Protocols in Cardiac CT

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DALHOUSIE UNIVERSITY

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Disclosure Statement: No Conflict of Interest

I do not have an affiliation, financial or otherwise, with a pharmaceutical company, medical device or communications organization.

I have no conflicts of interest to disclose (i.e. no industry funding received or other commercial relationships).

I have no financial relationship or advisory role with pharmaceutical or device-making companies, or CME provider.

I will not discuss or describe in my presentation at the meeting the investigational or unlabeled ("off-label") use of a medical device, product, or pharmaceutical that is classified by Health Canada as investigational for the intended use.

Objectives

1. At the end of this session, participants will be able to define the most up to date gating and scanning techniques utilized in acquiring cardiac CT.
2. Upon completion of the session, participants should be able to explain the rationale behind the various methods of contrast opacification of cardiac structures during cardiac CT using novel techniques.
3. At the end of this session, participants will be able to integrate the latest cardiac CT protocols into their daily practice.

Outline

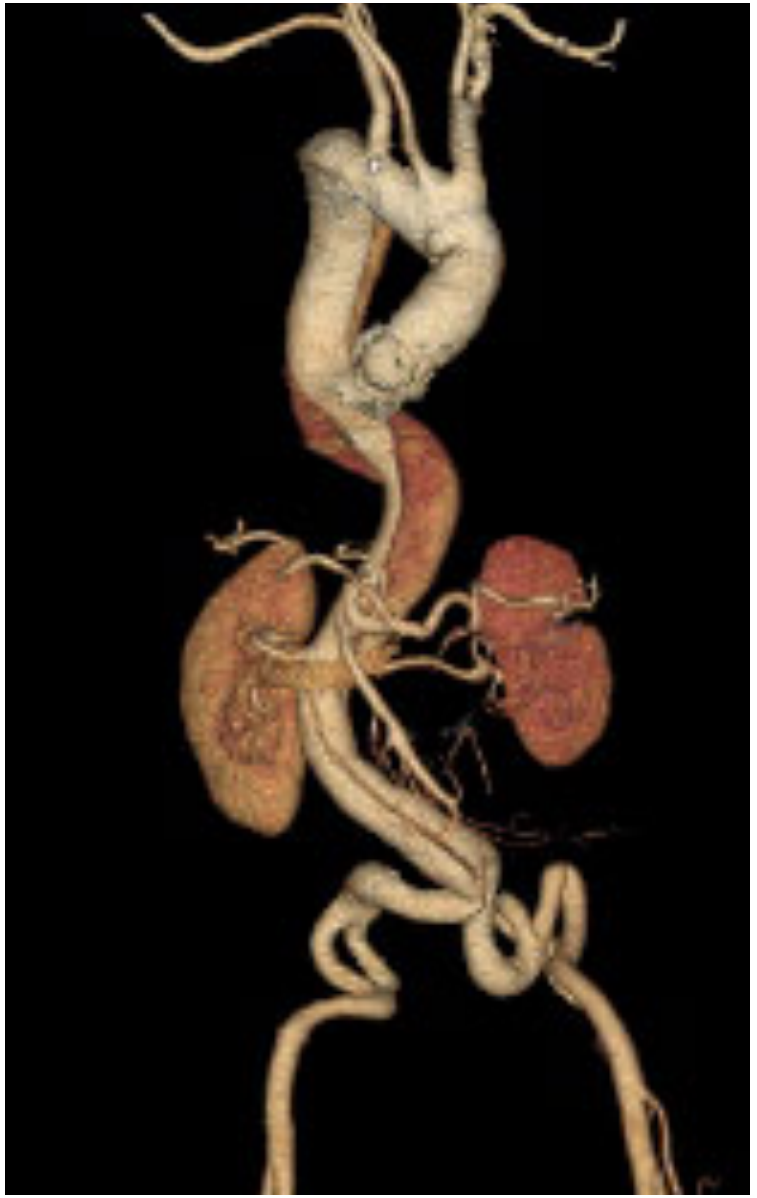
1. Review some fundamental principles of CTA before outlining the impact of recent technological CT advancements on cardiovascular CTA acquisition

2. Discuss a selection specific cardiac CT protocols using *case examples*

Modern CTA technique

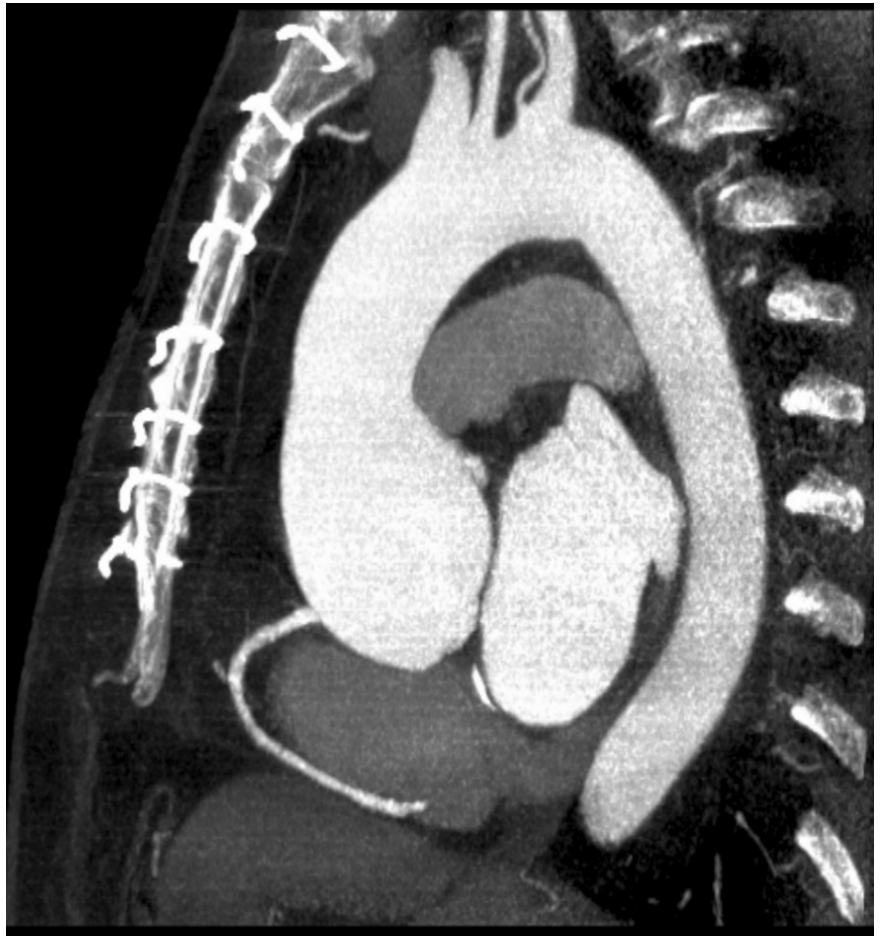
Still based on the following principles:

1. Fast, high resolution volumetric CT data acquisition
2. Strong contrast medium enhancement in the vascular structures of interest
3. 2D, 3D, or 4D image post-processing



Arterial enhancement:

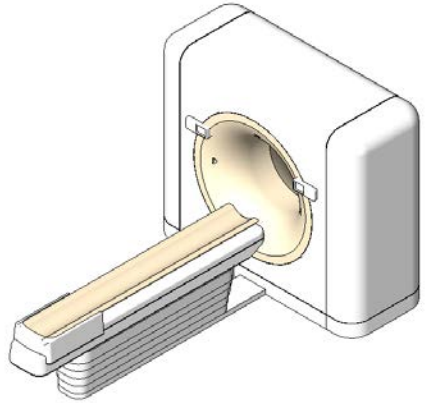
1. directly proportional to the contrast media injection rate (amount of iodine injected/unit of time)
2. increases cumulatively with longer injection duration
3. inversely proportional to cardiac output (typically unknown, but correlates reasonably well with body weight)
4. require short delay to fully opacify of large or diseased vessels



Basic contrast injection protocol for aortic CTA

- **Scan time**: 10 seconds (or less)
- **Injection duration**: 18 seconds
- **Injection rate**: weight based (5 cc/s for an 75-kg patient= 90 mL)
- **Scan timing**: automated bolus triggering off asc aorta with 8 second delay after contrast arrival is detected
  - using an injection duration longer than the scan time + extra 8 seconds ensures adequate filling even if significant pathology is present

Scan Time (Helical)



$T_{(scan)}$ = number of rotations* x gantry rotation time

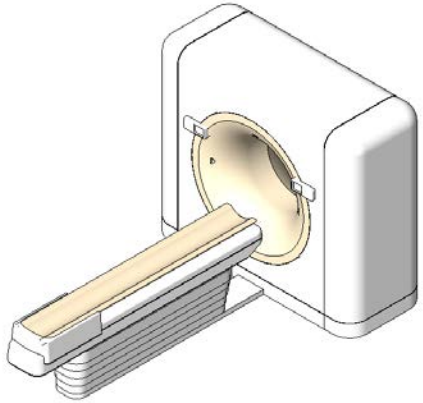
*Number of rotations = anatomic coverage (mm)/detector bank width (mm) x pitch

Table 2
Technical parameters of latest CT equipment by four major vendors

	X-Ray Tube Power Rating and Max. mA	Detector Design (Rows × mm)	Detector Bank Width	Channels (n)	Gantry Rotation (ms)	Temporal Resolution (ms)
GE revolution (Waukesha, WI)	103 kW 740 mA	256 × 0.625	16 cm	512	270 ms (200 ms)[a]	135 ms (100 ms)[a]
Phillips iCT (Best, The Netherlands)	120 kW 1000 mA	128 × 0.625	8 cm	256	270 ms	135 ms
Siemens FORCE (Erlangen, Germany)	2[b] × 120 kW 2[b] × 1300 mA	2[b] × 96	5.8 cm	2[b] × 192	250 ms	66 ms
Toshiba ONE (Otawara, Japan)	100 kW 900 mA	320 × 0.5	16 cm	640	275 ms	138 ms

[a] Faster gantry rotation announced.
[b] Indicates dual-source technology, which allows use of higher pitch

Scan Time – Step and Shoot



1. For volumes that are <u>smaller than the detector bank</u>
   - the scan time ***equals*** the gantry rotation time
2. For ECG triggered scans of the heart
   - the scan time is just slightly more than ***half*** the gantry rotation time
3. For volumes that are <u>larger than the detector bank</u>
   - the scan ***times for each group*** are added to the ***interscan time intervals*** needed for table repositioning

Scan Time vs. Temporal Resolution

Scan time:

- time it takes to acquire all the projection data for the entire anatomic volume scanned

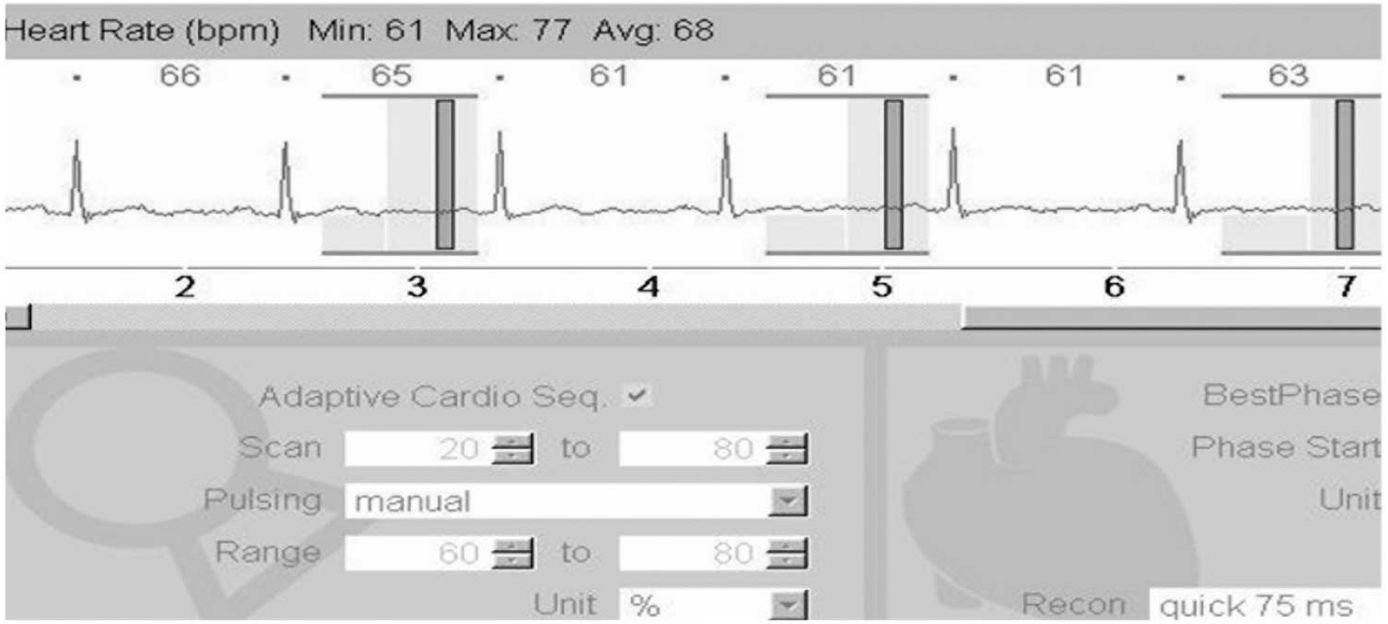
Temporal resolution:

- time window needed to acquire the projection data needed to reconstruct one CT image of many in a dataset

Temporal resolution can be much ***shorter*** than the scan time:

- *half* the gantry rotation time in single-source CT systems
- *quarter* of the gantry rotation time in dual-source CT systems

ECG Gating



- ECG gating techniques:
  - prospective gating
  - retrospective gating
  - high pitch gated mode

- Previously selection mainly depended on purpose/type of the study and patient factors (HR, etc.)…*now,* choice often relates the CT scanner model and its capabilities

