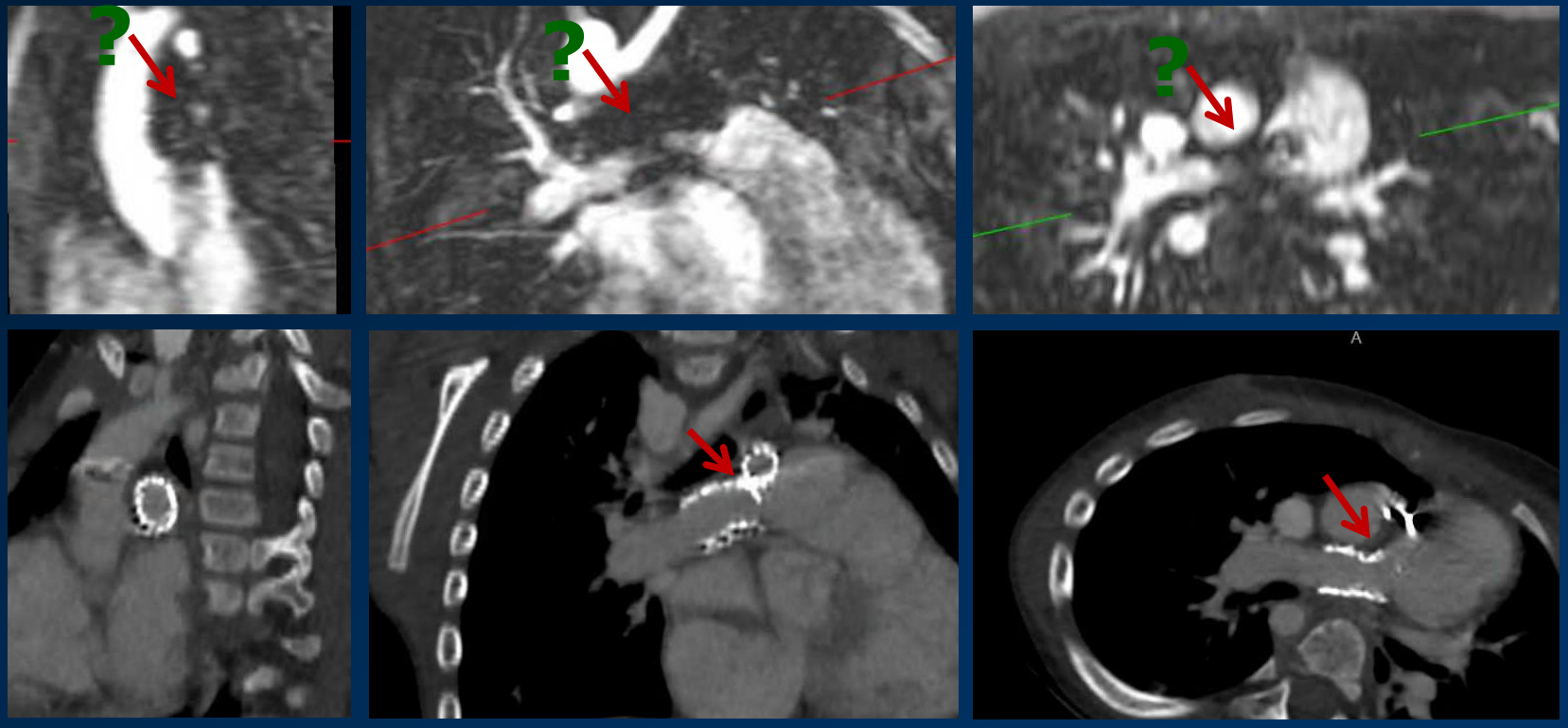
When to use Cardiac CT

- Artifacts from coils, stents, clips and other devices that are significant – can not interpret what you cannot see



