CT Dose calculations for individual patients – what you should know

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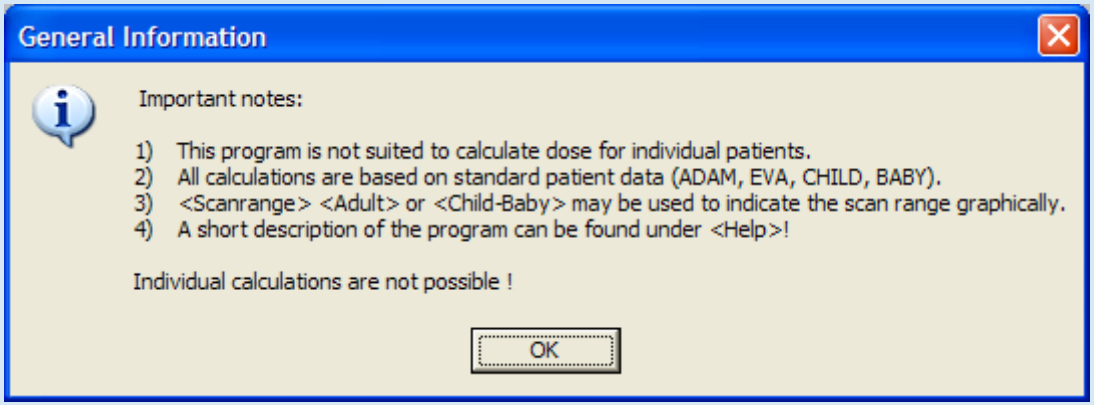
Does this put you off?

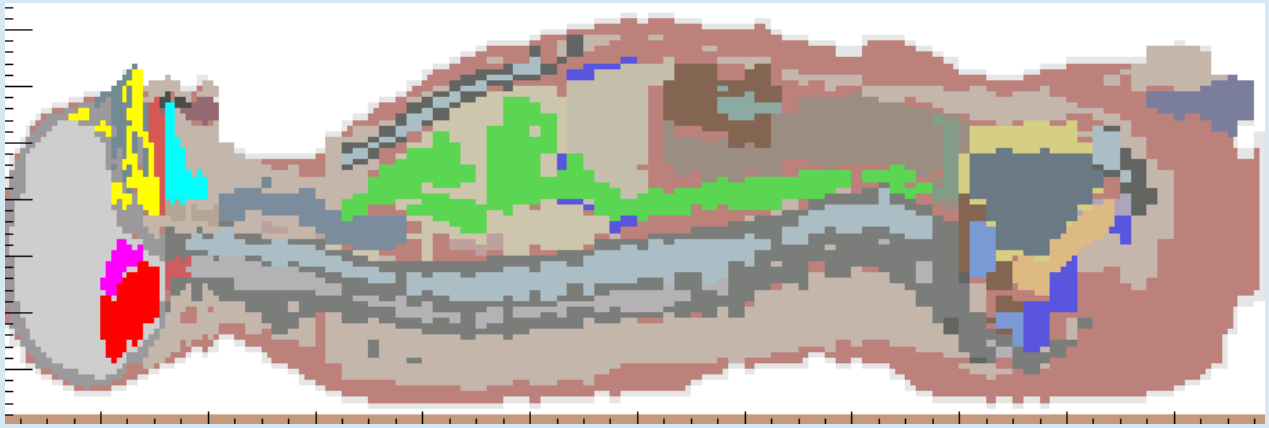


Objective

- how accurately can ImPACT CT dose calculator and CT-Expo calculate individual patient effective dose (ICRP 60)?

