CT angiography techniques

Boot camp
Overview

* Basic concepts
  - Contrast administration – arterial opacification
  - Time scan acquisition during the arterial phase

* Protocol examples
  - Helical non-gated CTA
    - Pulmonary embolism
    - Abdominal aorta
    - Aortogram with run-off
    - DIEP flap
  - ECG-synchronized CTA
    - Thoracic aorta
    - Thoraco-abdominal aorta
Contrast administration

basic concepts
Achieve arterial enhancement

- CT angiography
  - Need intravenous contrast to achieve arterial enhancement

- Proportional to the iodine administration rate
  - Increasing iodine concentration of contrast medium
  - Increasing Injection flow rate (mL/s)
    - Amount of iodinated contrast delivered per unit time
  - Longer injection duration (larger volume of contrast)

Fleischmann, D. Radiol Clin N Am, 2010; 48: 237
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Fleischmann, D. Radiol Clin N Am, 2010; 48: 237
Higher concentration of Iodine

Simulated contrast enhancement curves of the abdominal aorta

125 mL of contrast at 4 mL/s
Three CM concentrations

Bae KT. Radiology 2010;256:32
Flow rate

- **Higher rate**
  - Enhancement increases
  - Duration decreases

- **Routine injections rates 4-5 mL/sec**
  - Needle sizes
  - Vein size

- **Flow rates > 8 mL/s**
  - Don’t result in greater enhancement
  - Pooling in central venous system, reflux into IVC

Simulated contrast enhancement curves of the abdominal aorta

125 mL of 350 mg/mL contrast injected at three different rates

Higher flow rate of CM

Increased arterial enhancement

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Flow rate

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**Higher flow rate of CM**

**Increased arterial enhancement**
Flow rate

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  - Duration decreases

- Routine injections rates 4-5 mL/sec
  - Catheter size
  - Vein size

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Bae KT. Radiology 2010;256:32

Simulated contrast enhancement curves of the abdominal aorta

125 mL of 350 mg/mL contrast Injected at three different rates

Higher flow rate of CM

Increased arterial enhancement
Injection duration = contrast volume

Simulated aortic enhancement curves (adult male, 70kg, 170cm).

Varying injection durations of 350 mg/ml contrast at 3 cc/s.

- 5 sec = 15 cc
- 20 sec = 60 cc
- 40 sec = 120 cc
- 60 sec = 180 cc

Longer injection duration increased peak arterial enhancement

Bae KT. Radiology 2010;256:32
Contrast administration summary

- Iodinated contrast needed for CTA to enhance arterial vasculature

- Greater arterial opacification with higher iodine flux at the time of the scan
  - Higher iodine concentration contrast media
  - Higher flow rates
  - Longer injection durations
Saline chaser

- Pushes contrast in tubing and peripheral veins into central veins
  - 20 – 30 cc
- Allows reduction in contrast volume
- Increases peak attenuation
- Reduced streak artifacts from veins and right heart
- Simpler to implement with dual head injectors
Measured attenuation and image noise of a 2% iodine solution at different tube potentials.

- Attenuation increases with lower kVp
- Noise increases with lower kVp

McCollough CM. Radiol Clin N Am, 2009;47:27
Timing scan acquisition to the arterial phase
Arterial phase of contrast bolus

After contrast injection

- Time-to-peak enhancement differs for different target arteries (PA – coronary – aorta – foot)
  - Distance from venous access site
  - Individual cardiac output
- Differ due to local vascular pathology
  - Stenosis
  - Aneurysm
Arterial phase of contrast bolus

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Bae KT. Radiology 2010;256:32
Arterial phase of contrast bolus

- Contrast media arrival time ($t_{arr}$)
  - Time for the bolus to reach target vessel

- Can be determined for each individual and desired target vessel
  - Timing bolus
  - Bolus tracking

Bae KT. Radiology 2010;256:32
Scan timing methods

Timing bolus

- Select target location from scout topogram
- Inject small test-bolus
  - 15 – 20 mL contrast
- Acquire low-dose dynamic scan at specified location during injection
- ROI in target structure
- Measure time-attenuation curve
  - Contrast material arrival time in aortic root
Scan timing methods