Selection of ECG gating technique

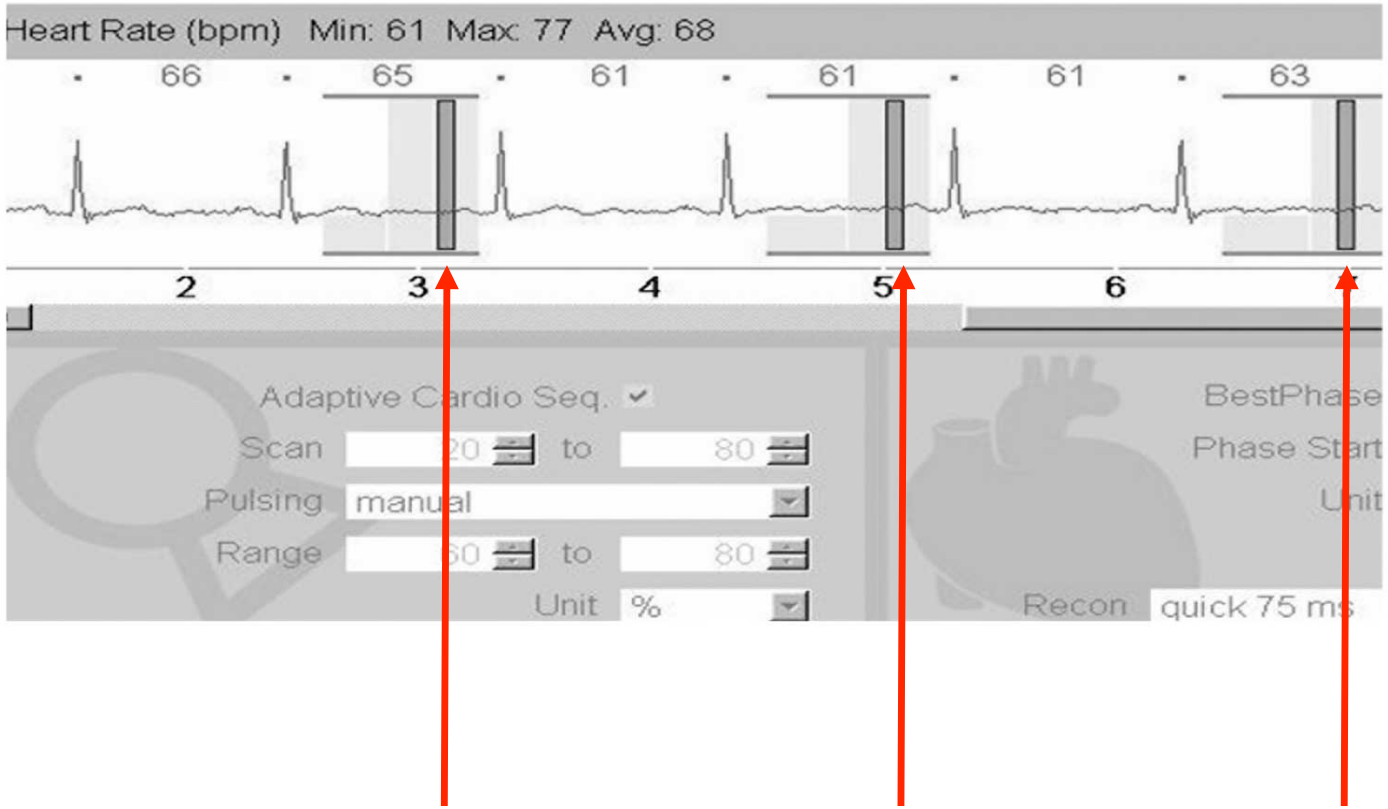
- Large detectors (8 cm or more) can use prospective triggering and still cover the entire volume of interest in a few seconds

- Smaller detectors (4 cm or less) can use helical acquisitions, which end up being faster than if they used prospective triggering even at low pitch

- Retrospective gating can be used with minimal to no dose penalty nowadays, provided rigorous ECG-based tube current modulation is used

Selection of ECG gating technique

- The most important consideration for any ECG synchronized study is the selection of the <u>width of the exposure window</u> relative to the cardiac cycle



Selection of ECG gating technique

- For many cardiovascular CTAs (coronaries, aortic root) the window is minimized (eg only at *diastole*) and any of the following modes can be used:
  - Prospective triggering
  - Retrospective gating
  - High-pitch mode (dual-source)

Selection of ECG gating technique

- If both systolic and diastolic phases of the cardiac cycle need to be visualized (functional, valvular, etc.), wider exposure windows are needed and the following modes can be used:
  - prospective triggering
  - retrospective gating

- With modern scanners, the radiation exposure is less determined by the mode of ECG synchronization used (prospective/retrospective), but more so by the proportion of cardiac phases that need to be evaluated to answer the clinical question

Cardiac CT Protocol

Case Examples

(Basic contrast injection protocol for aortic CTA)

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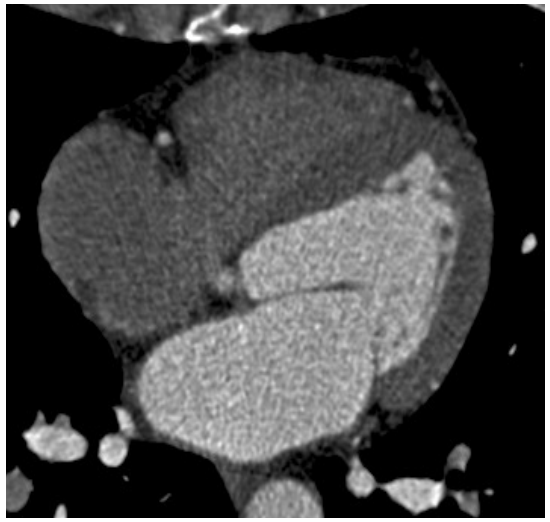
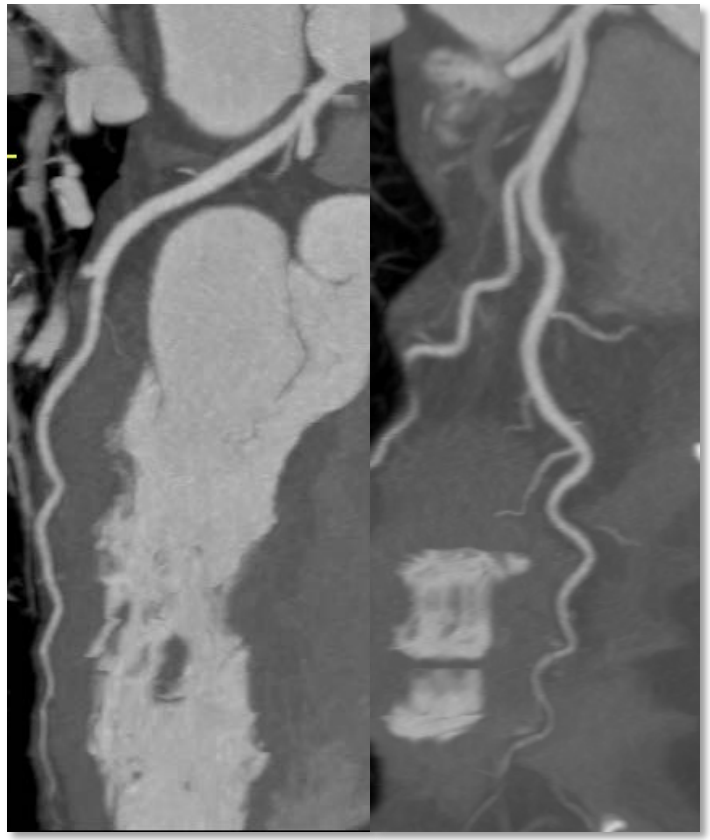
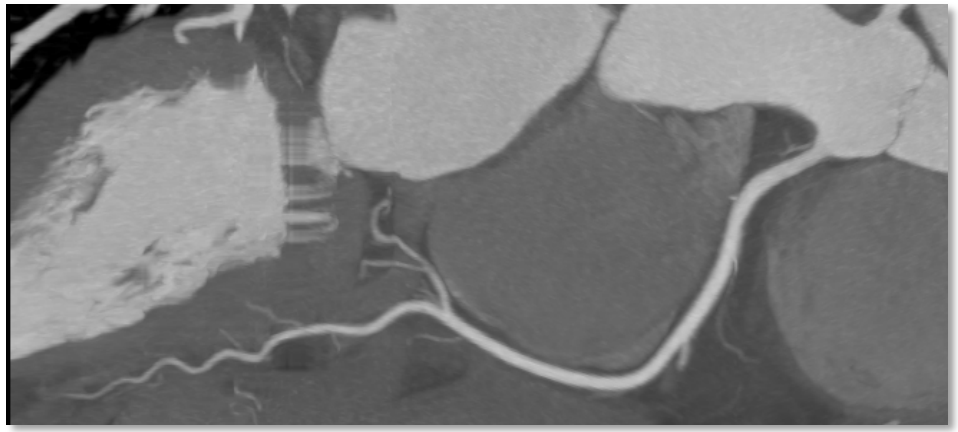
  - using an injection duration longer than the scan time + extra 8 seconds ensures adequate filling even if significant pathology is present

Coronary CTA

- Expand on basic CTA contrast injection protocol (mentioned previously)
- Triphasic contrast injection
  - phase 1 — 50 mL contrast at 5 cc/s
  - phase 2 — 50 mL 60/40 contrast/saline at 5 cc/s
  - phase 3 — 50 mL saline at 5 cc/s
- Scan timing: automated bolus triggering off asc aorta with 5 second delay after contrast arrival is detected

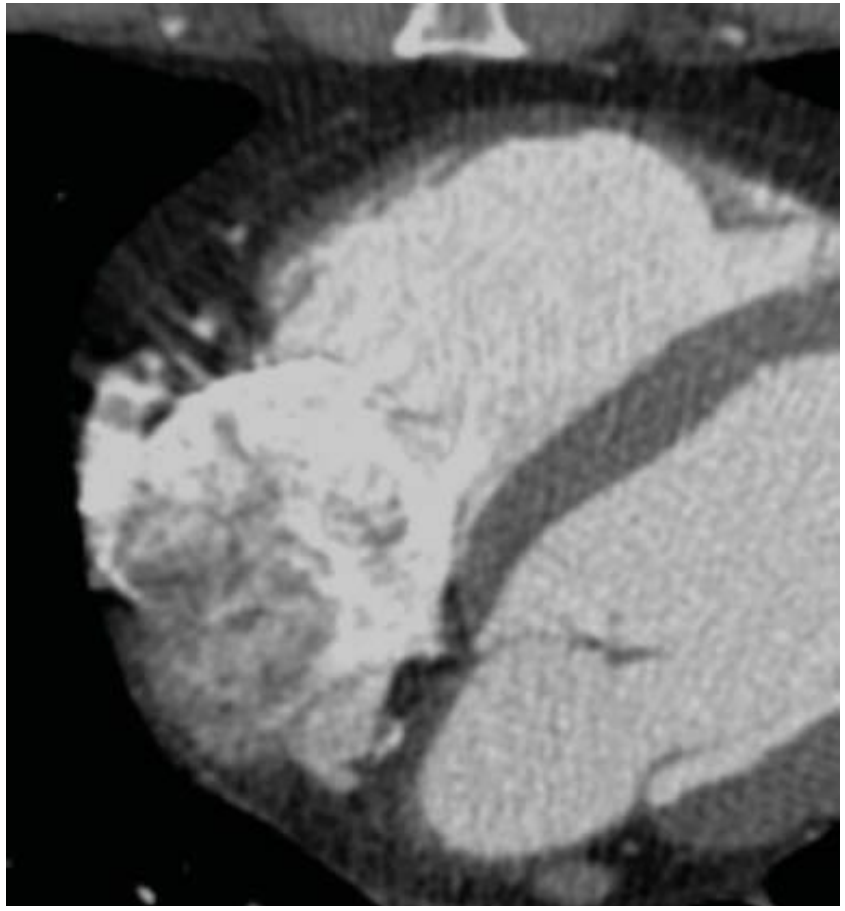


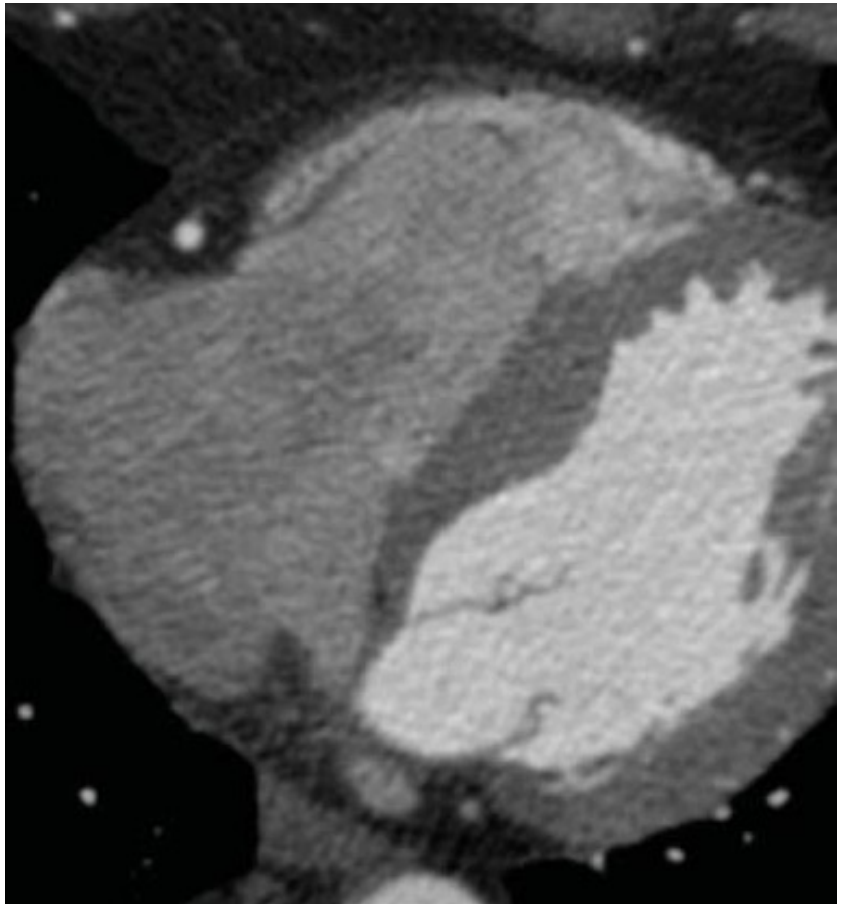




Saline

- Flush reduces streak artifact from veins being injected
- 60/40 mix results in intermediate attenuation in right heart to still allow some visualization of right heart structures while minimizing artifact