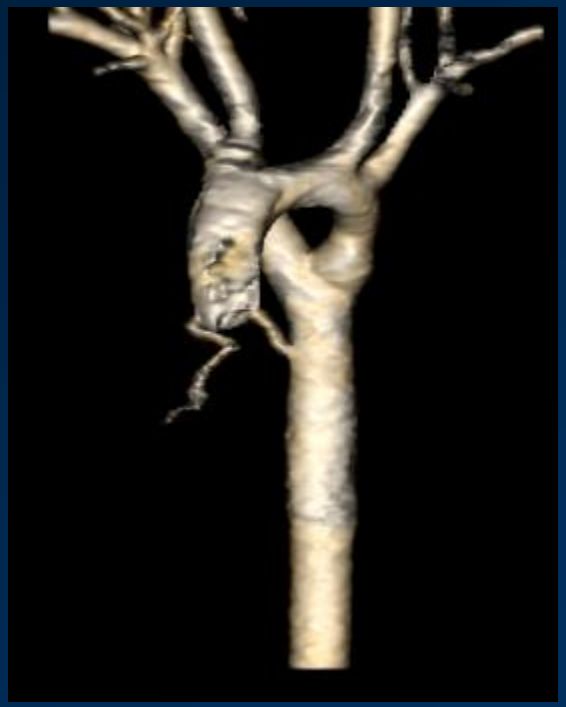
When to use Cardiac CT

- Inside devices/stents
  - Example of an RPA stent: cannot tell by CMR what stent looks like



When to use Cardiac CT

- 3D Relationship
  - Example: relationship of airway to vascular structures in 3-dimensions in double aortic arch

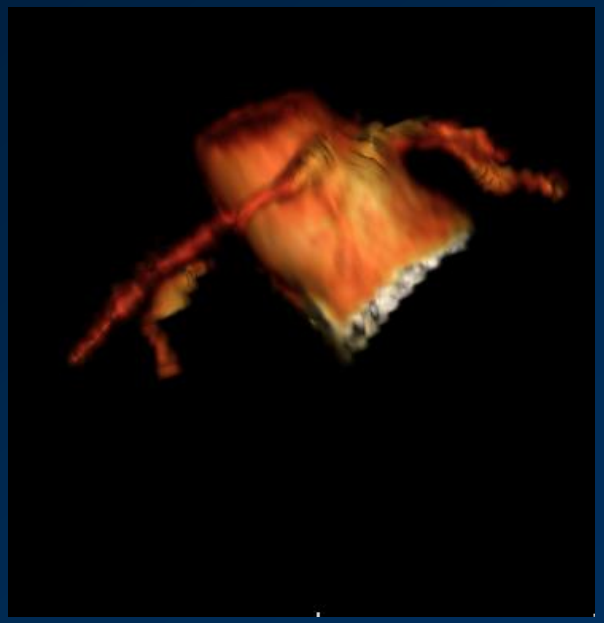


CMR

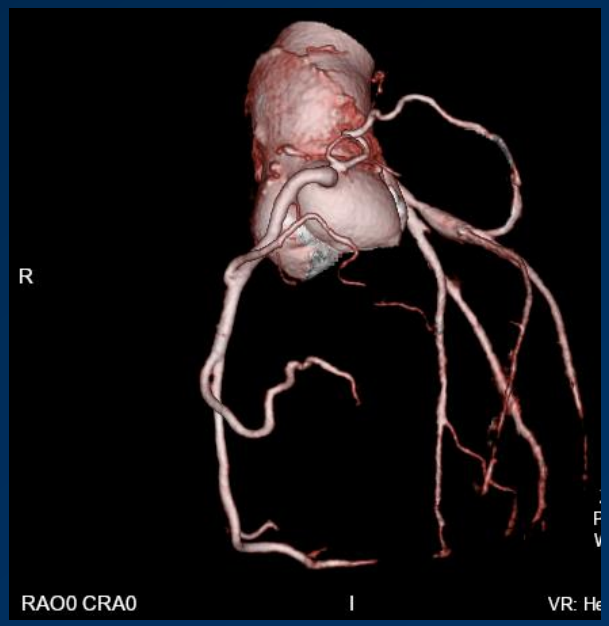
CT

When to use Cardiac CT

- Detail assessment of coronary artery system
  - Example: CMR (origins and proximal course) in anomalous origins of the RCA
  - CTA: delineated the whole course with details