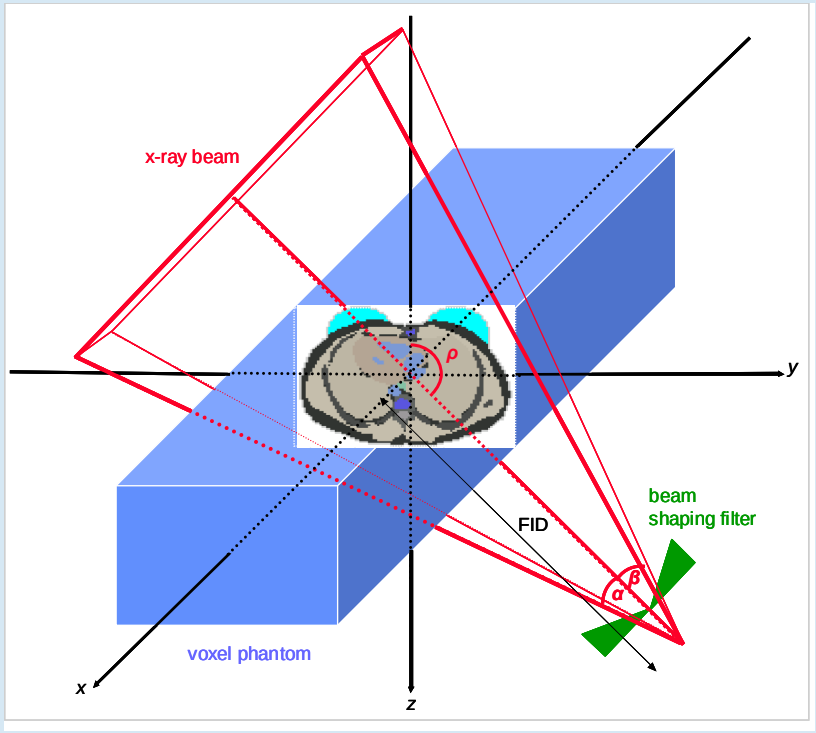
The patient, the code and the error

- modified Zubal voxelised adult phantom
  - breasts and ovaries added
  - all radiosensitive organs included
  - variable dimensions