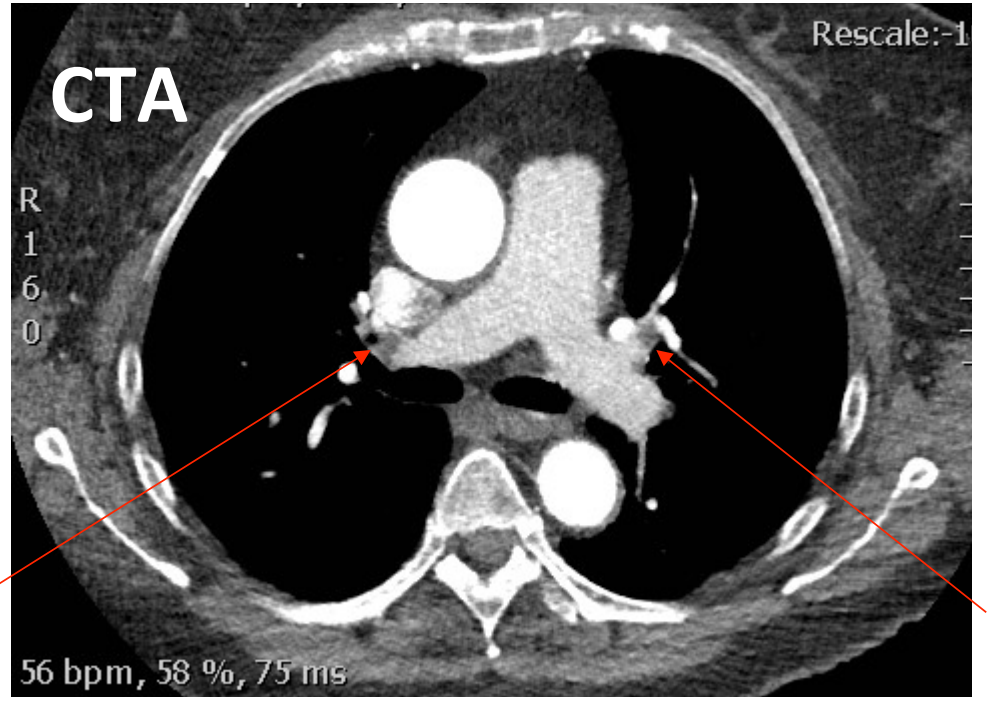


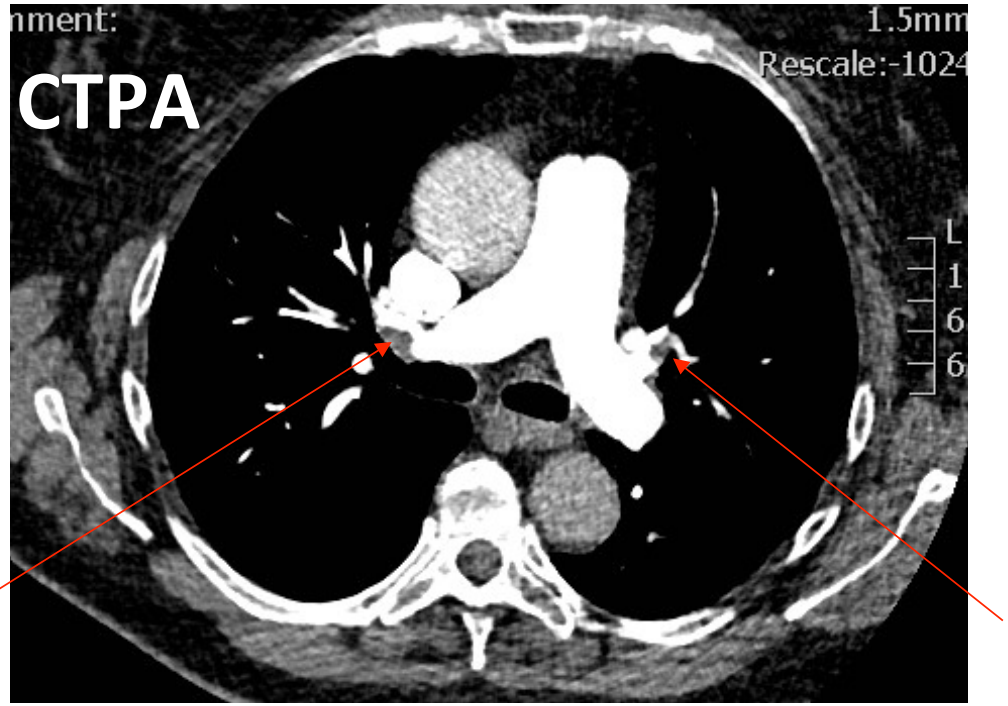


Beyond basic CTA protocol

"Triple Rule Out"

- Simultaneously opacify <u>three separate vascular territories</u>
  - PA – coronaries – Thoracic aorta
  - Reflect both *right* and *left* heart circulations

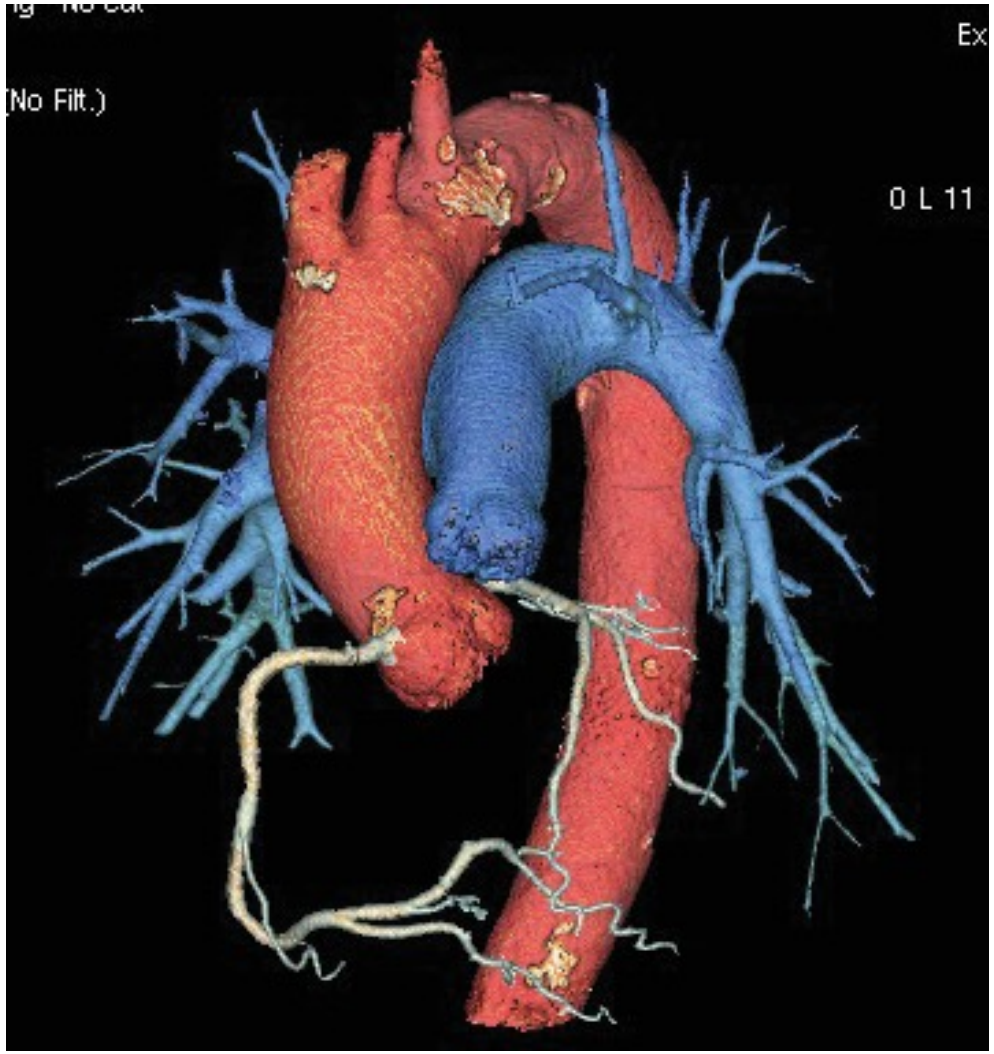




Triple Rule Out

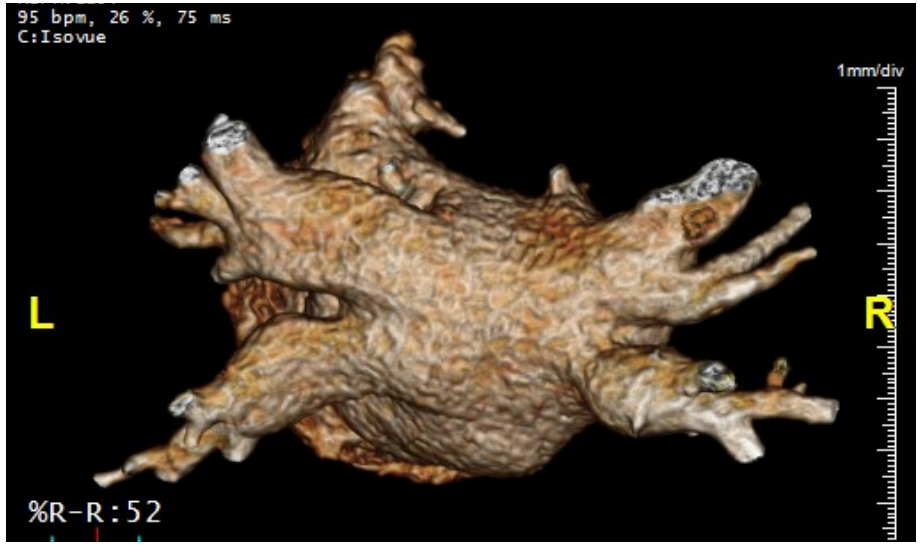
- Expand on basic CTA contrast injection protocol (mentioned previously)
- Modified biphasic contrast injection
  - phase 1 — 70 cc contrast at 5 cc/s
  - phase 2 — 50 cc 50/50 contrast/saline at 5 cc/s

- Scan timing: automated bolus triggering off LA with 5 second delay after contrast arrival is detected



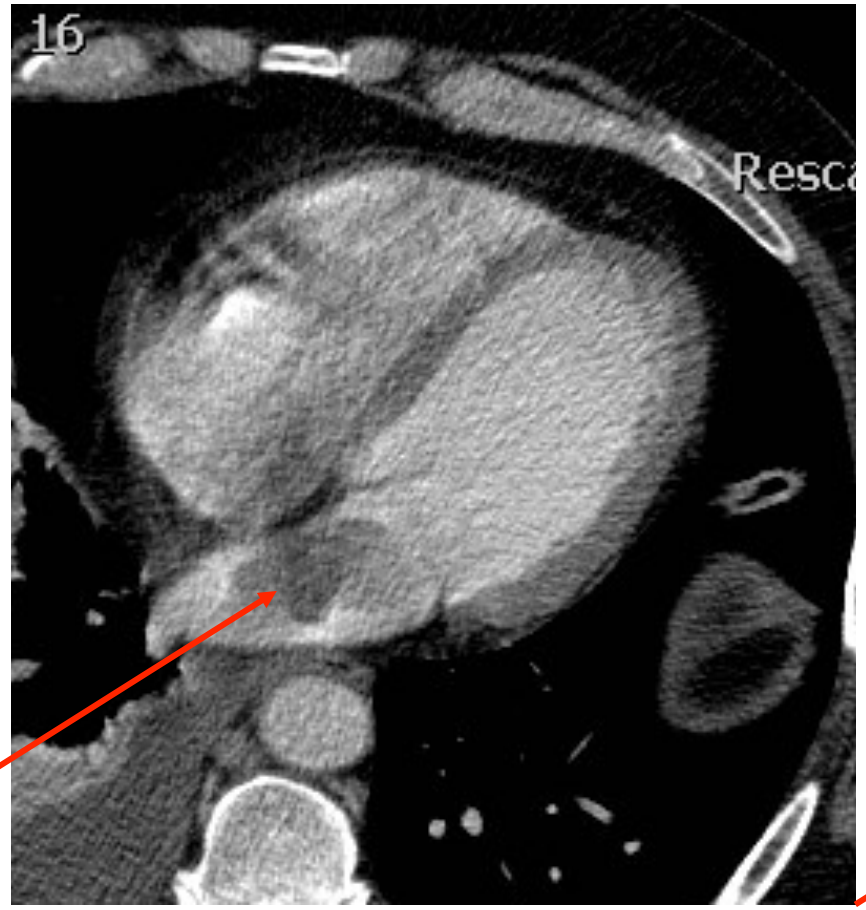
Pulmonary Vein Anatomy for AFIB ablation

- Triphasic “coronary” injection
- **Scan timing**: automated bolus triggering off LA with 5 second delay after contrast arrival is detected
- Can do further delay or scan prone if underfilling of LAA (“pseudothrombus”) is a problem +/- ECG gating



