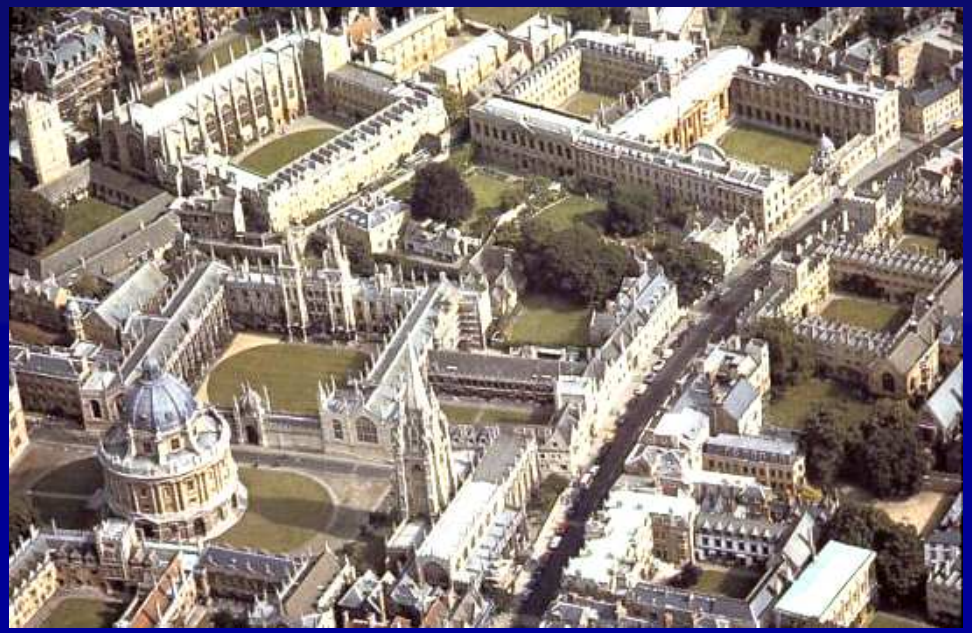
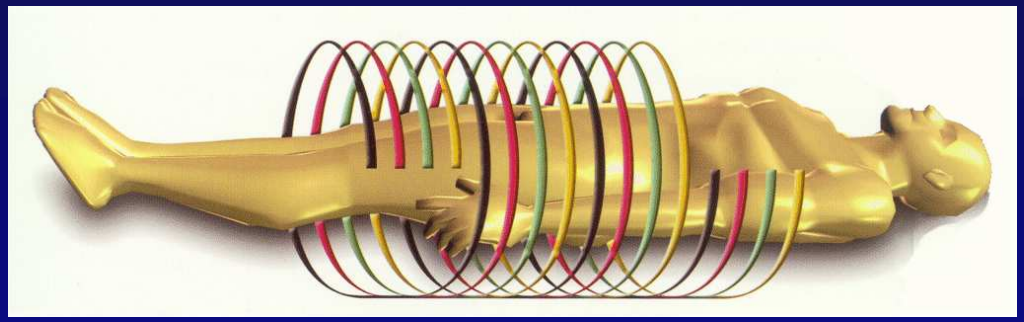
Optimisation in CT

A case for shared approach





Stephen J. Golding
University of Oxford

Body CT 1979:

10 mm sections

20 second exposure

60 second reconstruction

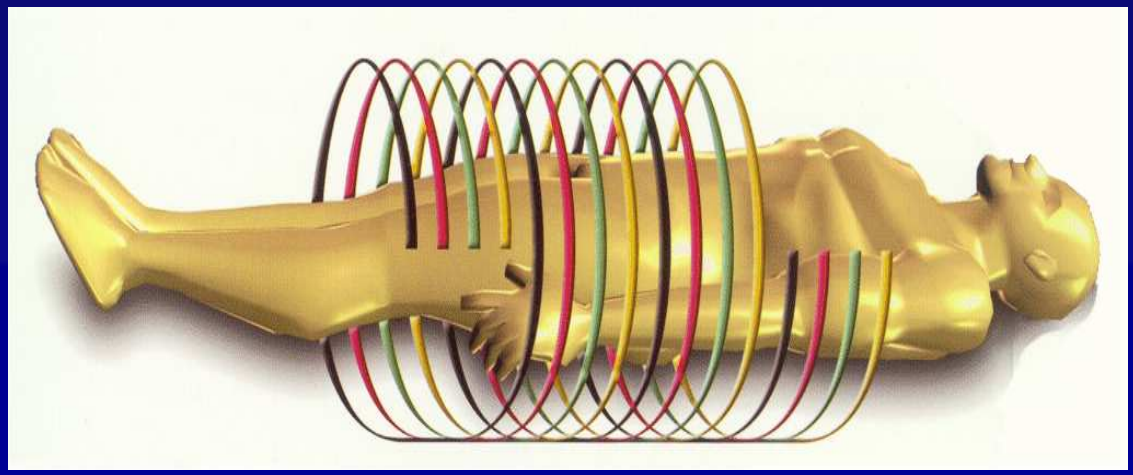
Body CT 2007

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

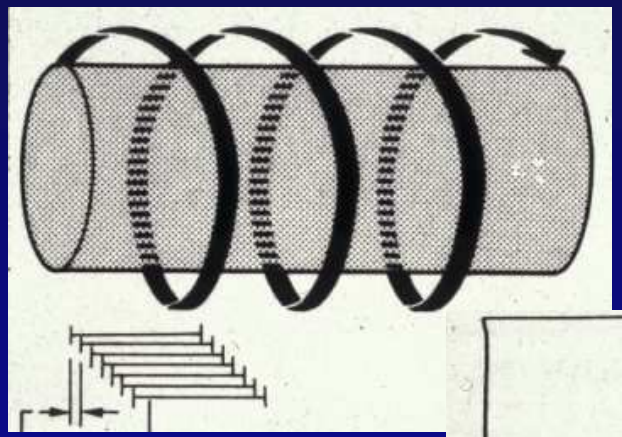
Tasks performed better

Tasks performed more easily

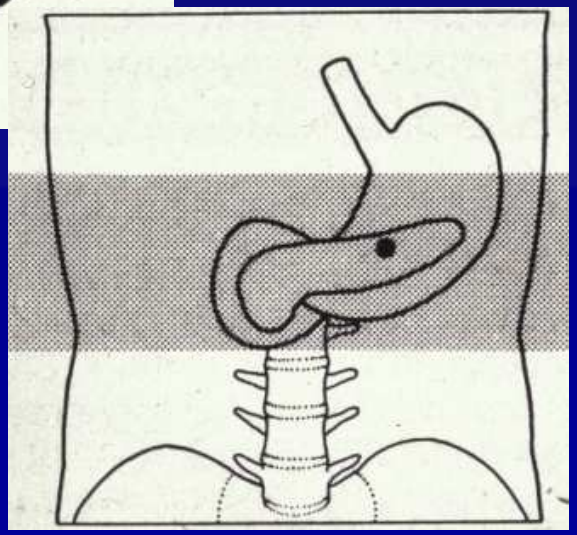
New applications

