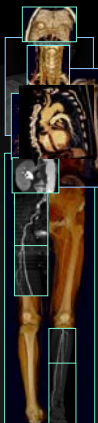


Contrast Medium Administration: Principles for Cardiovascular CT



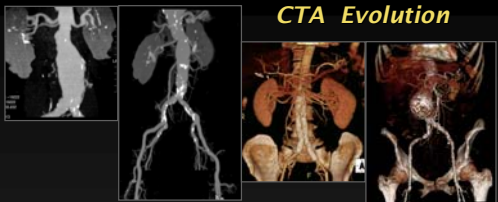
Dominik Fleischmann
 Department of Radiology
 Stanford University



Principles of CT - Angiography (Cardiovascular MDCT)

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

CTA Evolution




1998	1999	2002	2004
SDCT	4-MDCT	16-MDCT	64-MDCT
40 s	25 s	10 s	4 s

Scan times for abd.aorta CTA →

$4\text{mL/s} \times 40\text{s} = 160\text{ml}$

40 s



SDCT

3mm; 6mm/rot;
5mm; 10mm/rot; RI 2 mm

Same patient:

- 3 mo later, f/u
- with 4-Ch MDCT
- 16 s scan time


Same rule

- injection time=scan time
- scan timing: test-bolus

G.Rubin, Radiology 2001

$4\text{mL/s} \times 40\text{s} = 160\text{ml}$

40 s




SDCT

3mm; 6mm/rot;
5mm; 10mm/rot; RI 2 mm

$4\text{mL/s} \times 16\text{s} = 64\text{ml}$

16 s



MDCT

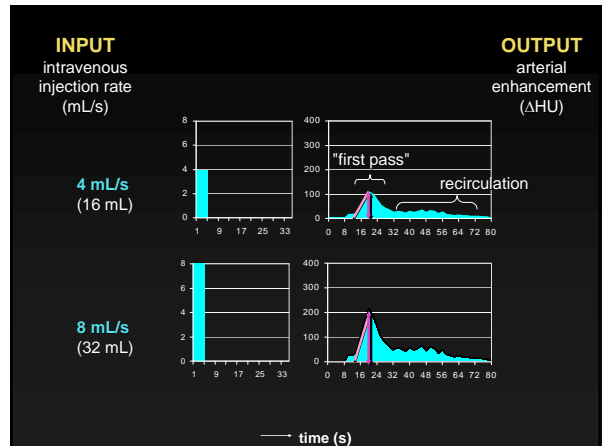
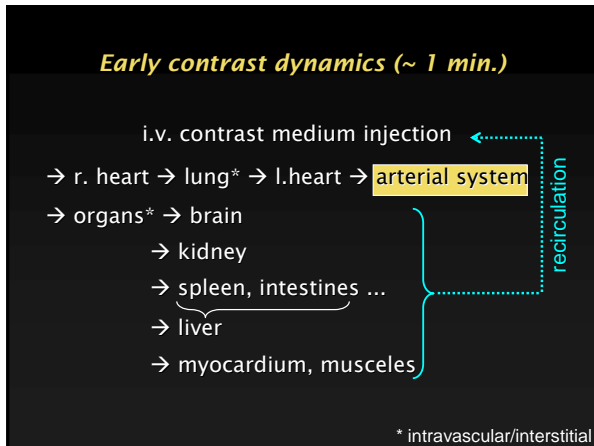
4x2.5mm; 15mm/rot; RI 1.3