Bolus triggering

- Select trigger location
- Acquire reference image
  - Place ROI in vascular structure of interest
- Inject contrast bolus
- Acquire low-dose dynamic scans
- Monitor attenuation in ROI
- Start scan when desired threshold reached

Fleischmann, D. Radiol Clin N Am, 2010; 48: 237
Scan timing methods

### Timing bolus

**Advantages**
- Test adequacy of contrast path
- Multiple ROIs
- (art and veins)
- replace if error
- Avoid artifacts
- Test patient response
  - Heart rate

**Disadvantages**
- Two contrast injections
- time

### Bolus triggering

**Advantages**
- Time efficient
- less contrast

**Disadvantages**
- Different scan delay times
- Single shot
  - Unable to trouble shoot
  - Adjust to problems
  - Streak artifacts, misplaced ROI, occluded vein, connector leak
Scan timing methods

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CT angiography: basic strategy

* Use a bolus of iodinated contrast to produce arterial enhancement

* Determine the contrast arrival time
  - Timing bolus
  - Bolus tracking

* Perform diagnostic scan near peak enhancement achieved with the contrast bolus in the target vessel
Basic strategy with timing bolus

- Select bolus to achieve sufficient vascular attenuation
  - Vol: 150 cc (350 mgI/mL)
  - Rate: 5 cc/s

- Determine contrast media arrival time ($t_{arr}$)
  - Timing bolus
    - 15 cc @ 5 cc/s + saline flush

- Specify diagnostic delay ($t_d$)
  - Account for larger volume of primary bolus
  - Achieve greater enhancement
    - Start scan = $t_{arr} + t_d$
    - Scan delay = $t_{arr} + 8$ sec

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Basic strategy with timing bolus

* Select bolus to achieve sufficient vascular attenuation
  - Vol: 150 cc (350 mgI/mL)
  - Rate: 5 cc/s

* Determine contrast media arrival time ($t_{arr}$)
  - Timing bolus
    - 15 cc @ 5 cc/s + saline flush

* Shorter diagnostic delay ($t_d$)
  - Lower arterial enhancement
    - 150 vs 200 HU
  - Start scan = $t_{arr} + t_d$
  - Scan delay = $t_{arr} + 4$ sec

Fleischmann, D. Radiol Clin N Am, 2010; 48: 237
Basic strategy with bolus tracking

- Select bolus to achieve sufficient vascular attenuation

- Determine contrast media arrival time ($t_{arr}$)
  - Inject primary bolus
  - Bolus tracking
  - 100 HU threshold (50 HU)

- Specify diagnostic delay ($t_d$)
  - Scan delay = $t_{arr} + t_d$
  - $t_{arr} + 8$ sec

Fleischmann, D. Radiol Clin N Am, 2010; 48: 237
CTA summary points

* Higher contrast concentrations
  * Higher arterial enhancement for the same volume of contrast

* Flow rate 4 – 5 mL/s

* Timing bolus or bolus tracking
  * Location
  * Size of target vessel
  * Expected complexity

* Saline chaser

* Lower kVp when possible
CTA protocols examples

Putting it all together
Imaging protocol: pulmonary embolism

**Timing bolus**

- AP and lateral scouts
- Timing bolus below carina. ROI in PA.
- Helical acquisition at timing bolus peak + 5 sec
- Contrast Omnipaque 350
- Caudal-cranial scan direction from diaphragm to lung apices

Timing bolus: 15 cc contrast (5 cc/s) + 15 cc saline (5cc/s)
Primary bolus: 85 cc contrast (5 cc/s) + 30 cc saline (5 cc/s)
CTA pulmonary embolism
Imaging protocol: CTA abdominal aorta

Bolus tracking

- AP and lateral scouts
- Bolus tracking at L1. ROI in abdominal aorta.
- Helical acquisition at threshold of 70 HU
- Contrast bolus
  - Omnipaque 350
- Cranial-caudal scan direction from diaphragm to lesser trochanter

< 55 kg: 120 cc contrast (4 cc/s) + 30 cc saline (4 cc/s)
55-74 kg: 125 cc contrast (4 cc/s) + flush
75-84 kg: 130 cc contrast (4.5 cc/s) + flush
85-94 kg: 145 cc contrast (4.5 cc/s) + flush
> 95 kg: 150 cc contrast (5 cc/s) + flush
CTA abdominal aorta
Imaging protocol: CTA aortogram with run-off