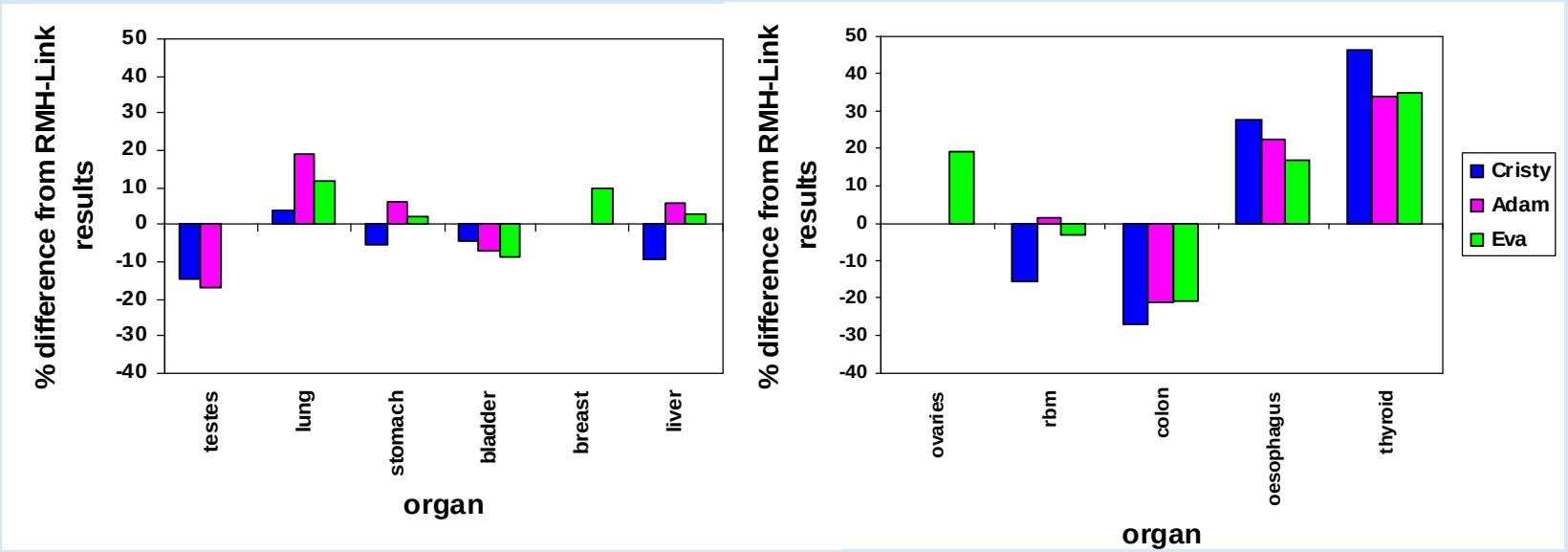
The patient, the code and the error

- RMH-Linköping Monte Carlo model
  - SSCT and MSCT scanners
  - geometry, spectrum, beam shaping filter, couch (OFF)
  - axial or helical scanning
- validated against experiment
  - < 10 %



How does RMH-Link compare against NRPB and GSF?

- two scanner models: HiSpeed CT/i SSCT and LightSpeed 16 MSCT
- whole body irradiation
- compared against ImPACT calculator and scaled CT-Expo

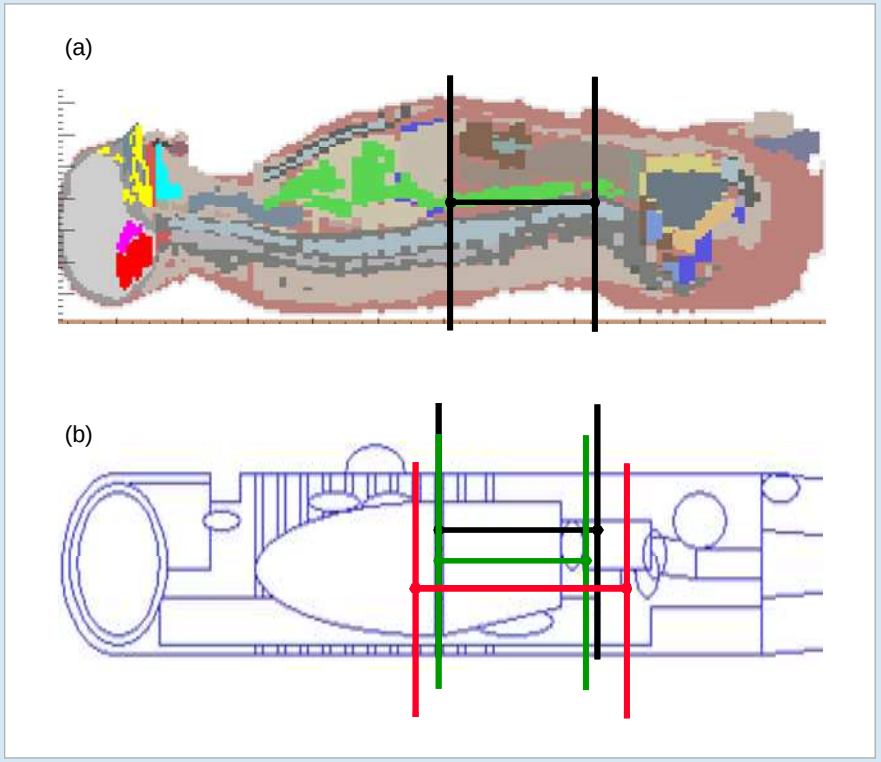


HiSpeed CT/i

- differences due to organ modelling
- similar results for LightSpeed 16
- effective doses agree to within 7 %