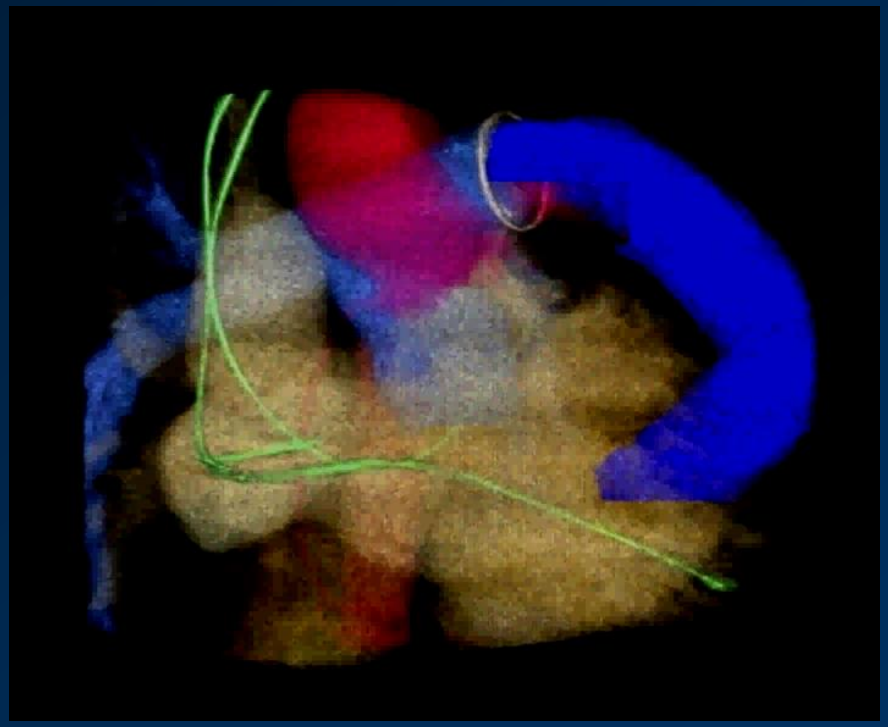
CMR



CT

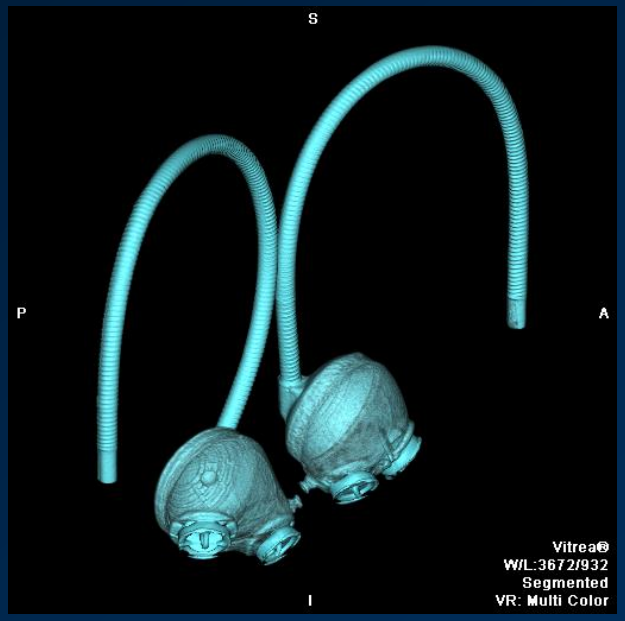
When to use Cardiac CT

- Tracking wires or catheters course
  - Example: D-TGA s/p Senning with apical LV to PA conduit – when leads go off course.
  - Where is the ventricular lead?