Long scan duration

- AP and lateral scouts
- Bolus tracking at L1. ROI in abdominal aorta.
- Helical acquisition at threshold of 100 HU
- Contrast bolus
  Omnipaque 350
  Scan delay = 40 sec – scan duration
  Biphasic rate injection
- Cranial-caudal scan direction from diaphragm through toes

Small patient: 20 cc contrast (4 cc/s) + 95 cc contrast (3.2 cc/s) + 30 cc saline (3.2 cc/s)
Medium patient: 25 cc (5 cc/s) + 120 cc (4 cc/s) + 30 cc saline (4 cc/s)
Large patient: 30 cc (6 cc/s) + 140 cc (4.8 cc/s) + 30 cc saline (4.8 cc/s)
Aortogram with peripheral run-off
Biphasic injection: prolong plateau

Uniphasic injection

50 mL @ 2 mL/s
Continuously upsloping curve

Biphasic rate injection

25 mL @ 2 mL/s + 25 mL @ 1.4 mL/s
More prolonged enhancement curve with two peaks
CTA for DIEP flap breast reconstruction

Alternate delay for veins

- AP and lateral scouts
- Timing bolus at level of acetabulum. ROI in right external iliac artery.
- Helical acquisition at timing bolus peak + 10 sec
- Caudal-cranial scan direction from lesser femoral trochanters to 4 cm above umbilicus

Primary bolus: 100 cc contrast (5 cc/s) + 30 cc saline (5 cc/s)
Example 3d Images

Volume rendered skin view for Location map of where perforator exits fascia

Sagittal and axial oblique views of point where perforator exits fascia and IM course

right perforator 1
Imaging protocol: prospective ECG-triggered thoracic CT aortogram

Gated scan, timing bolus

- AP and lateral scouts
- **Right arm** IV placement
  - Avoid streak artifacts across arch vessels
- Timing bolus below carina. ROI in ascending thoracic aorta.
- PT sequential axial acquisition at timing bolus peak + 6 sec
- **Contrast**
  - Omnipaque 350
  - Biphasic blended
- Cranial-caudal scan direction from clavicles to L1

70 cc contrast (5 cc/s) + 50 cc (70/30 blend, 5 cc/s) + 50 cc saline (5 cc/s)
Prospective ECG triggered CTA thoracic aorta
**Imaging protocol: prospective ECG-triggered CT aortogram**

**ECG gated, prolonged scan duration**

- AP and lateral scouts
- Right arm IV placement
  - Avoid streak artifacts across arch vessels
- Timing bolus below carina. ROI in descending thoracic aorta.
- PT sequential axial acquisition at timing bolus peak + 4 sec
- Contrast
  - Biphasic size based bolus
- Cranial-caudal scan direction from clavicles to lesser femoral trochanter

**Contrast doses**

- **Small patient:** 20 cc contrast (4 cc/s) + 95 cc contrast (3.2 cc/s) + 30 cc saline (3.2 cc/s)
- **Medium patient:** 25 cc contrast (5 cc/s) + 120 cc (4 cc/s) + 30 cc saline (4 cc/s)
- **Large patient:** 30 cc contrast (6 cc/s) + 140 cc (4.8 cc/s) + 30 cc saline (4.8 cc/s)
76 yo female with multifocal disease—aneurysms in the aortic arch, descending thoracic and abdominal aorta. Volume rendered (left), multiplanar reformatted (MPR), and thin MIP images of the thoracic and abdominal aorta.
Imaging protocol: upper extremity CTA

**Distal timing bolus**

- AP and lateral scouts
- **Contralateral arm** IV placement
- Timing bolus near area of concern. ROI in target artery.
- Helical acquisition at timing bolus peak + 4 sec
- Scan through extremity from hand to chest.
  - Decrease venous contamination

Bolus > 20 sec, 100 cc (5 cc/s)

Anderson S, Radiology 2008;249:1064
upper extremity
upper extremity
In closing

- Basic concepts of CT angiography
- Contrast administration and bolus shaping
- Scan timing
- Protocol examples
  - Modifications based on the anatomy and pathology imaged