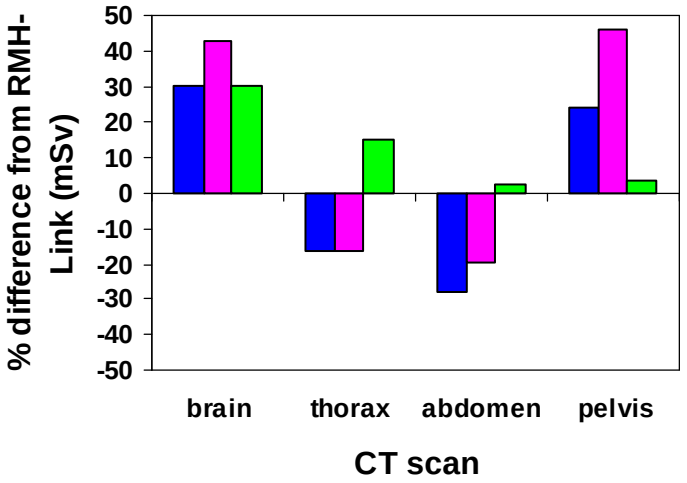
How do I set the scan range?

- four strategies
  - anatomical landmarks
  - scan range
  - fractions of irradiated organs
  - NRPB technique
- which one?
- simulate
  - brain, thorax, abdomen, pelvis scans
  - one scanner: HiSpeed CT/i

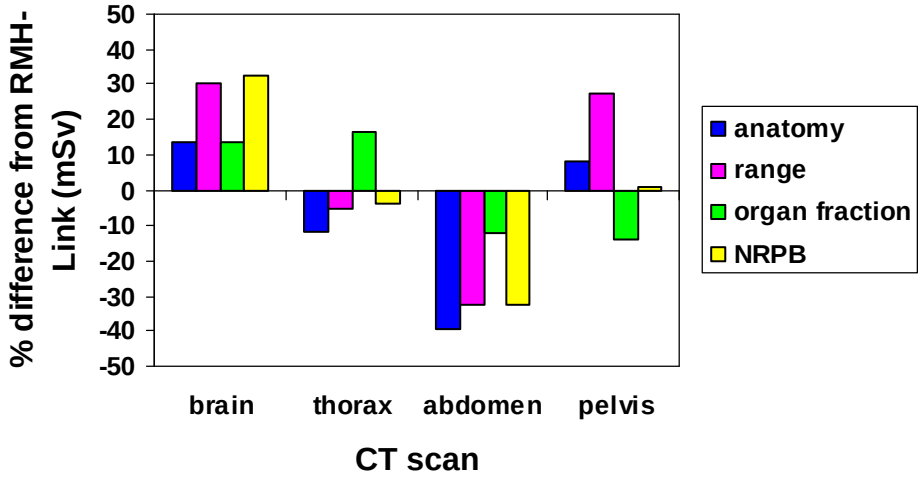


How do I set the scan range?

scaled CT Expo

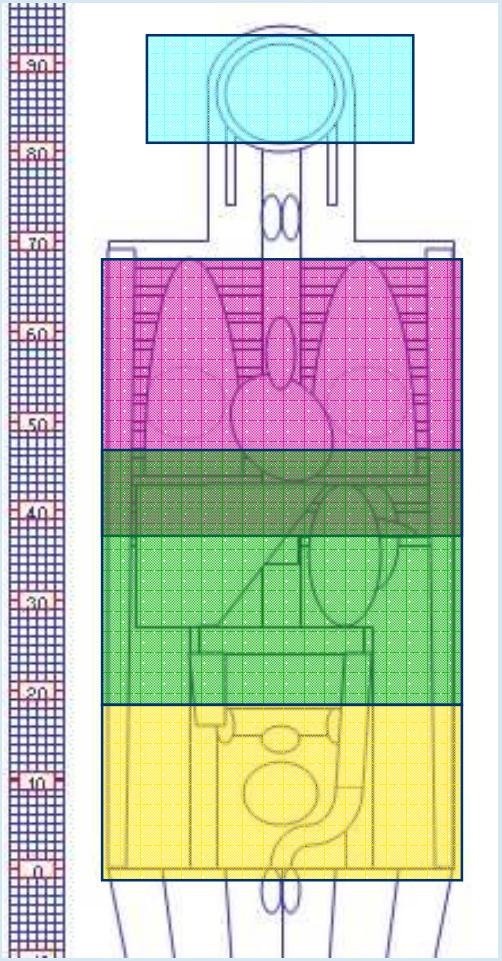


ImPACT dose calculator



- effective doses for male phantom
  - similar results for female and hermaphrodite phantom
- matching fraction of irradiated organs most accurate
  - agreement within 20 %