When to use Cardiac CT

- Device planning
  - Example: case of SynCardia Total artificial heart from scanning device, pre-operative, virtual implantation to post-implantation



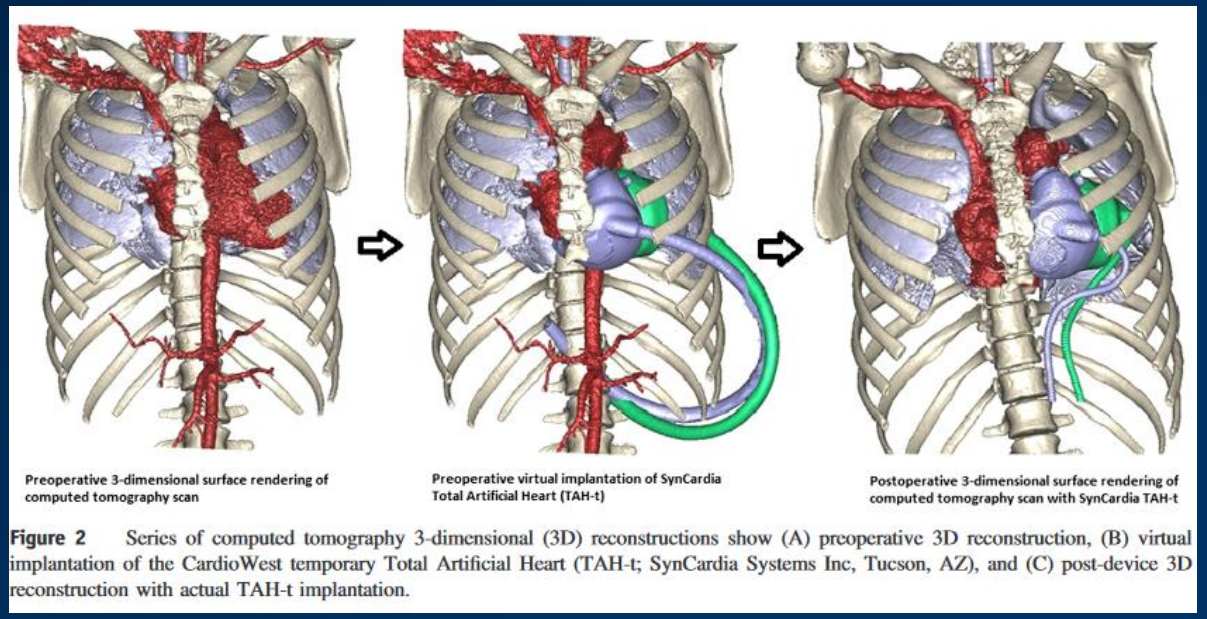
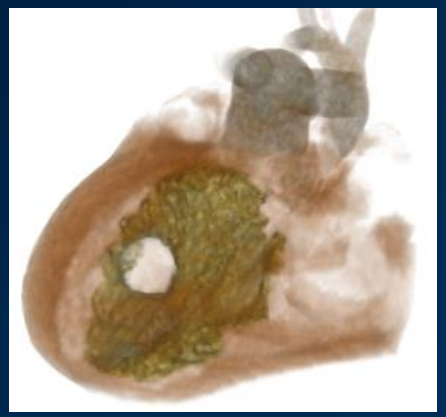
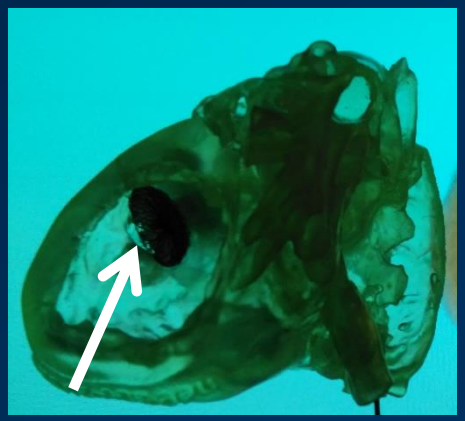
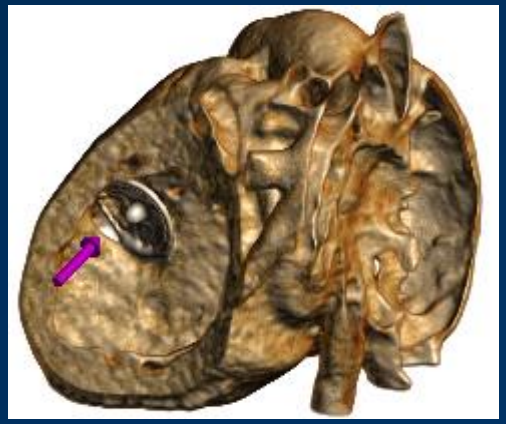
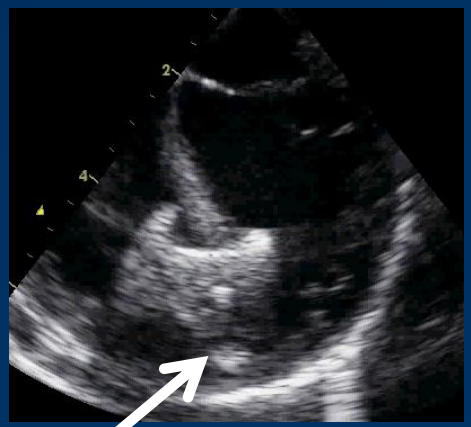


