CT Dose calculations for individual patients – what you should know

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Does this put you off?

![General Information]

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1) This program is not suited to calculate dose for individual patients.
2) All calculations are based on standard patient data (ADAM, EVA, CHILD, BABY).
3) `<Scanrange> <Adult> or <Child-Baby>` may be used to indicate the scan range graphically.
4) A short description of the program can be found under `<Help>`!

Individual calculations are not possible!
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?

- 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?

<table>
<thead>
<tr>
<th>scan</th>
<th>landmarks</th>
<th>start cm</th>
<th>end cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>brain</td>
<td>base of skull to vertex</td>
<td>81</td>
<td>93</td>
</tr>
<tr>
<td>thorax</td>
<td>lung apices to bases</td>
<td>36</td>
<td>68</td>
</tr>
<tr>
<td>abdomen</td>
<td>dome of diaphragm to iliac crest</td>
<td>17</td>
<td>47</td>
</tr>
<tr>
<td>pelvis</td>
<td>iliac crest to symphysis pubis</td>
<td>-1</td>
<td>17</td>
</tr>
</tbody>
</table>
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
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

![Graph showing comparison between E using commercial package and E using RMH-Link CT model](image)

- abdomen scan

CTUG 2010
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

<table>
<thead>
<tr>
<th>scan</th>
<th>effective dose ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 kg</td>
</tr>
<tr>
<td>brain*</td>
<td>0.99</td>
</tr>
<tr>
<td>thorax</td>
<td>1.13</td>
</tr>
<tr>
<td>abdomen</td>
<td>1.10</td>
</tr>
<tr>
<td>pelvis</td>
<td>1.13</td>
</tr>
</tbody>
</table>

* 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

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

* 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