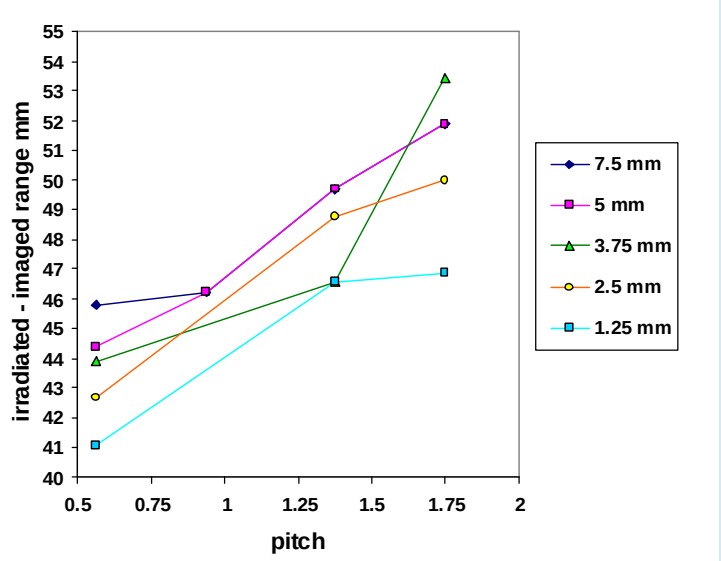
How do I set the scan range?



scan	landmarks	start cm	end cm
brain	base of skull to vertex	81	93
thorax	lung apices to bases	36	68
abdomen	dome of diaphragm to iliac crest	17	47
pelvis	iliac crest to symphysis pubis	-1	17

Do I need to allow for helical over-ranging?

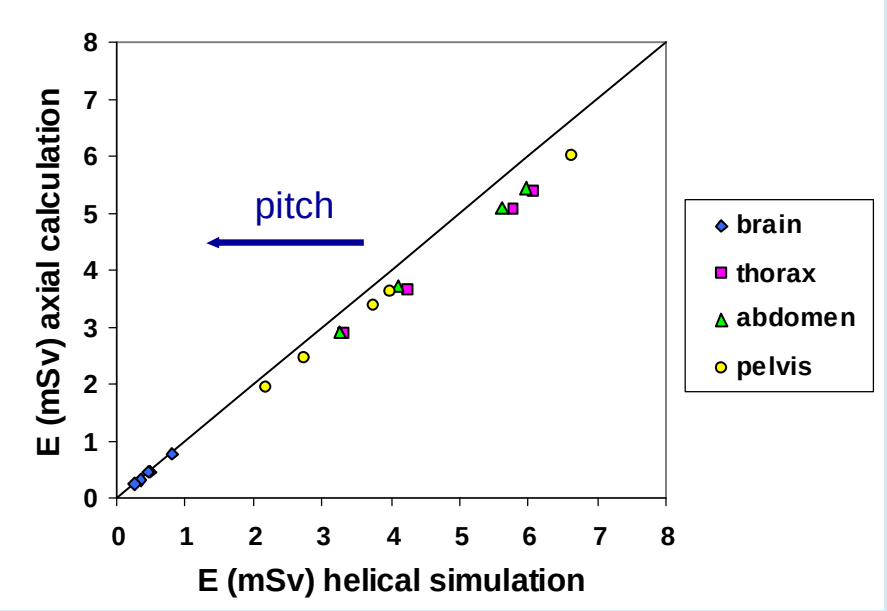
- measure over-range
  - from total exposure time and scan parameters
- add over-range to scan range
- simulate
  - one scanner: LightSpeed 16
  - brain, thorax, abdomen, pelvis scans
  - helical mode with varying pitch
  - axial mode without over-ranging
    - equivalent to dose calculators



LightSpeed 16

Do I need to allow for helical over-ranging?

