**Contrast Medium Administration: Principles for Cardiovascular CT**

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**Principles of CT – Angiography (Cardiovascular MDCT)**

- fast, high resolution, volumetric CT Acquisition (± EKG gating)
- strong arterial Contrast medium enhancement
- Post-processing 2D, 3D, (4D)

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**CTA Evolution**

<table>
<thead>
<tr>
<th>Year</th>
<th>Modality</th>
<th>Scan Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>SDCT</td>
<td>40 s</td>
</tr>
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<td>1999</td>
<td>4-MDCT</td>
<td>25 s</td>
</tr>
<tr>
<td>2002</td>
<td>16-MDCT</td>
<td>10 s</td>
</tr>
<tr>
<td>2004</td>
<td>64-MDCT</td>
<td>4 s</td>
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</table>

Scan times for abd.aorta CTA

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**Physiology and Pharmacokinetics**

**Key Rules for CTA**

.. to understand relationship between i.v. CM delivery and arterial enhancement (time attenuation response)
**Early contrast dynamics (~ 1 min.)**

i.v. contrast medium injection → r. heart → lung → l. heart → arterial system
→ organs* → brain
→ kidney
→ spleen, intestines ...
→ liver
→ myocardium, muscles

* intravascular/interstitial

**Early Contrast Dynamics**

Key Rules for CTA

1. arterial enhancement is proportional to iodine administration rates

2. arterial enhancement increases ("cumulative") with longer injection duration

**INPUT**

intravenous injection rate (mL/s)

**OUTPUT**

arterial enhancement (ΔHU)

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**Early Contrast Dynamics**

**Key Rules for CTA**

1. Arterial enhancement is proportional to iodine administration rates.
2. Arterial enhancement increases ("cumulative") with longer injection duration.

**think about CTA injection protocols as**

\[ \text{Flow} \times \text{duration} \]

- 120 mL @ 4mL/s
- 150 mL @ 5mL/s
- 60 mL @ 6 mL/s

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**"Patient Factor"**

Arterial enhancement inversely related to:

- Cardiac output (CO)
- Central blood volume (CBV)

CO (and CBV) correlate with body weight \(^1\) at least in pts. with ~normal LVF

\(^1\) Hittmüller & Fleischmann, JCAT 2001

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**Cardiac Output in CTEPH**

- 34 y.o. man
  - PAP: 63/12 (34)
  - CO: 5.4 L/min
  - CI: 2.5 L/min/m²

- 59 y.o. woman
  - PAP: 67/23 (40)
  - CO: 3.4 L/min
  - CI: 1.7 L/min/m²

Testbolus: 16 mL @ 4mL/s

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**Beta Blocker**

\[ \text{HU} \]

- 10% ↑ 4 s

Courtesy of C. Becker, Munich
Early Contrast Dynamics
Key Rules for CTA

§1 arterial enhancement is proportional to iodine administration rates

§2 arterial enhancement increases ("cumulative") with longer injection duration

§3 adjust inj. rate and CM volume (±20%) for pts. ≤60kg and ≥90kg

For very short injections, the SD-CTA approach (inj.-duration = scan time) does not work.

- need i.v cannula >17G
- inj.rate > 8mL/s, does not translate into proportional arterial enhancement
- timing too unforgiving

G.Rubin, Radiology 2001
**Aortic CTA**

**Symptomatic AAA**

MDCT16 × 1.25
12 s acquisition
20 s injection (12 + 8 s)
100 mL (350 mg I/mL) @ 5 mL/s

Delay:
\[ \tau_{TMC} = 8 \text{ s} \] ("smart prep")

\( \tau_{TMC} \) = contrast medium transit time

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**Limitations of fast CTA Acquisition**

- short acquisitions (injections) give lower enhancement
- increase the injection rate (iodine flux needed)
- increased risk of completely missing the bolus
- risk of outrunning the bolus (aneurysms, peripheral CTA ..)

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Scan times for abd. aorta CTA:

- 1998: 40 s
- 1999: 25 s
- 2002: 10 s
- 2004: 5-10 s

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**66 y/o obese woman (115 kg)**

cor.CTA before gastric bypass surgery
small IV line (20G)

\[ \rightarrow 35 \text{ s injection (4 mL/s)} \]

\[ \rightarrow \text{long delay (} \tau_{CMT} + 18 \text{ s)} \]

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**Scan times for abd. aorta CTA**

1998 SDCT: 40 s
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For very short injections, the SD-CTA approach (inj.-duration = scan time) does not work.