Figure 2 Series of computed tomography 3-dimensional (3D) reconstructions show (A) preoperative 3D reconstruction, (B) virtual implantation of the CardioWest temporary Total Artificial Heart (TAH-t; SynCardia Systems Inc, Tucson, AZ), and (C) post-device 3D reconstruction with actual TAH-t implantation.

Moore et al, J Heart Lung Transplant, 2016

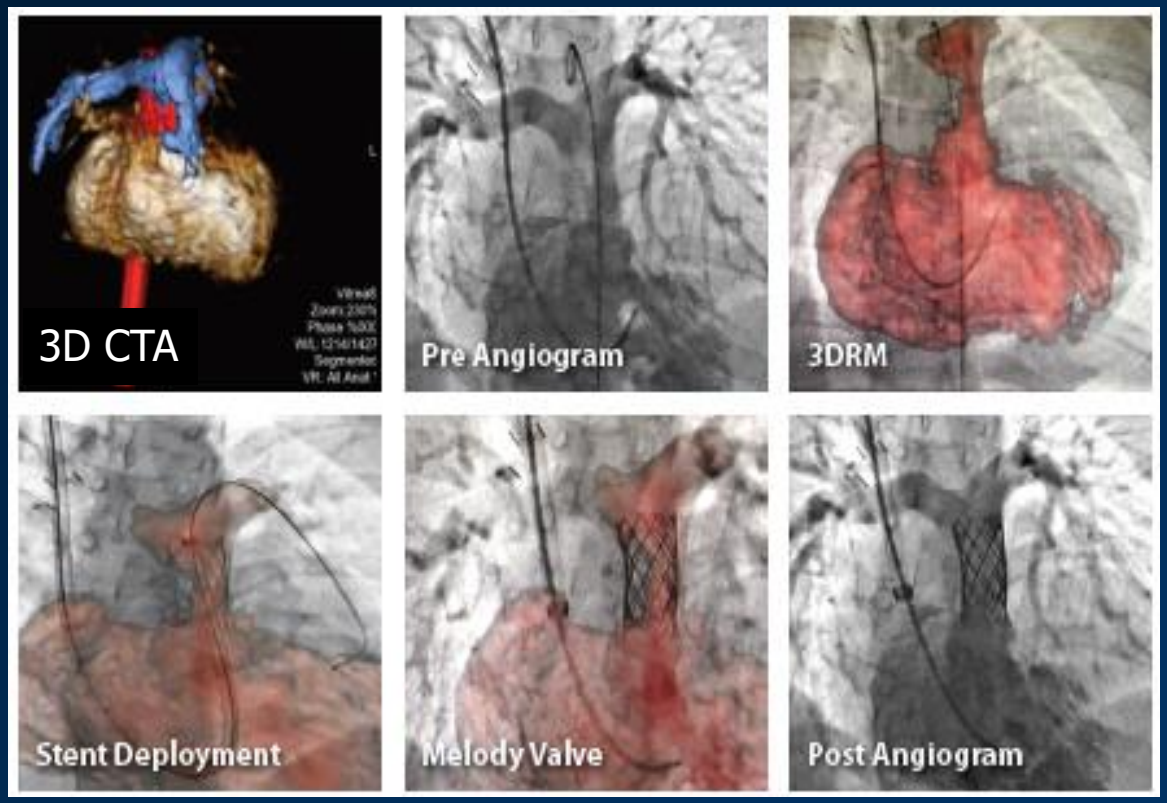
When to use Cardiac CT

- Device planning
  - Example: case of large apical muscular VSD, what is the best approach?
  - 3D dataset for virtual assessment, 3D printing for device selection, post-device assessment on model and implantation
  - Trans-atrial approach by modeling with prediction of small residual defect

When to use Cardiac CT

- Fusion for Catheterization (decrease time, contrast and radiation exposure)?