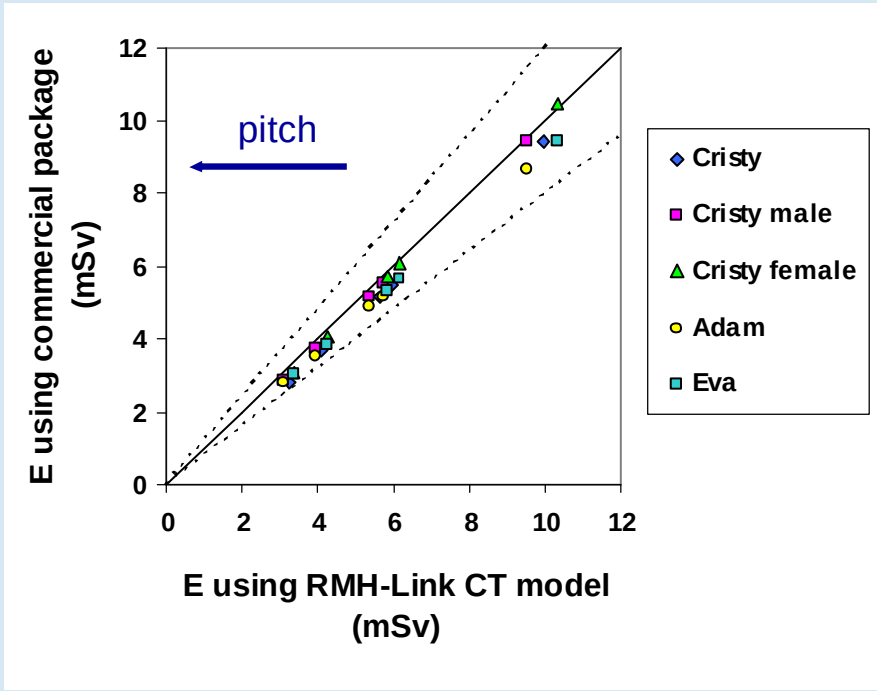
- helical v axial comparison
  - 4 to 13 % discrepancy
  - depends on radiosensitivity of boundary organs



RMH-Link model only

Do I need to allow for helical over-ranging?

- comparison with MC calculators
  - agreement better than 20 % for thorax, abdomen and pelvis scans



abdomen scan

Do I need to adjust for patient size?

- simulate
  - three phantoms
    - 50, 70 and 90 kg
  - one scanner
    - HiSpeed CT/i
  - brain, thorax, abdomen, pelvis scans
  - axial scanning
  - fixed exposure parameters

Do I need to adjust for patient size?

- effective dose increases in smaller patients
- 13 % change in effective dose for 30 % change in weight

scan	effective dose ratio		
	50 kg	70 kg	90 kg
brain*	0.99*	1.00	0.94
thorax	1.13	1.00	0.87
abdomen	1.10	1.00	0.87
pelvis	1.13	1.00	0.91

* scaled separately

And what about mA modulation?

- retrospective patient dose survey
- 30 patients
- TAP protocol
  - 120 kV, 20 mm collimation, 1.375 pitch, 7.5/7.5 mm slices
- data collection
  - mA, scan range from images
  - DLP from patient log book

