Optimisation in CT

A case for shared approach

Stephen J. Golding
University of Oxford
Body CT 1979:

- 10 mm sections
- 20 second exposure
- 60 second reconstruction
Body CT 2007

Submillimetre sections
“instant” reconstruction
64 slice, 128, 256…….

Subsecond exposure

Data volume a problem
CT is now our major radiation protection challenge
Impact of new technique

Tasks performed better

Tasks performed more easily

New applications
Clinical Benefits of MSCT: traditional applications

**Speed**: - image quality

**Cover**: - Reduced anatomical misregistration
Clinical Benefits of MSCT: new applications

- Multiphase enhancement
- CT Angiography
- CT Urography
- 3D/virtual reality
Hepatic enhancement; carcinoma of pancreas
CT angiography
The Era of 3D/Virtual Reality/4D
Clinical benefits of MDCT

Multiphase enhancement
CT Angiography
CT Urography
3D/Virtual reality
Screening
Small pulmonary nodules: detection at chest CT and outcome

- Chest CT: 3445
- Inclusion criteria: 344
- Characterisation: 87
- Benign: 77
- Malignant: 10 (0.29%)
- Primary neoplasm: 9 (0.03%)

Benjamin et al, 2003
Acute Appendicitis: effect of increased use of CT on selecting patients earlier

“With increased CT use there were less severe imaging findings, including absence of periappendiceal stranding, and a significant decrease in surgical-pathologic severity of appendiceal disease and hospital stay.”

Raptopoulos et al, 2003
Applications have risen dramatically since 2000.

Many young patients, benign disease

But that this not the only problem
CT: contributions to dose

1995  30%  Shrimpton & Wall

1998  40%  Shrimpton & Edyvean
Mettler et al., 2001

11% of examinations
67% of dose
11% in children

Hart and Wall, 2004

47% of dose
7% of examinations
Dose variance

Factors of 10-40

(Shrimpton et al 1991)

Factors of 8-20

(Olerud 1997)

Examination technique: variations

Optimisation of technique is now our major challenge
JRH CT - DLP Dec 00 and Jan 01

No of pats

mGy-cm
## JRH cases over 1000 mGy·cm

<table>
<thead>
<tr>
<th>Description</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>17</td>
</tr>
<tr>
<td>Brain + 4 parts</td>
<td>1</td>
</tr>
<tr>
<td>Brain + 3 parts</td>
<td>1</td>
</tr>
<tr>
<td>Brain + 2 parts</td>
<td>6</td>
</tr>
<tr>
<td>Brain + 1 part</td>
<td>5</td>
</tr>
<tr>
<td>3 trunk parts</td>
<td>5</td>
</tr>
<tr>
<td>2 trunk parts</td>
<td>13</td>
</tr>
<tr>
<td>1 trunk part</td>
<td>9</td>
</tr>
<tr>
<td>CTA</td>
<td>4</td>
</tr>
</tbody>
</table>
Reasons for variable practice

- Clinical indications
- Growing applications
- Poor knowledge/practice
- Workload pressure
- Inexperience
Is this the age of imaging over-kill?

Clinical/workload pressures motivate against quality/protection

Optimisation of practice now represents the major challenge in dose reduction.

The evidence base for practice change is weak
To what extent should technology alter technique?

Has disease changed?

Have diagnostic criteria changed?

Will clinical management change?

Are there risk limitation implications?
EC Directive 97/43

Justification
Optimisation
Audit
National law 2000

Is it right to regard these as separate processes?
Optimisation

- Equipment – quality control
- Equipment – advances
- Examinations – threshold exposure (DRLs)
- Practice – optimisation includes justification
Automatic Exposure Control (AEC)

- All modern manufacturers
- Dose depends on tube rotation time and tube current (to a lesser extent kV)
- Most common to vary mAs
- preset algorithm
Oxford Experience: 1, 4, 8, 16 slice
Modifying the examination

• Extent – should be practised in all cases
  • BUT: modern practice/workload motivates against

• Exposure
  • The aim is to complete the examination with the minimum threshold exposure
  • BUT – the evidence base for minimum exposure is weak.
Modifying extent – what can be done?