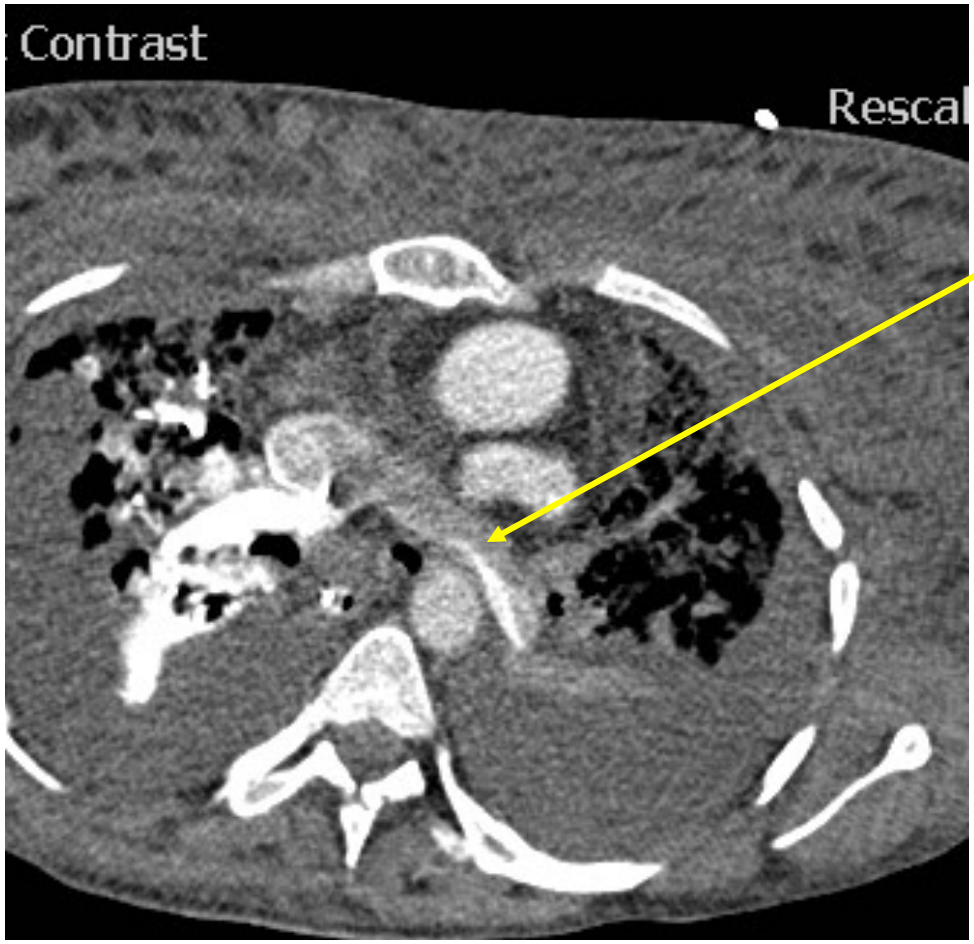
Cardiac Mass

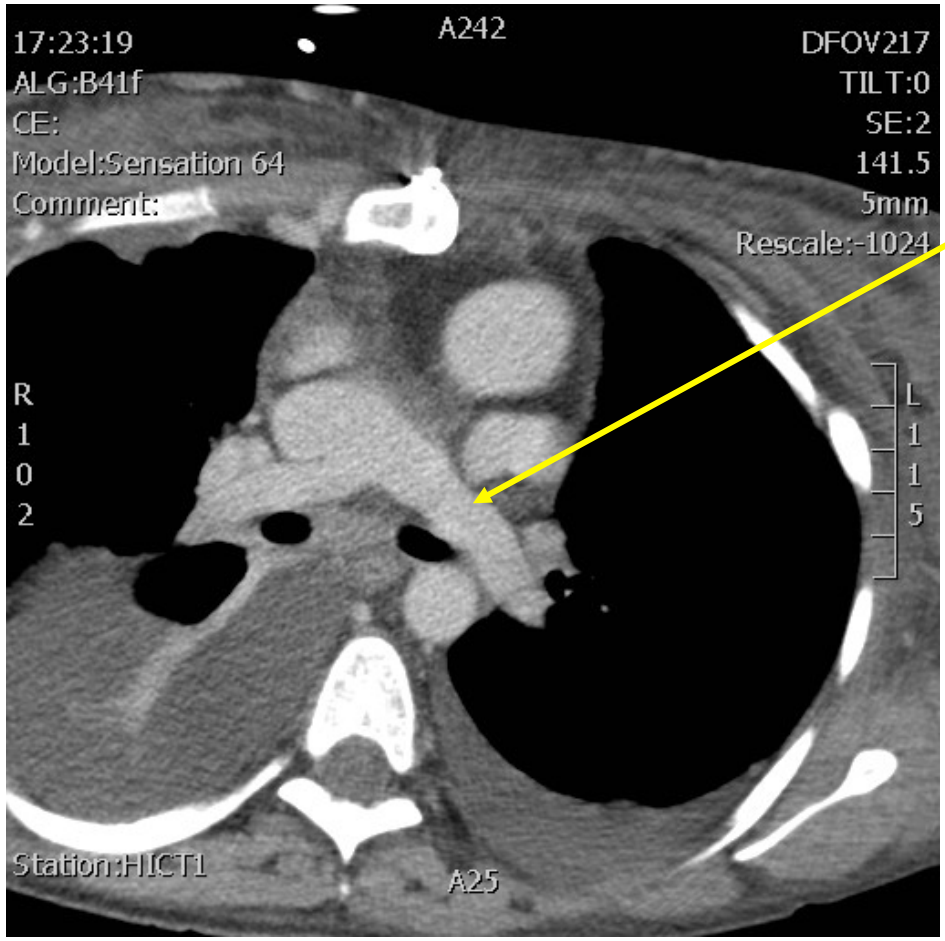
- ECG gating and add delayed phase 90-120 sec



CHD – Fontan – Query PE

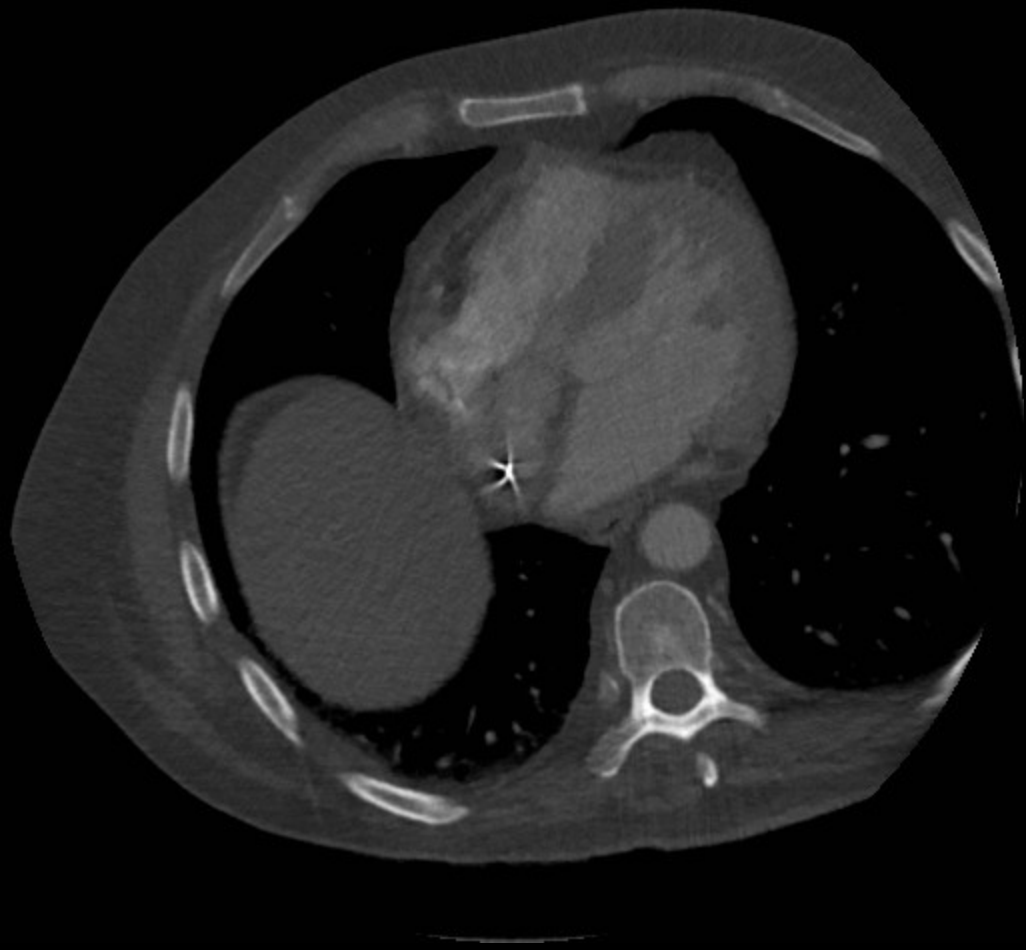
- 90-120 sec delay to allow recirculation and opacification of venous return from IVC through to LPA (RPA opacifies early from SVC via right arm injection)

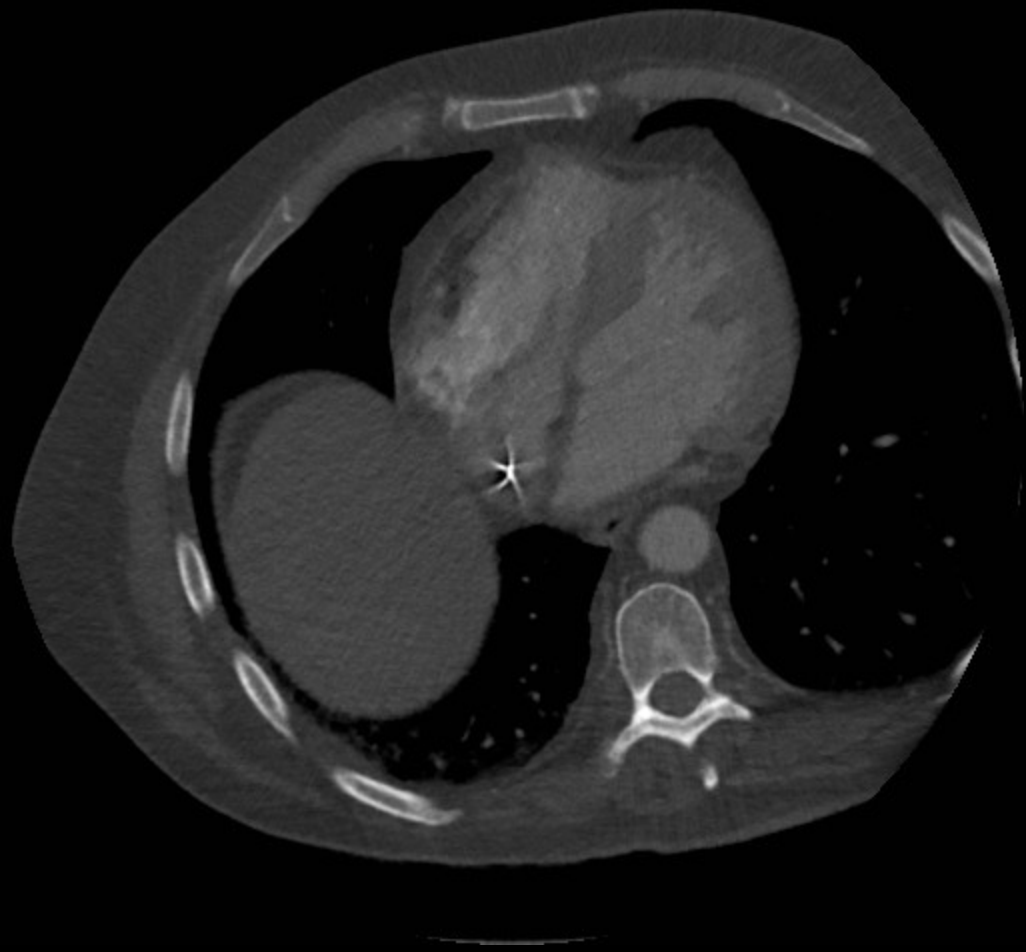


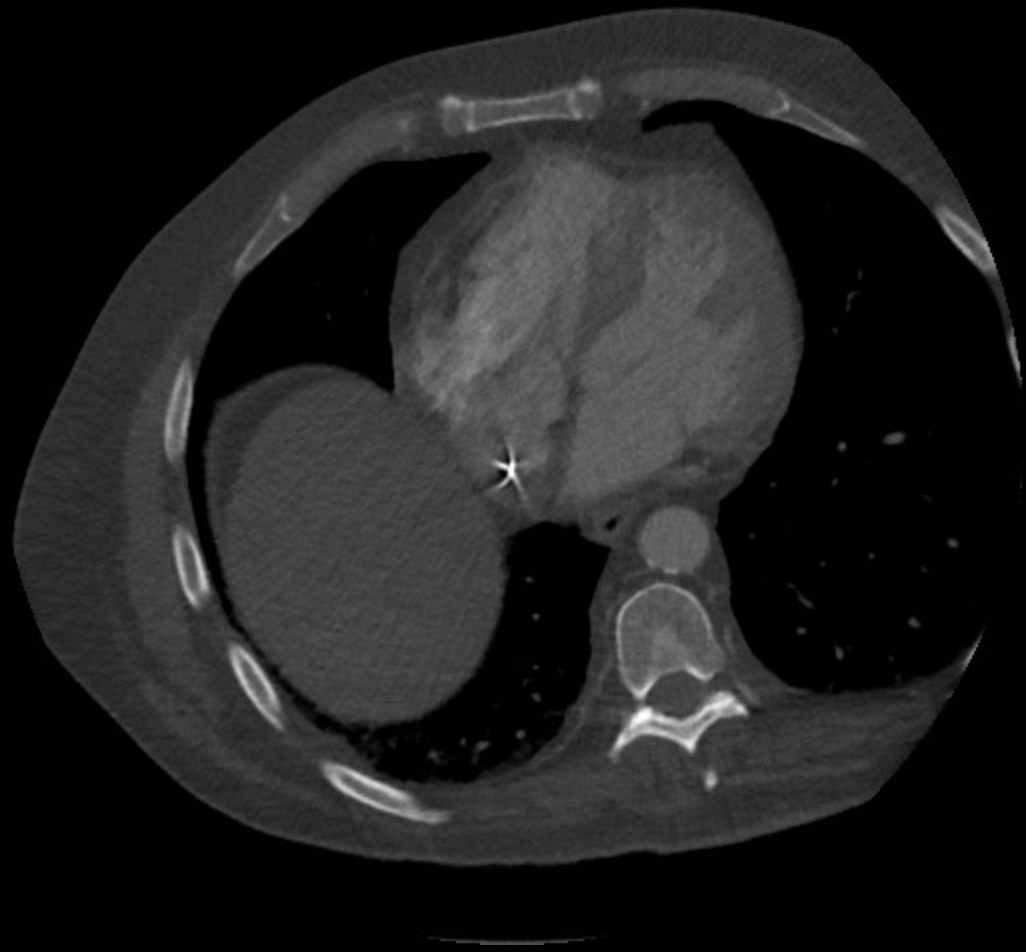


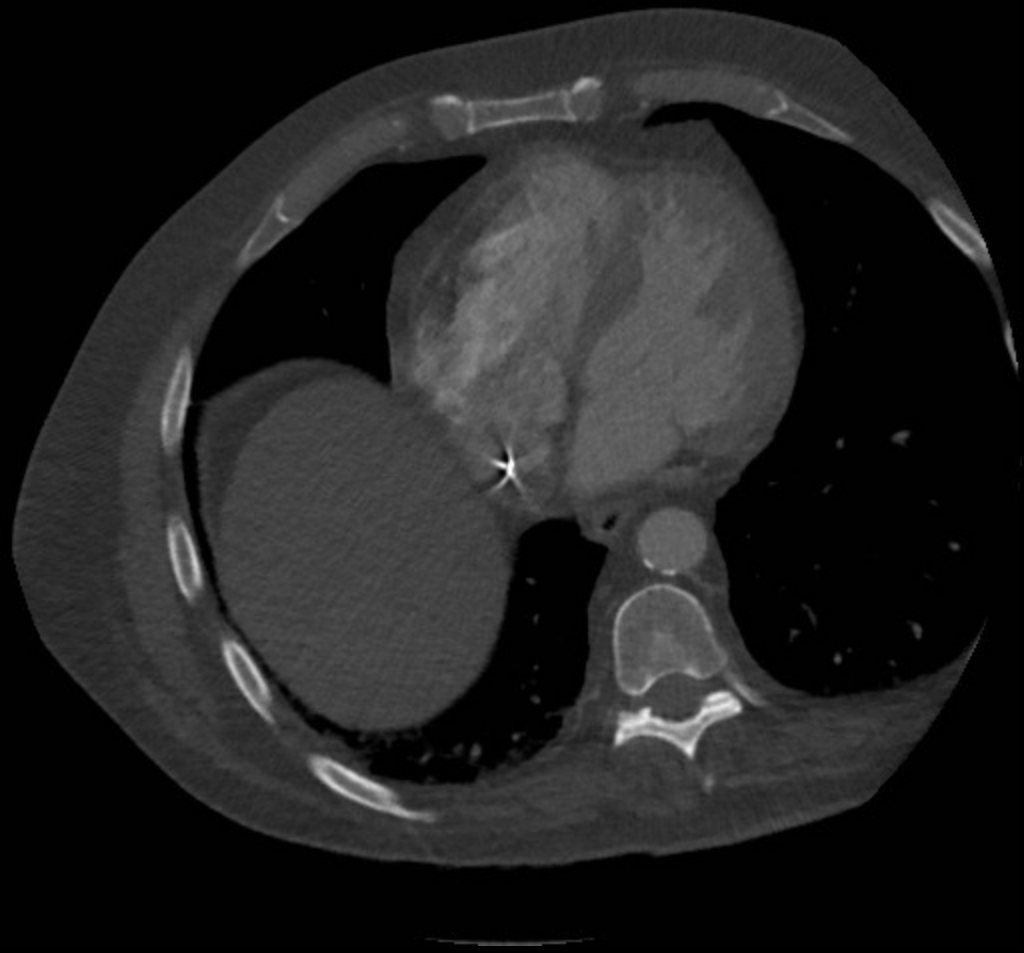
CT technique for evaluation of perforation of implantable leads