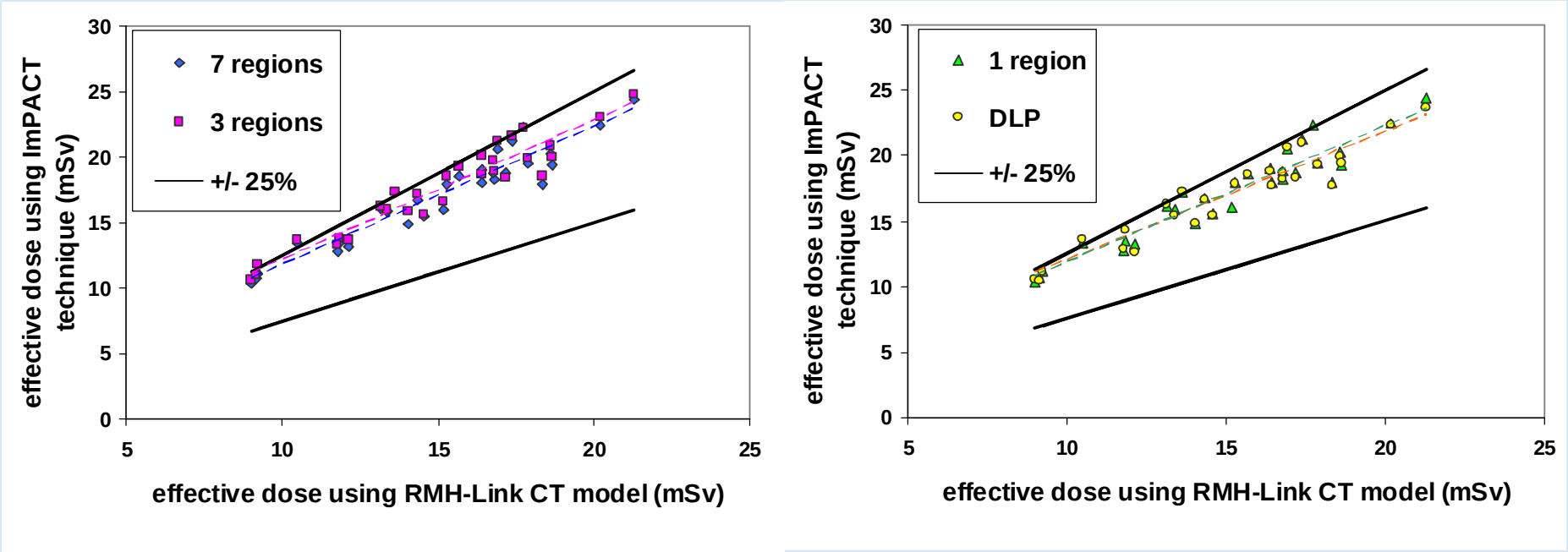
And what about mA modulation?

- individualised effective dose calculation
- RMH-Link MC model
  - resize voxel phantom to each patient
  - assume scan range set on landmarks consistently
    - include helical over-ranging
  - calculate conversion factor per rotation
  - estimate average mAs per rotation
    - from images
  - scale conversion factor by mAs per rotation
  - sum contribution from all rotations

And what about mA modulation?

- best approach with the ImPACT dose calculator
  - Cristy phantom divided into anatomical regions:
    - 7 regions: shoulders, lungs, lung / liver overlap, liver, bowel, pelvis, femora
    - 3 regions: thorax, abdomen, pelvis
    - 1 region: torso
- conversion factors calculated for each region
- average mAs estimated for each region
  - from images
- average mAs estimated from DLP
- effective dose corrected for patient size

And what about mA modulation?



- ImPACT dose calculator overestimates effective dose by 13 – 19 % on average
  - scanner matching is a factor
- average mAs for the scan provides sufficient accuracy

What you should know

source of error	error	optimisation technique	optimised error
Monte Carlo codes	7 %	none	7 %
scan range	40 %	match fraction of irradiated organs	20 %
helical over-ranging	13 % for 16-SCT	add helical over-range	~ 0 %
patient size	13 % for 30 kg deviation	correct for patient size	~ 0 %
mA modulation	13 %*	average mAs or $CTDI_{vol}$	13 %*
combined	46 %		25 %

* comparison of Link-RMH effective doses with and without tube current modulation

Conclusions

- effective doses can be calculated with 25 % accuracy if
  - set scan range by matching fractions of organs irradiated
  - include helical over-range
  - correct for patient size
  - use average mAs for the scan
- effective doses can be calculated with 45 % accuracy for 50 – 90 kg patients otherwise