G.Rubin, Radiology 2001

Physiology and Pharmacokinetics

Key Rules for CTA

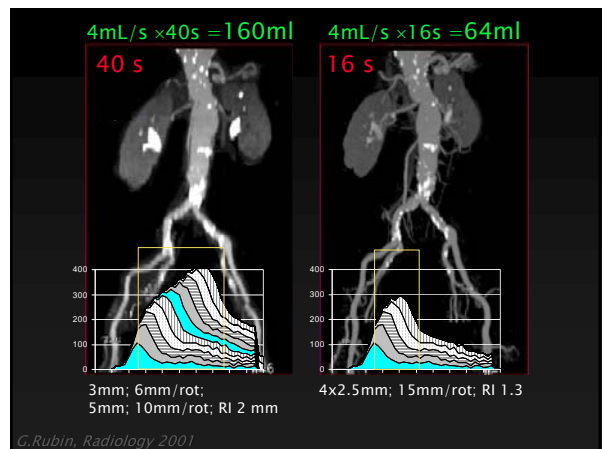
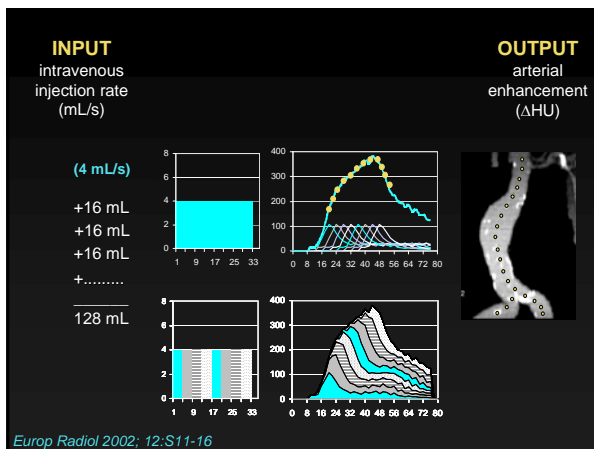
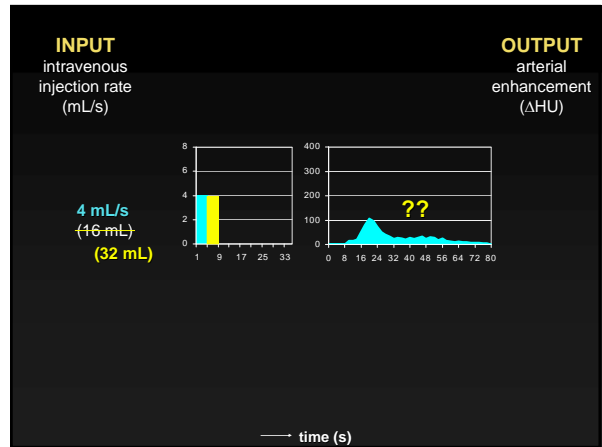
.. to understand relationship between i.v. CM delivery and arterial enhancement (time attenuation response)



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



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

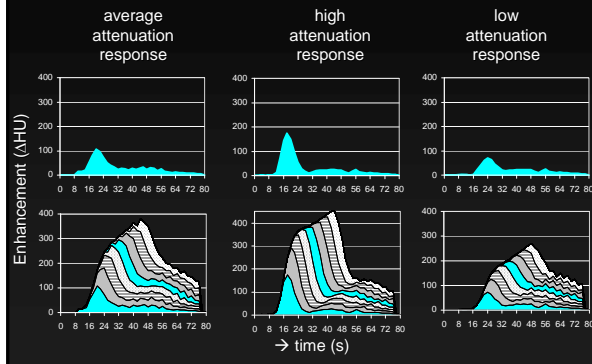
Early Contrast Dynamics Key Rules for CTA

think about CTA injection protocols as

Flow × duration

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

" Patient - Factor "



" Patient - Factor "

arterial enhancement inversely related to:

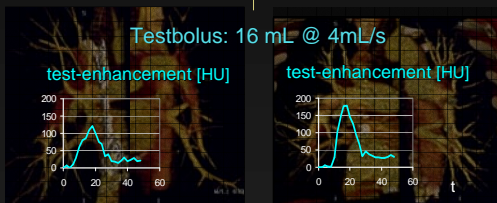
- Cardiac output (CO)
- Central blood volume (CBV) } usually unknown

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

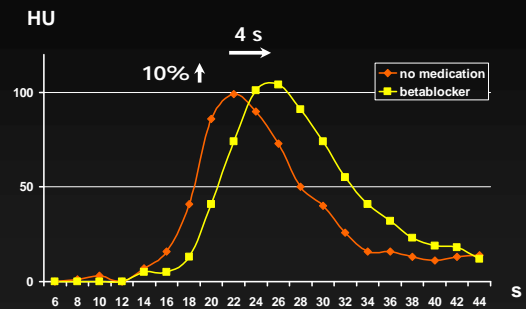
¹⁾ Hittmair & Fleischmann, JCAT 2001

Cardiac Output in CTEPH

- | | |
|--------------------------------|--------------------------------|
| • 34 y.o. man | • 59 y.o. woman |
| • PAP: 63/12 (34) | • PAP: 67/23 (40) |
| • CO: 5.4 L/min | • CO: 3.4 L/min |
| • CI: 2.5 L/min/m ² | • CI: 1.7 L/min/m ² |