  - Example: Overlay of 3D for Melody valve



- **CT** offers easier overlay as there are structures (airway and bone) that can be used to map without the need to plan ahead

MRI on the other hand needs some marker (planning ahead needed)

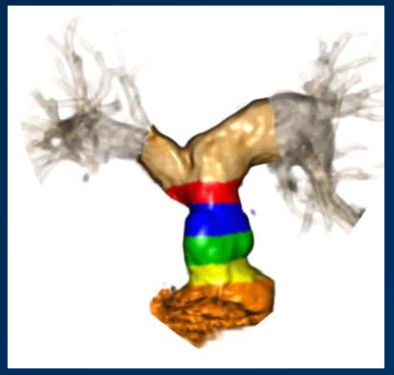
*https://medical.**toshiba**.com/download/angio-cs-multi-modality-**fusion***

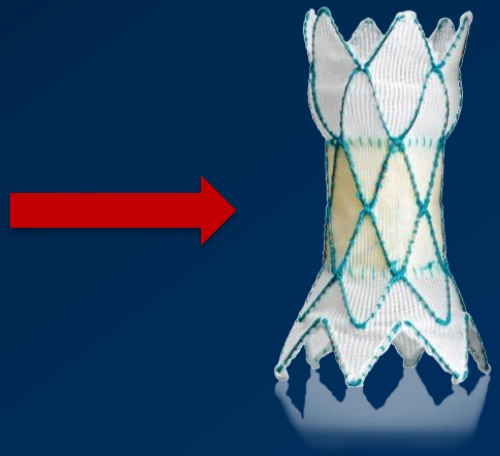
When to use Cardiac CT

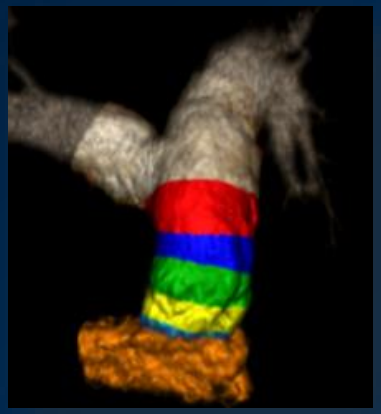
- Dynamic vs Static 3D Imaging
  - Example: Native Transcatheter Pulmonary Valve Trial to assess which many RVOT variant fits into a single self expandable valve
  - Can static MRA: performed over multiple heart beats predict best candidate compared to dynamic CT?

When to use Cardiac CT

- Using 3D static imaging from MRA: can we predict which RVOT fits into this valve?