- Frequent audit against DRL
- Continual audit/challenge
- Important role for Physicist - proactive
Modifying exposure

CT of the chest: minimal tube current (50%)
Mayo et al, 1995

Low dose CT in orbital trauma (90%)
Jackson & Whitehouse, 1993

Radiation dose reduction in CT (96%)
Starck et al, 1998
A Scientific Basis for Dose Reduction in Multislice CT of the Face: H. Nwume, 2002

- Phantom
- 8 steps, 10-80 mA
- 4 slice: pitch 3, 6
- 8 slice: pitch 0.67, 1.67
- Scoring
Results – 8-slice

Comparison of objective image quality relative to scanning dose. Axial Images

Comparison of subjective image quality relative to scanning dose. Axial Images

Comparison of objective image quality relative to scanning dose. 3D Images

Comparison of subjective image quality relative to scanning dose. 3D Images
HRCT of the face: conclusions:

Acceptable axial images at 40mA

Acceptable 3D images at 10mA

(Manufacturer’s recommendation: 140mA)
New work: Cervical and Lumbar Spine Trauma

• Reduce dose without degrading fracture detectability

• Phantoms built with artificial fractures

• Order of vertebrae randomised each time

• Scans with tube current 120 -10 mA
Spine Phantoms 2
Exposure influences noise and therefore contrast resolution.

Soft tissue lesion detection is the real anxiety.
Experiment 2: dose reduction in the brain

Creation of “lesions”

Variable attenuation
Variable size
Variable position
Brain “lesions”: the answer

Commercial jelly (orange)

Bubblewrap
Experiment 2: preliminary conclusions

Large lesions: dose may be reduced 50%

Small lesions: further study needed
European Commission Study Group

1994 to 2007

7 countries

Nationally paired Physicist/Radiologist
CT working group – 4th Framework

- European guidelines
- Quality criteria for computed tomography

1999
5th Framework Programme Concerted Action

Guidelines for MSCT

European Field Survey

MSCT dosimetry

Assessment of patient dose in CT
European Field Survey

14 applications

53 institutions

8 countries
Abdomen, abscess

The graph shows a linear relationship between DLP (mGy.cm) and effective dose (mSv). The equation of the line is given by $y = 59.471x$. The x-axis represents the effective dose in mSv, and the y-axis represents the DLP in mGy.cm.
Liver metastasis, colorectal carcinoma

Effective dose, mSv

- Sequence 4
- Sequence 3
- Sequence 2
- Sequence 1

Hospital #
## European Field Survey

Large difference in protocols
Large difference in parameters

<table>
<thead>
<tr>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scanned range</td>
</tr>
<tr>
<td>No. of series/repeats</td>
</tr>
<tr>
<td>Tube current</td>
</tr>
<tr>
<td>Section thickness</td>
</tr>
</tbody>
</table>

Great dose reduction potential exists
6th Framework Programme

Prospective studies; applications MSCT: justification

Automatic exposure controls: optimisation

Paediatric MSCT: justification/optimisation

New approaches to MSCT dosimetry: audit

Website: www.msct.eu
Technical principles

Clinical principles
  paediatrics

Good technique

26 applications

Guidelines on dose
Justification in Optimisation

• Examination necessary?

• Examination the right one?

• Examination the right extent/quality?

• i.e. more than just:  ? CT indicated?
What is the clinical question?

Surgeon needs to know:
  ? depressed orbital floor
  ? extent
Delayed diagnosis: ultra-low dose

10-20mA  DLP  40mGy-cm
Increasing the availability of both ultrasound and MRI will reduce reliance upon techniques involving x-rays, particularly for young patients at higher risk.

NRPB (1990)

How far can the UK follow this advice?
Effective justification

Is there a case for using non-radiation tests in the first instance?

Irrespective of sensitivity?

Pre-radiation screening?

Is this compatible with British health care?
“Black Bone” MRI

Can MRI replace CT?

In what circumstances is the greater resolution of CT for cortical bone essential to management?
Volume acquisition
Acquisition time 3 mins
Gradient echo
5° flip angle
PD weighting
In-phase TE

256^2 → 512^2
The Future

More evidence is needed

Dose audit is mandatory

Further surveys/studies

Continued/updated advice

Vigilance!
If you seek to regulate the people by law they will learn how to stay out of gaol but feel no shame.

If lead by virtue and propriety they will feel shame and become good.

Kongzi (Confucius), 551-459 BC