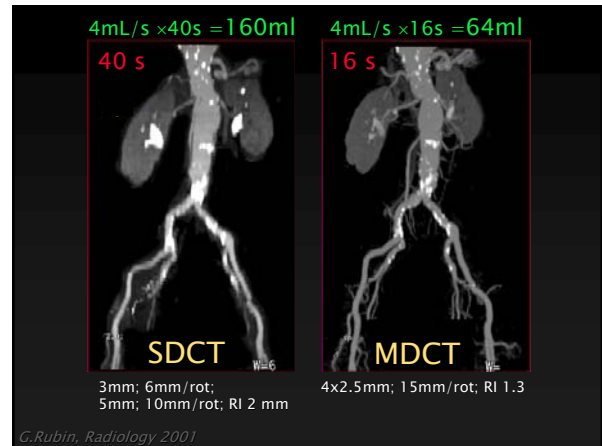
Beta Blocker



courtesy of C. Becker, Munich

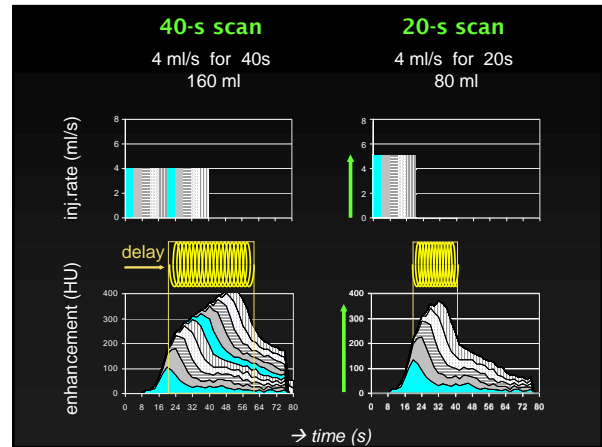
Early Contrast Dynamics Key Rules for CTA

- §1 arterial enhancement is proportional to iodine administration rates
(inverse to CO)
- §2 arterial enhancement increases ("cumulative") with longer injection duration
(inverse to CO and body-weight)
- §3 adjust inj. rate and CM volume ($\pm 20\%$) for pts. $\leq 60\text{kg}$ and $\geq 90\text{kg}$



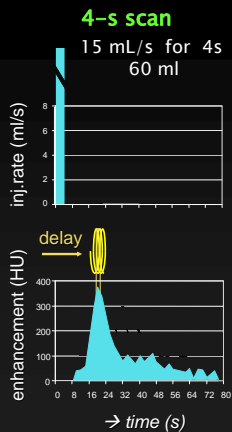
Early Contrast Dynamics Key Rules for CTA

- §1 arterial enhancement is proportional to iodine administration rate
mL / s (Injection rate)
mg I / mL (iodine concentration)



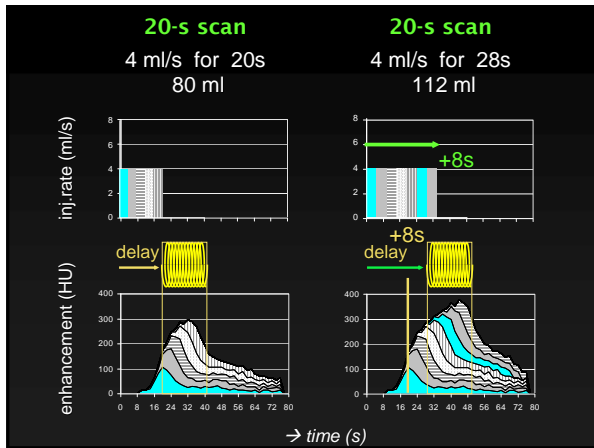
For very short injections, the SD-CTA approach (inj.-duration = scan time) does not work.