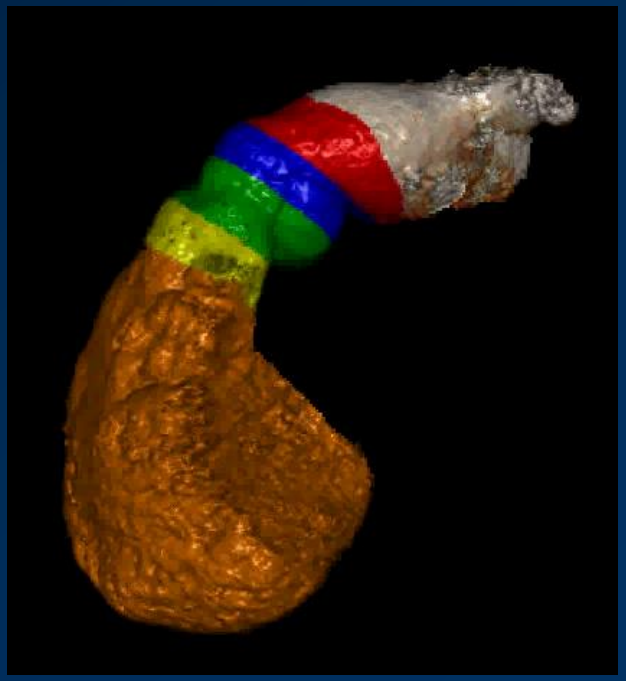
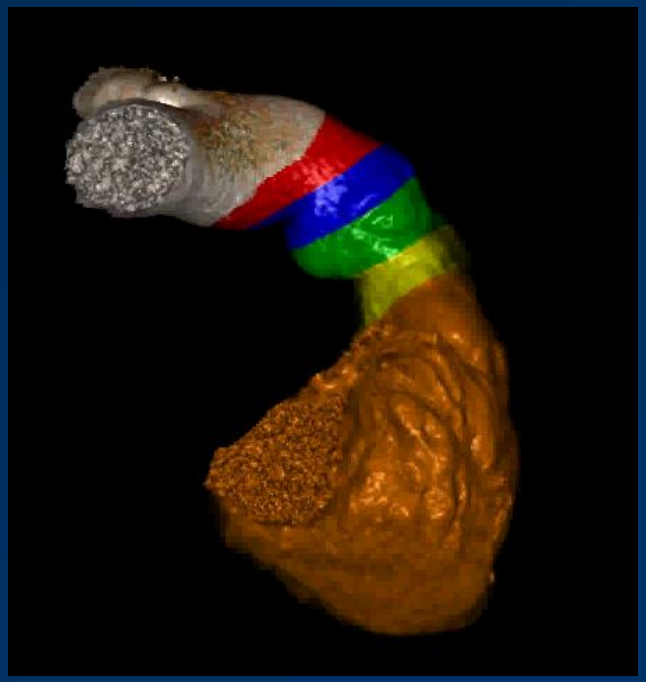




No, this RVOT was too dynamic!

When to use Cardiac CT

- Dynamic vs Static 3D Imaging
  - Based on current method, MRA compare to CTA has a wide limit of agreement
  - Future MRI technique has to address this dynamic component


Stay tune for more of this in a future talk

Thank you!

Questions?

3DRA

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CT Angiography: When to use Cardiac CT

- Pacemakers – generally absolute contraindication:
  Exception -> MRI-conditional pacemakers

Table 1

Main modifications introduced in MRI-conditional pacing systems

Modification	Purpose
Reduction in ferromagnetic components	Reduce magnetic attraction and susceptibility artifacts
Replacement of reed switch by Hall sensor	Avoid unpredictable reed switch behavior
Lead coil design and insulation	Minimize lead heating and electrical current induction
Filter circuitry	Prevent damage to internal power supply
Dedicated pacemaker programming	Prevent inappropriate pacemaker inhibition
	Prevent competing rhythms

Ferreira et al, Med Dev, 2014