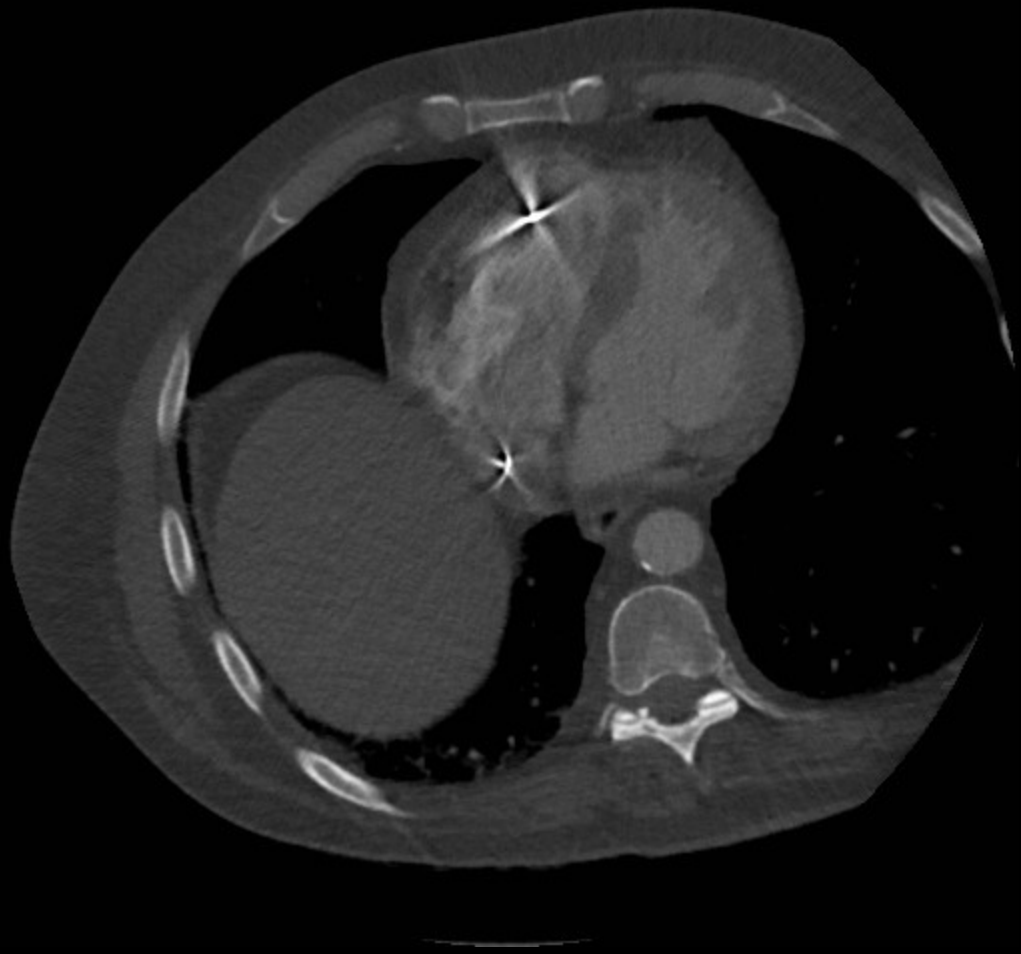
- ECG gating (can be prospective or retrospective – 70% of R-R)
- Can be done without beta blockade
- Thin slices (at least 2mm but 0.6 mm better) for MPR
- Can be done without contrast
- Dual energy and IR to reduce streak artifact and noise