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Limitations of fast CTA Acquisition

- short acquisitions (injections) give lower enhancement
- increase the injection rate (iodine flux needed)
  - increased risk of completely missing the bolus
  - risk of outrunning the bolus (aneurysms, peripheral CTA ..)

Maybe we should not always scan as fast as possible?

- short acquisitions (injections) give lower enhancement
- increase the injection rate (iodine flux needed)
- increased risk of completely missing the bolus
- risk of outrunning the bolus (aneurysms, peripheral CTA ..)
### Traditional 'Design' of CTA Scanning/Injection Protocols

**Scanner technology**
- Scanning protocol: spatial resolution vs. volume coverage
- Injection protocol: arterial enhancement
- Trade-off: Scan Time
- Try to scan as fast as possible

### Integrated 'Design' of CTA Injection/Scanning Protocols

**Physiology**
- Use fixed scan time

### Integrated Scanning-Injection Protocol

**64 - channel CTA of the abdominal Aorta**

- **Scantime:** 10s for ALL patients (pitch variable)
- **Inj. duration:** 18s for ALL patients
- **Delay:** "care-bolus" w/ 8s delay ($t_{CMT} + 8$)

### Automated tube current modulation (Care-Dose-4D)

<table>
<thead>
<tr>
<th>Weight</th>
<th>Flow</th>
<th>Volume</th>
</tr>
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<tbody>
<tr>
<td>&lt;55 kg</td>
<td>4.0 mL/s</td>
<td>72 mL</td>
</tr>
<tr>
<td>55-65</td>
<td>4.5 mL/s</td>
<td>81 mL</td>
</tr>
<tr>
<td>66-85</td>
<td>5.0 mL/s</td>
<td>90 mL</td>
</tr>
<tr>
<td>86-95</td>
<td>5.5 mL/s</td>
<td>99 mL</td>
</tr>
<tr>
<td>&gt;95 kg</td>
<td>6.0 mL/s</td>
<td>108 mL</td>
</tr>
</tbody>
</table>

+ saline flush

### Stanford Cardiovascular CT Protocols

*(eternal work-in-progress)*
"executive exam"
Coronary CTA

Premed: 100mg Atenolol
sublingual nitro

MDCT 64×0.6mm
12 s scan time

20 s injection (12+8s)
100 mL (370mg I/mL)
@ 5 mL/s

Delay:
$T_{MC} + 8s$ (care-bolus+8')

$t_{MC} =$ contrast medium transit time

Contrast Medium

<table>
<thead>
<tr>
<th>weight</th>
<th>mL/s</th>
<th>Volume</th>
<th>Volume</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;121 lb</td>
<td>4.0</td>
<td>72</td>
<td>80</td>
<td>88</td>
</tr>
<tr>
<td>121–143</td>
<td>4.5</td>
<td>81</td>
<td>90</td>
<td>99</td>
</tr>
<tr>
<td>143–187</td>
<td>5.0</td>
<td>90</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>187–209</td>
<td>5.5</td>
<td>99</td>
<td>110</td>
<td>121</td>
</tr>
<tr>
<td>&gt;209 lb</td>
<td>6.0</td>
<td>108</td>
<td>120</td>
<td>132</td>
</tr>
</tbody>
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Integrated Scanning-Injection Protocol

64 - channel Lower Extremities

Scantime: 40s for ALL patients (pitch variable)
(automated tube current modulation)

Inj duration: 35s for ALL patients

Delay: bolus triggering

weight
Biphasic Injection
<55kg 20 mL (4.0mL/s) + 96 mL (3.2mL/s)
<65kg 23 mL (4.5mL/s) + 108 mL (3.6mL/s)
75kg 25 mL (5.0mL/s) + 120 mL (4.0mL/s)
>85kg 28 mL (5.5mL/s) + 132 mL (4.4mL/s)
>95kg 30 mL (6.0mL/s) + 144 mL (4.8mL/s)

Cardiovascular CT
(cardiac CT, CT-Angiography)

DIAGNOSTIC INFORMATION OF CV-CT DEPENDS ON TECHNICAL QUALITY

- acquisition with high spatial and temporal resolution
- strong arterial opacification
- postprocessing (2D, 3D, and '4D')

Thank You ...