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



Early Contrast Dynamics Key Rules for CTA

- §1 arterial enhancement is proportional to iodine administration rate
mg I / mL (iodine concentration)
mL / s (Injection rate)
- §2 arterial enhancement increase ("cumulative") with longer injection duration
inject longer (than scan time)
increase delay (relative to t_{CMT})



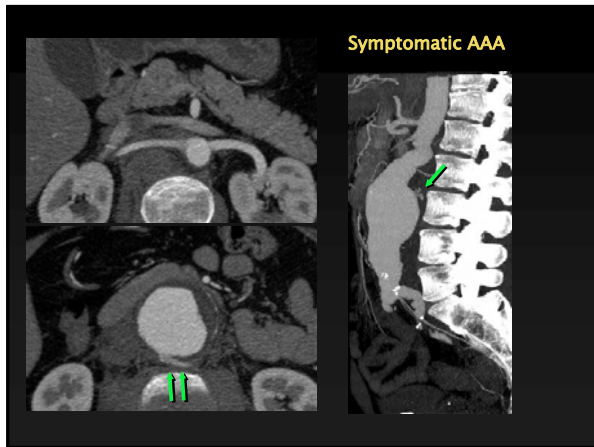
Aortic CTA
Symptomatic AAA

MDCT16×1.25
12 s acquisition

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

Delay:
 $t_{TMC} + 8s$ ("smart prep")

t_{TMC} = contrast medium transit time



66 y/o obese woman (115kg)
cor.CTA before gastric bypass surgery
small IV line (20G)

→35s injection (4 mL/s)
loong delay ($t_{CMT} + 18s$)

390 HU

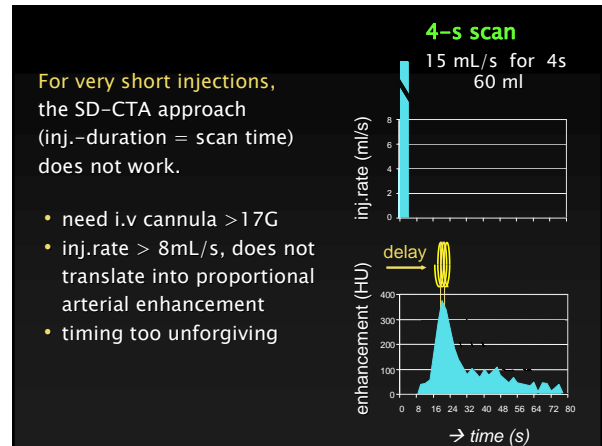
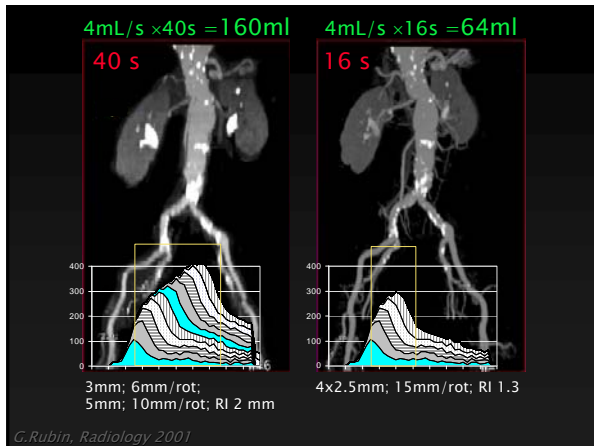
CTA Evolution

1998	1999	2002	2004
SDCT	4-MDCT	16-MDCT	64-MDCT
40 s	25 s	10 s	4 s - 10s

Scan times for abd.aorta CTA

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 ..)



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

Limitations of fast CTA Acquisition

- short acquisitions (injections) give lower enhancement
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- risk of outrunning the bolus (aneurysms, peripheral CTA ..)

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 ..)

302 HU

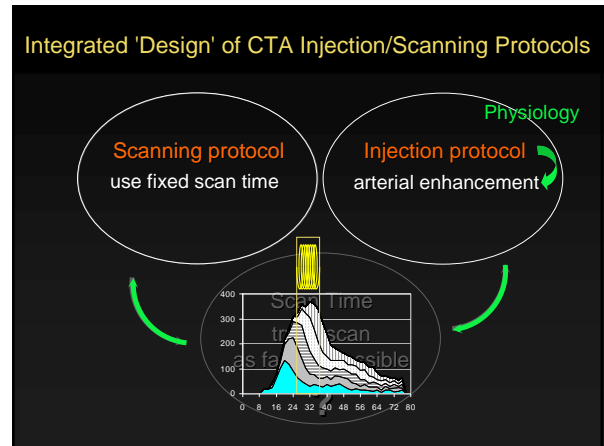
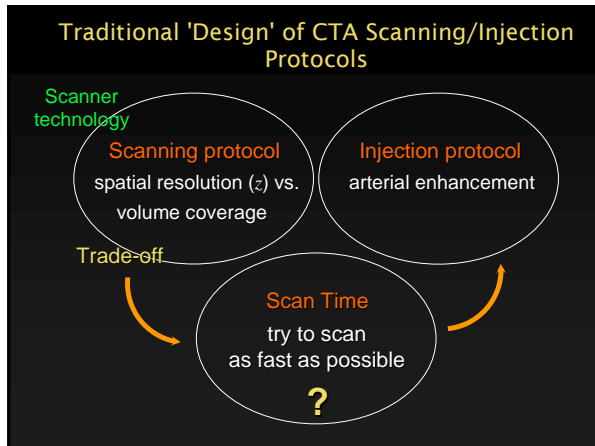
abdominal 64- CTA (6s)
bolus triggering in abd. aorta, without additional delay