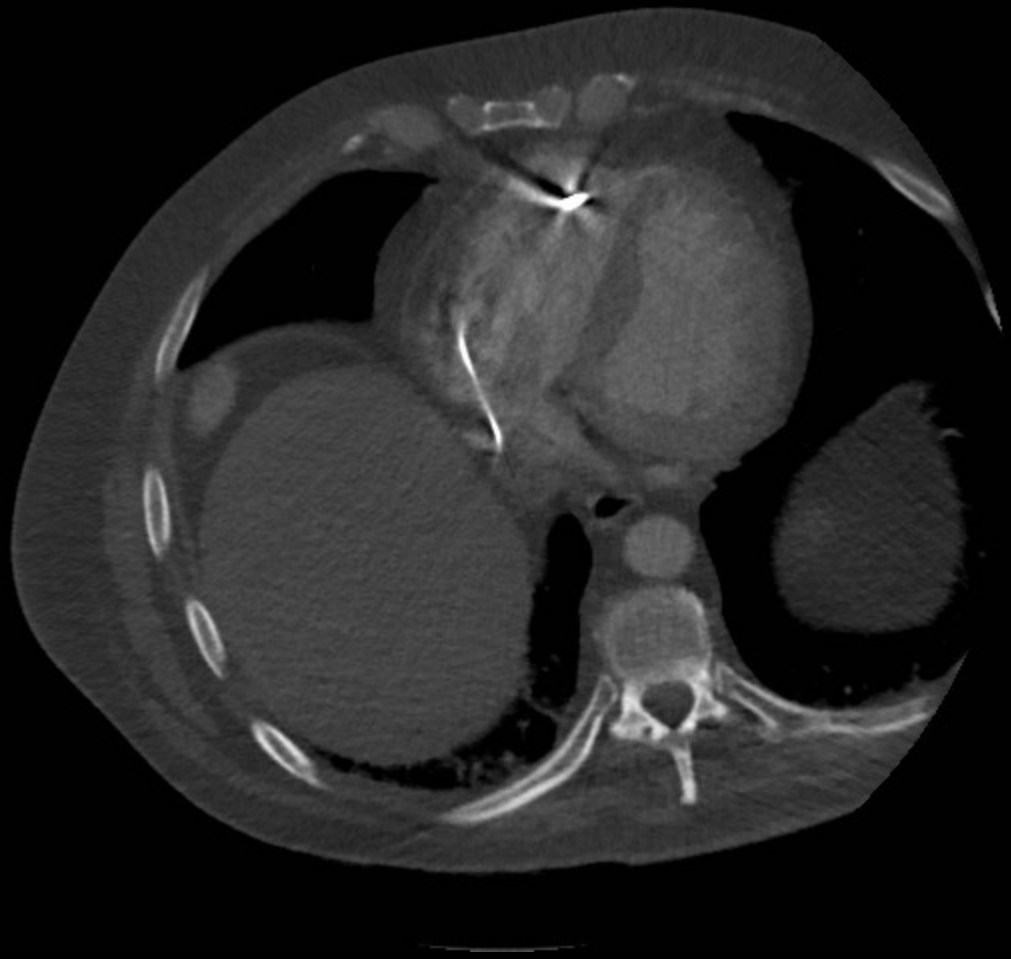


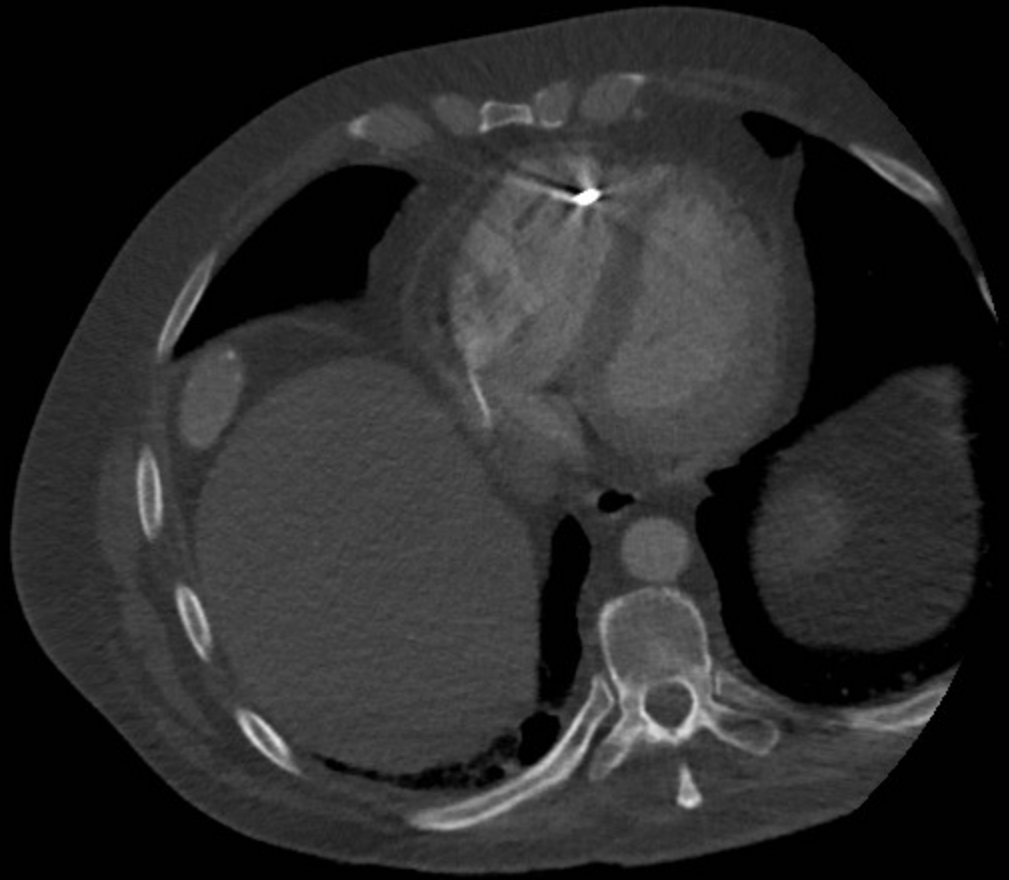


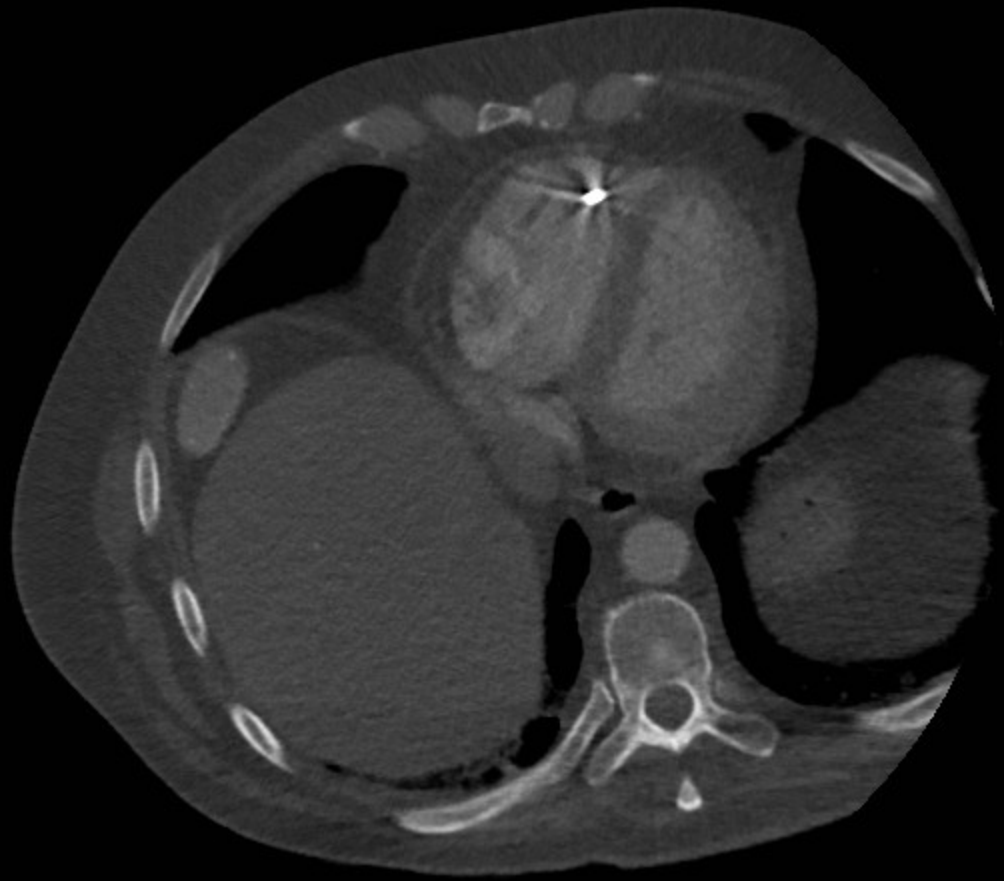


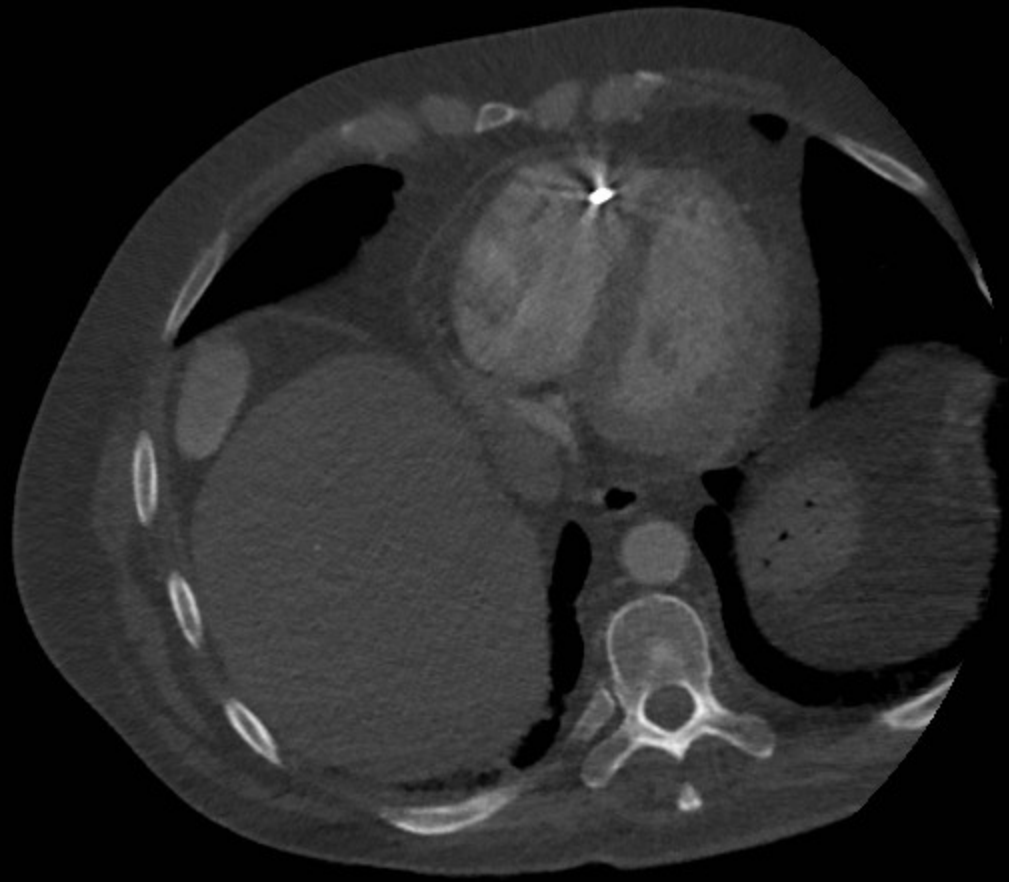


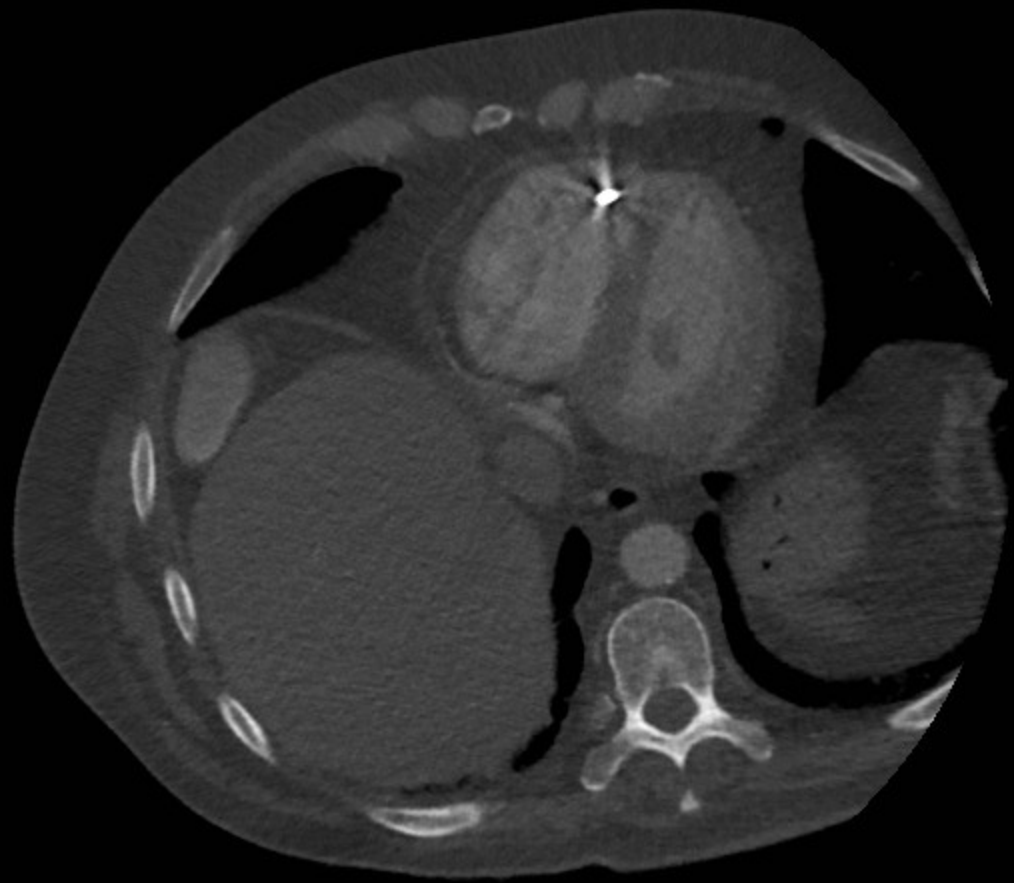


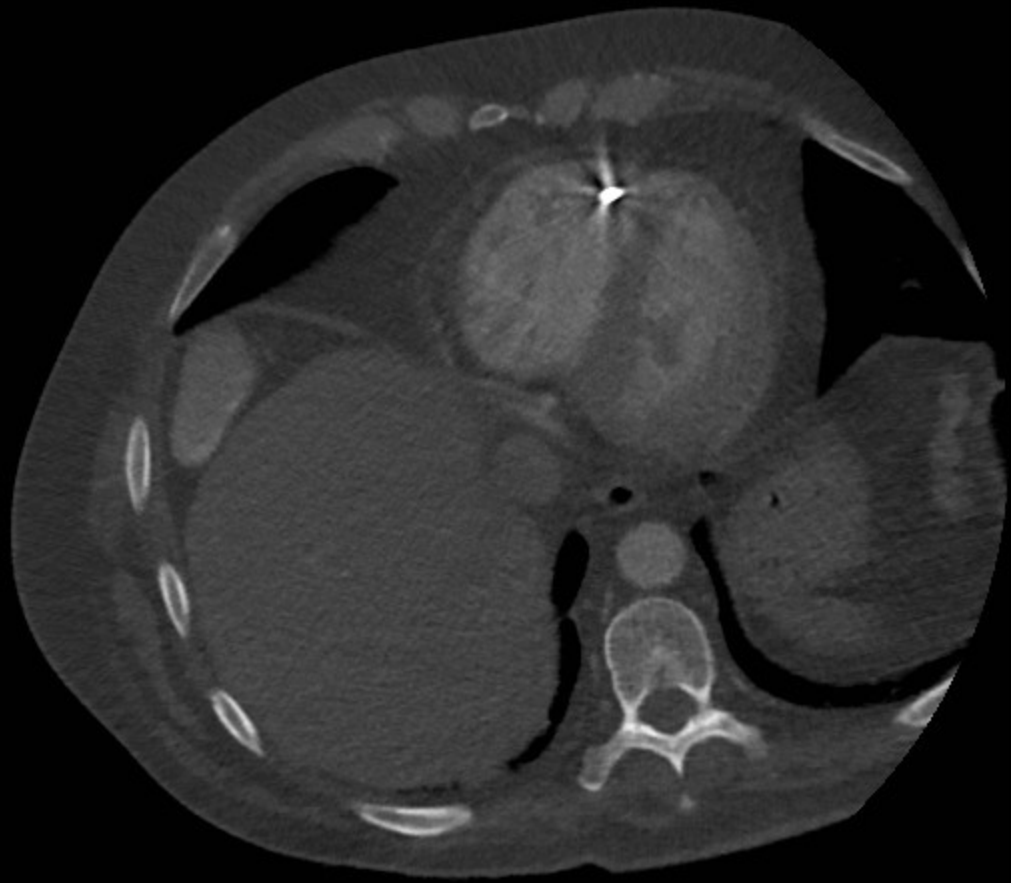


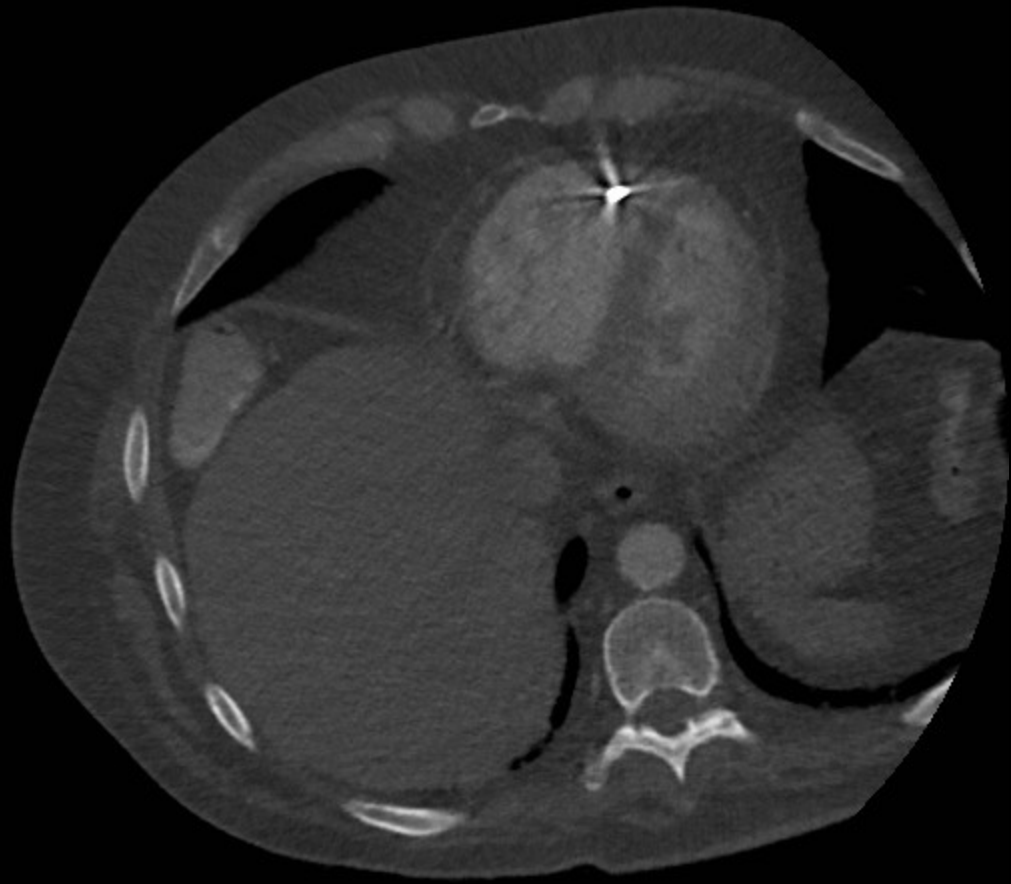


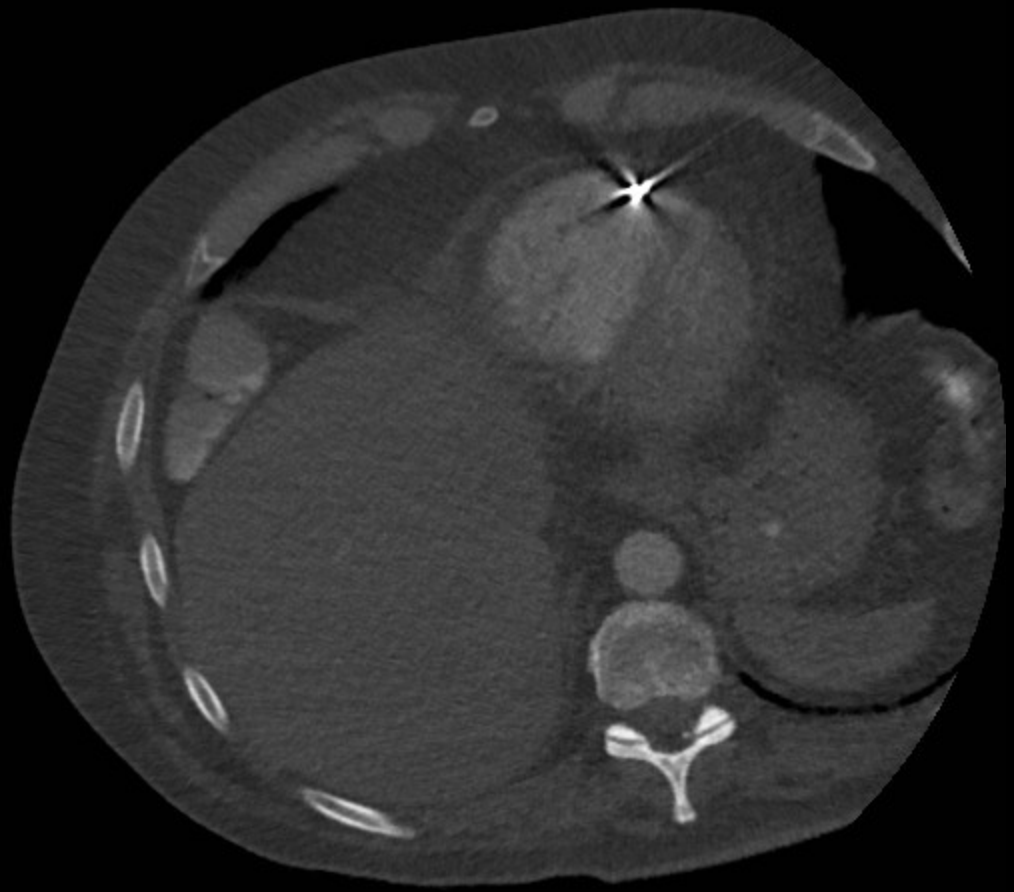


