Approaches to Contrast Enhancement for CTA

Ernest Scalzetti, MD
SUNY Upstate Medical University
Syracuse, NY

• Purpose:
  To understand and design contrast injection protocols for thoracic CTA
• What is CTA?
  – Goals
  – Vascular territories
• Contrast media

What is CTA?

• Definition: contrast-enhanced CT imaging for assessment of blood vessels
• Goals of CTA: to achieve
  – Adequate enhancement of blood vessels
  – Must be able to extract vessels for 3D rendering
  – In the vascular territory of interest
  – Synchronized with the CT acquisition


What is thoracic CTA?

• Vascular territories
  – Multiple interesting territories in the chest
    • Pulmonary arteries
    • Thoracic aorta
    • Heart and coronary arteries
    • Central veins
    • Pulmonary veins
  – They overlap anatomically
  – They enhance at different times

Contrast media

• Iodine concentration of the contrast medium
  – “Adequate enhancement” depends on the task
  – CT numbers, measured in blood vessels
    • Affected by cardiac output and body size
    • Directly proportional to local iodine concentration
  – Enhancement depends on:
    • Amount of iodine delivered per unit time
      – Iodine Concentration x Injection Rate
    • Injection duration
    – Iodine concentration up to 370 mg/dl
Power injection

- Usually described as **volume** and **rate**
  - Example: 75 cc contrast at 5 cc/second
- May also be thought of as **duration** and **rate**
  - Example: 15 second injection at 5 cc/second
  - Conveys the same information
  - Emphasizes contrast bolus duration—**key concept**
  - Duration of at least 10 seconds for CTA

Power injection

- **Volume and rate**
  - Volume usually in the range of 50-150 cc
  - Rate usually in the range of 2.5-6 cc/second

Power injection

- **Phases**
  - Monophasic injection satisfactory for most CTA
    - Single injection of undiluted contrast
    - Saline bolus post-contrast
  - Biphasic injection
    - First phase: injection of undiluted contrast
    - Second phase: injection of contrast-saline mixture
    - Saline bolus post-contrast
    - Preserves RV contrast for functional assessment in combined coronary + cardiac CTA

Power injection

- **Saline bolus**
  - Same rate as contrast bolus
  - Volume usually 30-50 ml

Technique factors

- **kVp**
  - Range of available kVp settings: 80-140
  - Decreasing kVp increases image contrast
  - Decreasing kVp also increases image noise
    - For any given mA • s
Scan timing

- Fixed pre-scan delay method
  - Self-explanatory
  - Can work well with long injection durations
  - Does not attempt to compensate for physiologic variables such as cardiac output
    - Higher cardiac output: contrast appears more rapidly but with a lower, broader peak
    - Lower cardiac output: contrast appears more slowly but with a higher, narrower peak

- Bolus tracking (BT) method
  - Arterial enhancement is a dynamic process
    - "Time-attenuation response" varies, person to person
  - First, a CT image at an anatomic level of interest
  - Next, begin the contrast injection
  - Then acquire monitoring CT images
  - As soon as vessel enhancement rises above a pre-determined threshold, start the CTA

- Circulation time (a.k.a. test bolus) method
  - Short-duration contrast bolus ("test bolus")
  - Given at same rate as for CTA
  - Monitoring images at a fixed anatomic location
    - Frequency of monitoring images: 1-3 seconds
    - Determination of time to peak enhancement
    - Delay time = time-to-peak + something extra
    - Extra delay time depends on vascular territory

- Timing the pulmonary arterial circulation
  - Bolus tracking method
    - Anatomic level
    - Threshold
  - Circulation time method
    - Anatomic level
    - Extra delay

- Timing the pulmonary veins
  - Bolus tracking method
    - Anatomic level
    - Threshold
  - Circulation time method
    - Anatomic level
    - Extra delay
**Scan timing**

- Timing the thoracic aorta
  - Bolus tracking method
    - Anatomic level
    - Threshold
  - Circulation time method
    - Anatomic level
    - Extra delay

- Timing the heart and coronary arteries
  - Bolus tracking method
    - Anatomic level
    - Threshold
  - Circulation time method
    - Anatomic level
    - Extra delay

- Timing the central veins
  - Long injection duration
    - 40 seconds at 2.5 cc/second (volume 100 cc)
  - Fixed pre-scan delay: 60 seconds

**Scan timing**

- New directions based on circulation time
  - Modified circulation time method
  - Prospect of measuring physiologic parameters
    - Cardiac output
    - Pulmonary blood volume

**Closing thoughts**

- CTA challenges
  - Getting adequate enhancement
  - Getting the timing right
- Enhancement depends on:
  - Iodine administration rate
  - Injection rate
  - Injection duration
- Optimal timing depends on adapting to the individual hemodynamics of the patient

**Readings**