64 HU

Limitations of fast CTA Acquisition

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

Maybe we should not always scan as fast as possible?



Integrated Scanning-Injection Protocol

64 - channel CTA of the abdominal Aorta

Scantime: 10s for ALL patients (pitch variable) (automated tube current modulation)

Inj.duration: 18s for ALL patients

Delay: 'care-bolus' w/ 8s delay ($t_{CMT}+8$)

Integrated Scanning-Injection Protocol

64 - channel CTA of the abdominal Aorta

Scantime: 10s for ALL patients (pitch variable) (automated tube current modulation)

Inj.duration: 18s for ALL patients

Delay: 'care-bolus' w/ 8s delay ($t_{CMT}+8$)

	weight	flow	volume
	<55 kg	4.0 mL/s	72 mL
	55-65	4.5 mL/s	81 mL
(average)	66-85	5.0 mL/s	90 mL
	86-95	5.5 mL/s	99 mL
	>95 kg	6.0 mL/s	108 mL

+ saline flush

Automated tube current modulation (Care-Dose-4D) ^{S-64}

q-ref.mAs: 250	q-ref.mAs: 250
eff.mAs: 136	eff.mAs: 270
mA: 282-364	mA: 318-530

81 y/o woman, AAA (161cm, 55 kg)

83 y/o man, AAA (173cm, 95 kg)

Stanford Cardiovascular CT Protocols (eternal work-in-progress)


"executive exam"
Coronary CTA

Premed: 100mg Atenolol
 sublingual nitro

MDCT 64x0.6mm
 12 s scan time

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

Delay:
 $t_{TMC} + 8s$ ('care-bolus+8')



t_{TMC} = contrast medium transit time

Contrast Medium

	Inj.durat: (scan time+8)	18 sec. (10+8)	20 sec. (12+8)	22 sec. (14+8)
weight	mL/s	Volume	Volume	Volume
<121 lb	4.0	72	80	88
121-143	4.5	81	90	99
143-187	5.0	90	100	110
187-209	5.5	99	110	121
>209 lb	6.0	108	120	132

Integrated Scanning-Injection Protocol **64**

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**

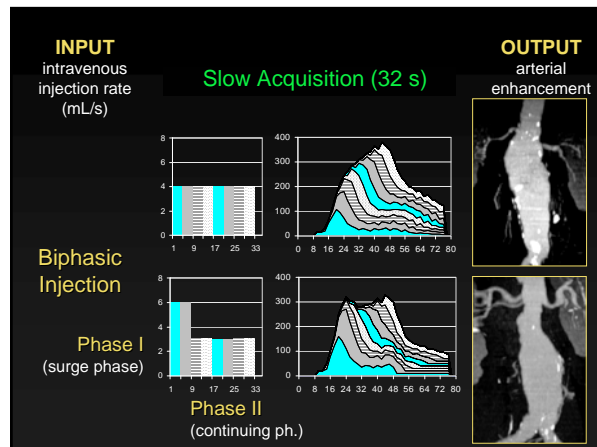
<55kg 20 mL (4.0mL/s) + 96 mL (3.2mL/s)

<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)

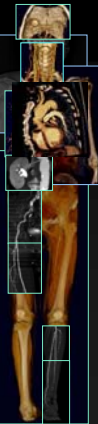
>95kg 30 mL (6.0mL/s) + 144 mL (4.8mL/s)



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')



ECG-Gated Cardiovascular CT - Workshop
 Lucas Learning Center - Stanford Radiology
 June 6, 2009

Thank You ...

Department of Radiology
 Stanford University