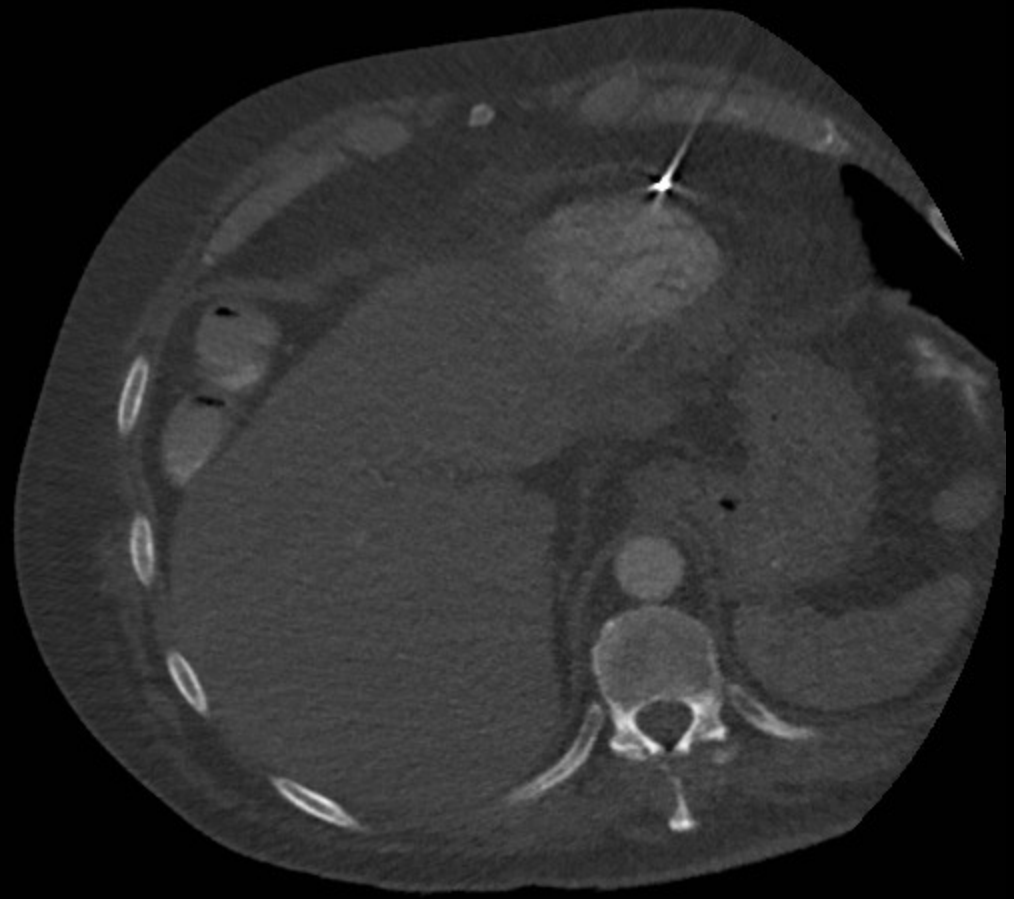


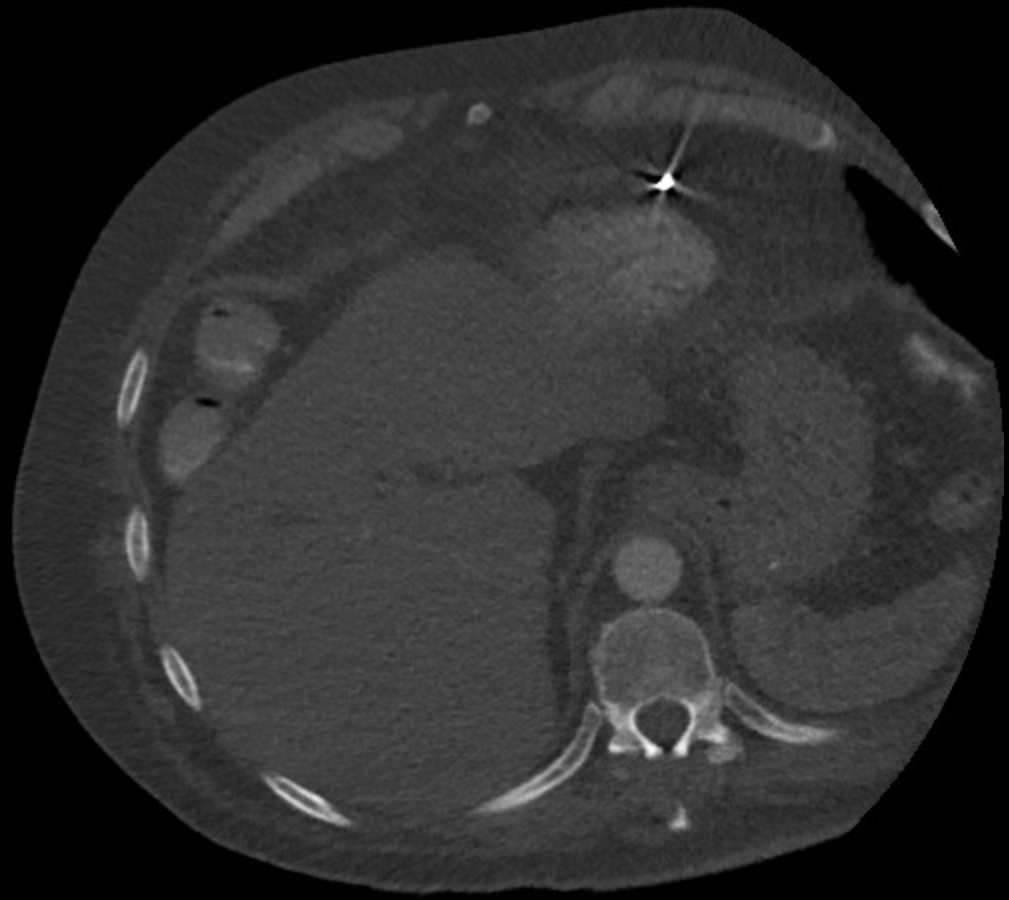


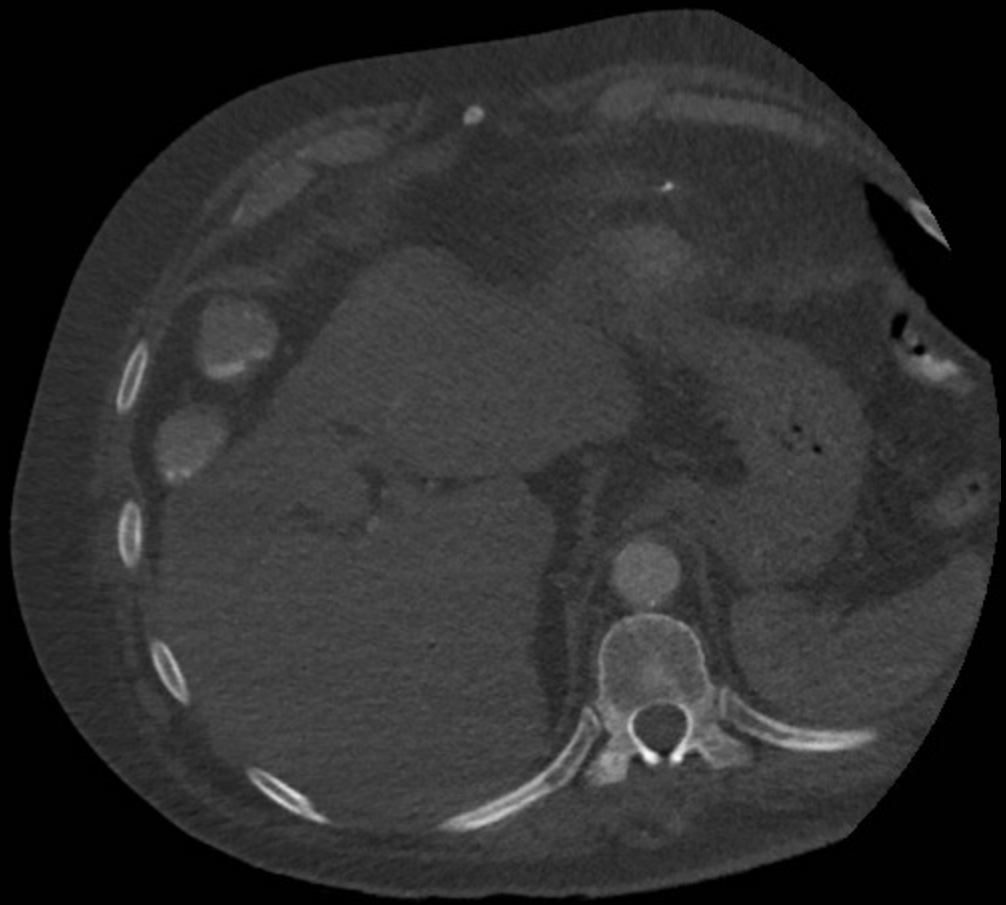


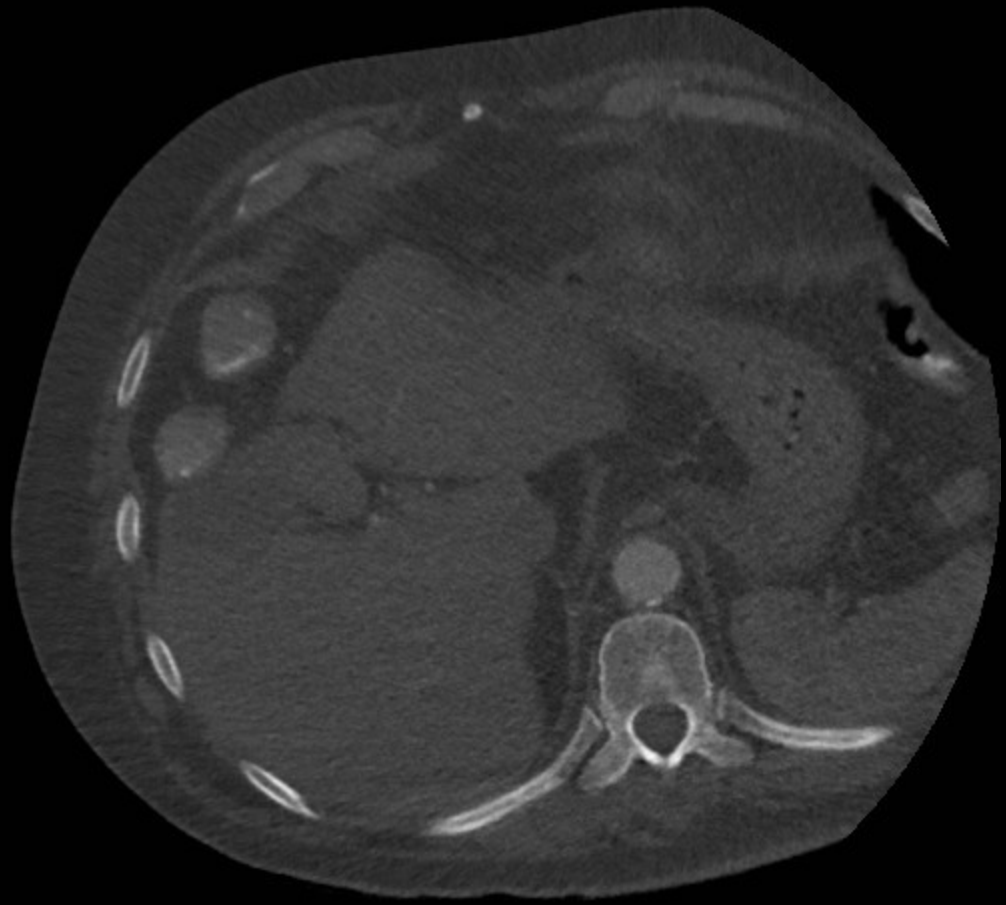


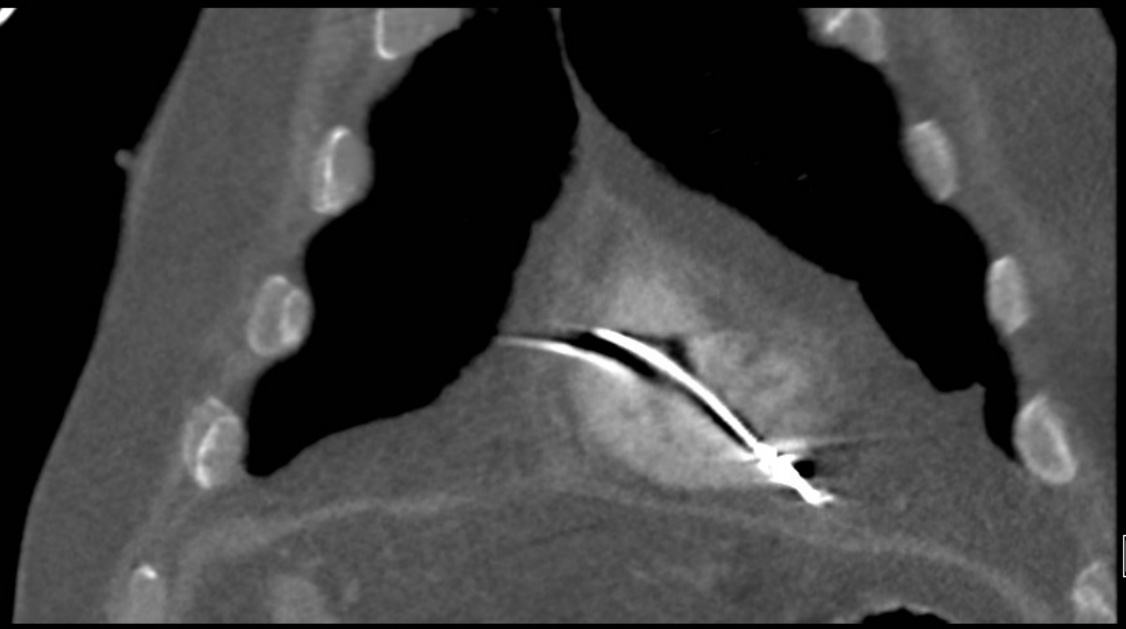








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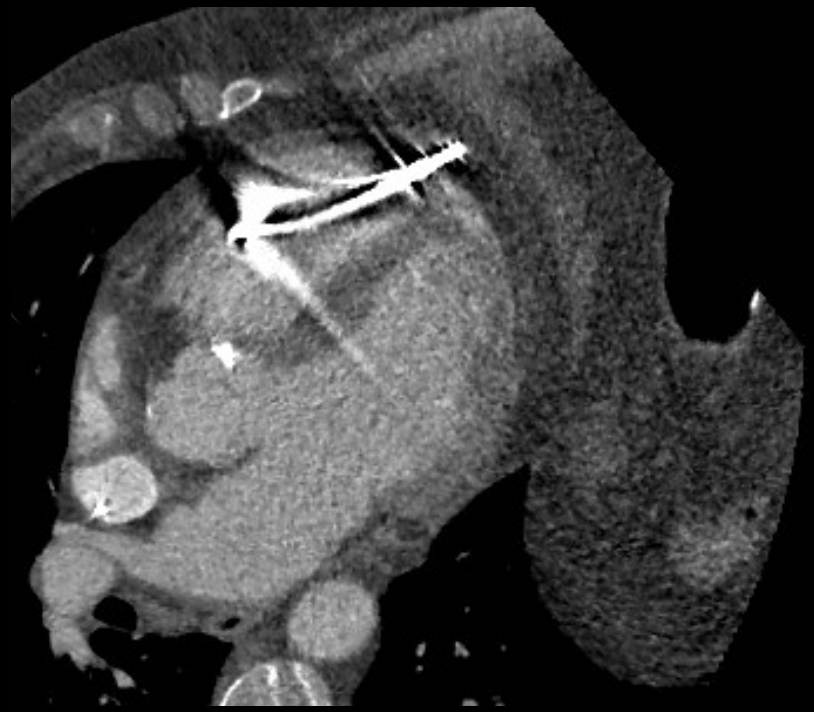

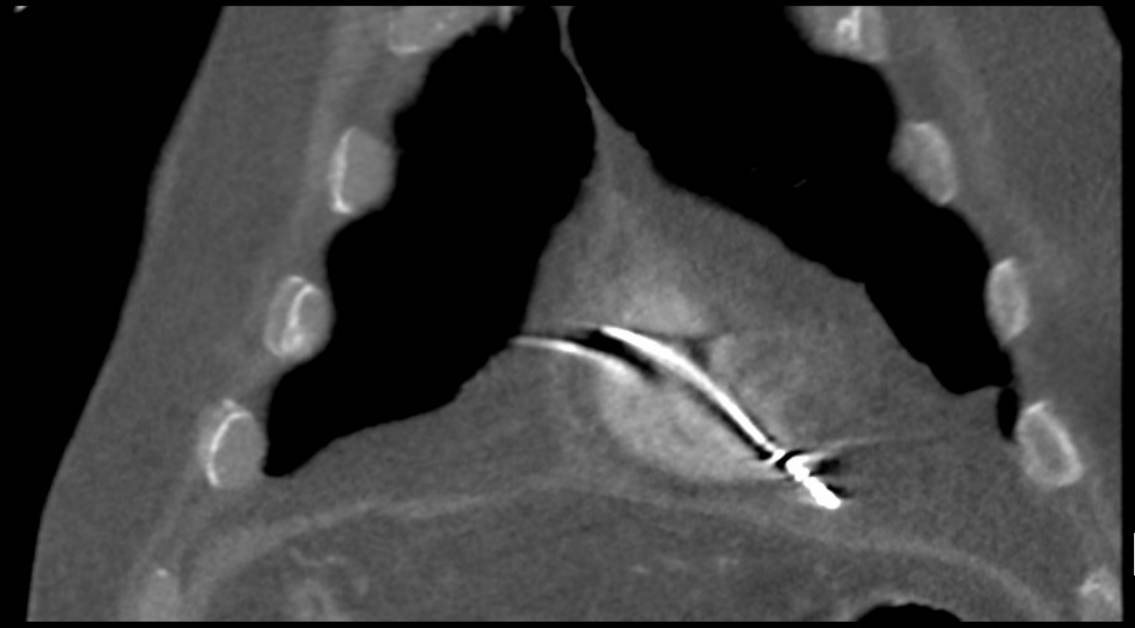
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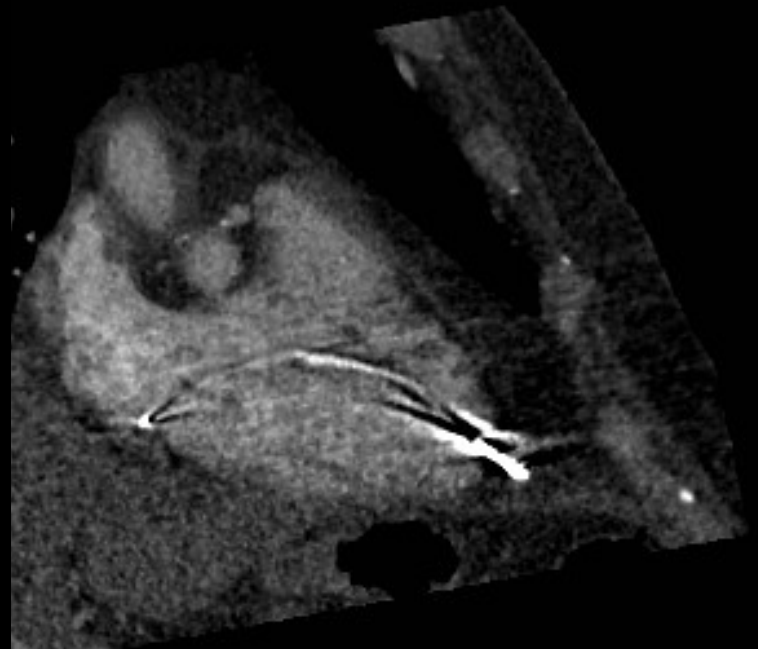

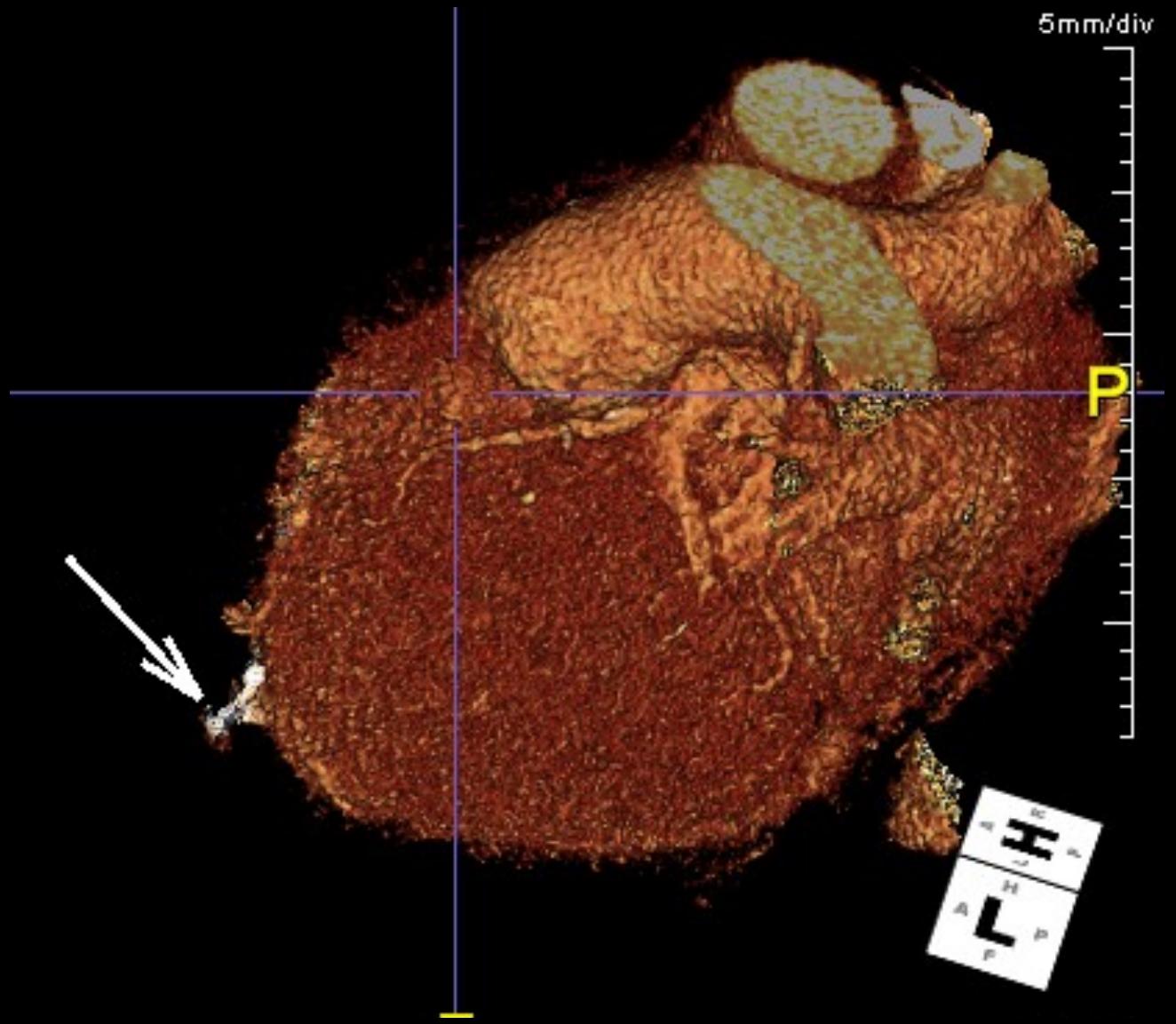
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CT technique for Imaging devices - LVADs

- Retrospectively ECG-gated
  - morphologic and dynamic information of the aortic and mitral valves throughout the cardiac cycle
- Contrast enhanced CTA or noncontrast if just for positioning
- Thin slices for MPR


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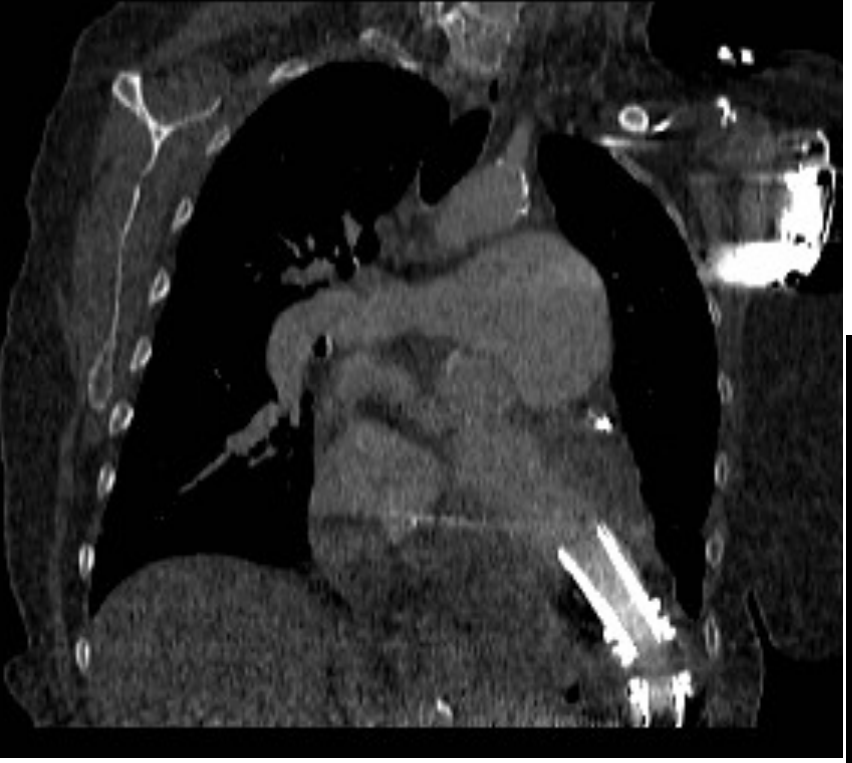
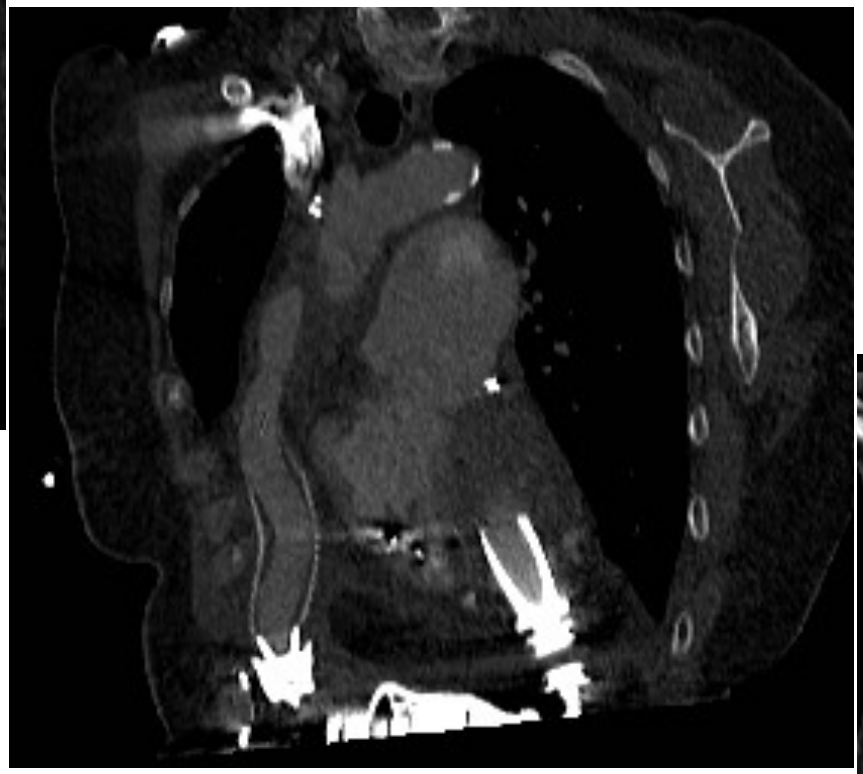
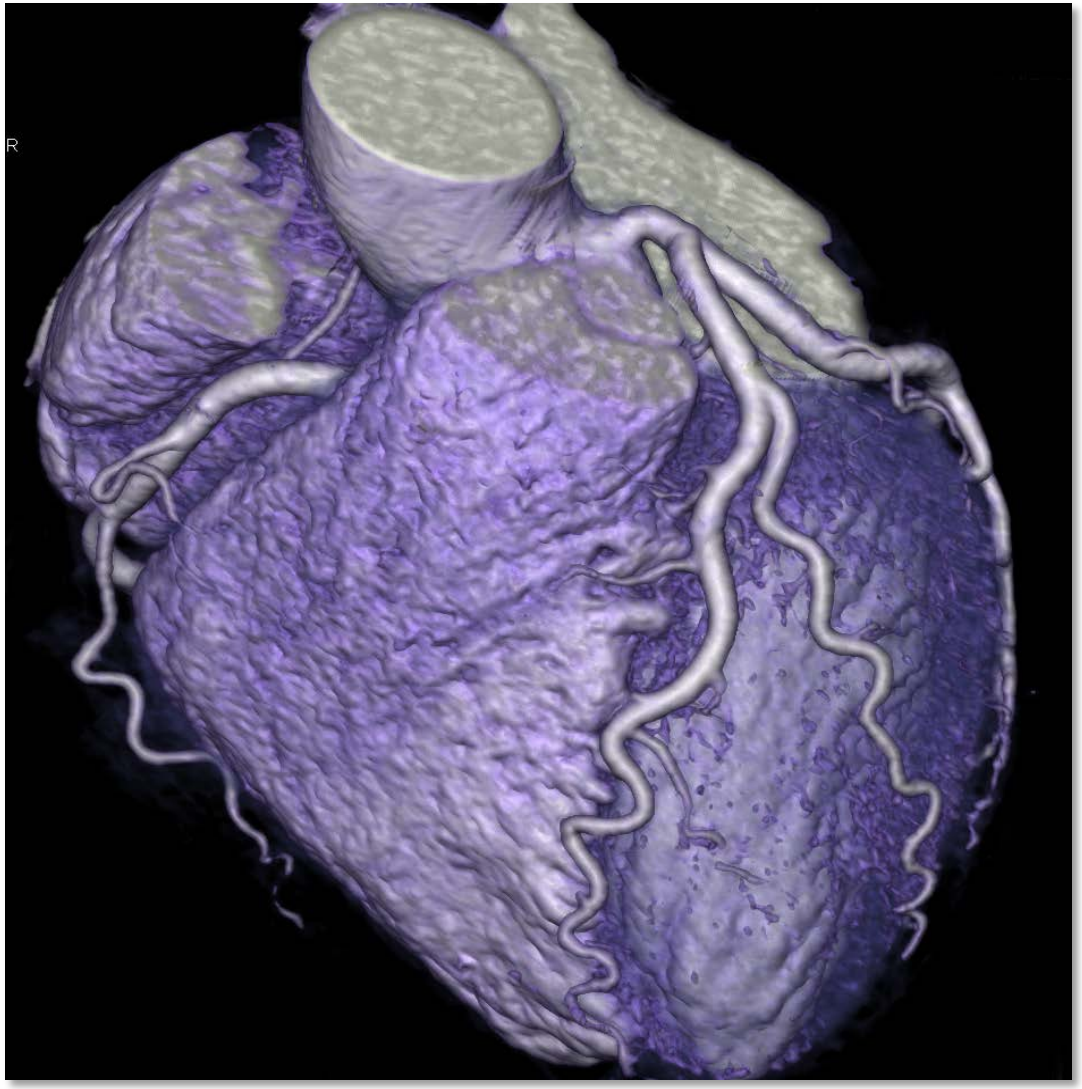




Summary

While many of the basic principles of CTA remain unchanged…

…ongoing technical developments in CT are continuing to expand the amount of information that can be obtained from modern cardiovascular CTA for the benefit of many patients with cardiovascular disease



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Thank-you

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