Clinical Benefits of MSCT: traditional applications

Speed : - image quality



Cover : - Reduced anatomical misregistration



Clinical Benefits of MSCT: new applications

Multiphase enhancement

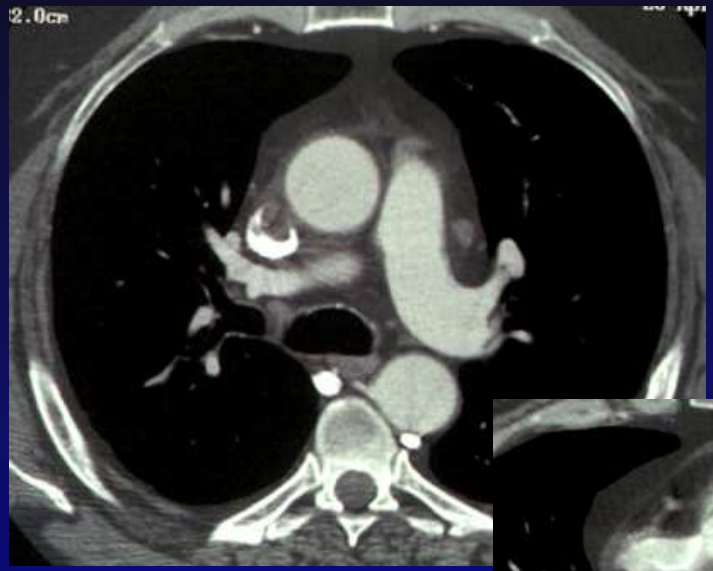
CT Angiography

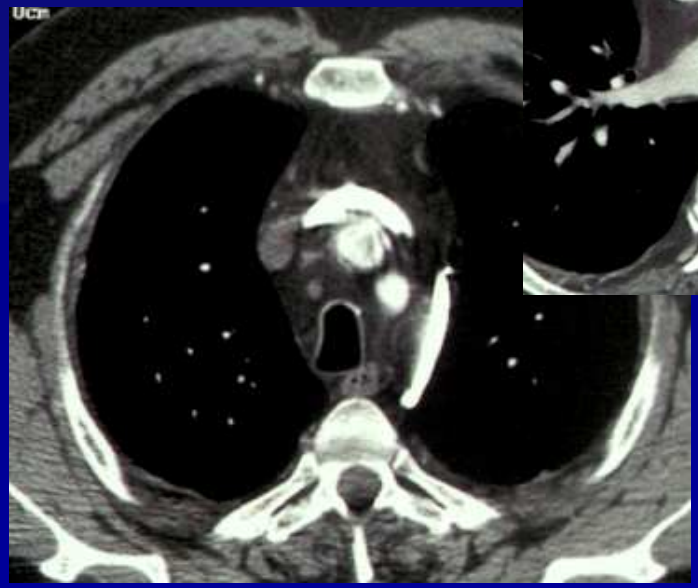
CT Urography

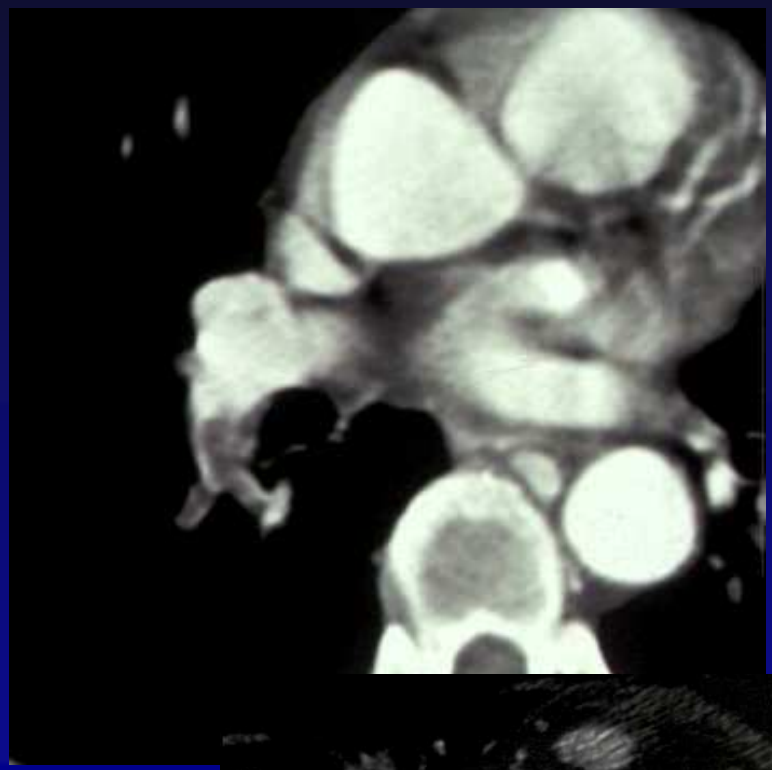
3D/virtual reality

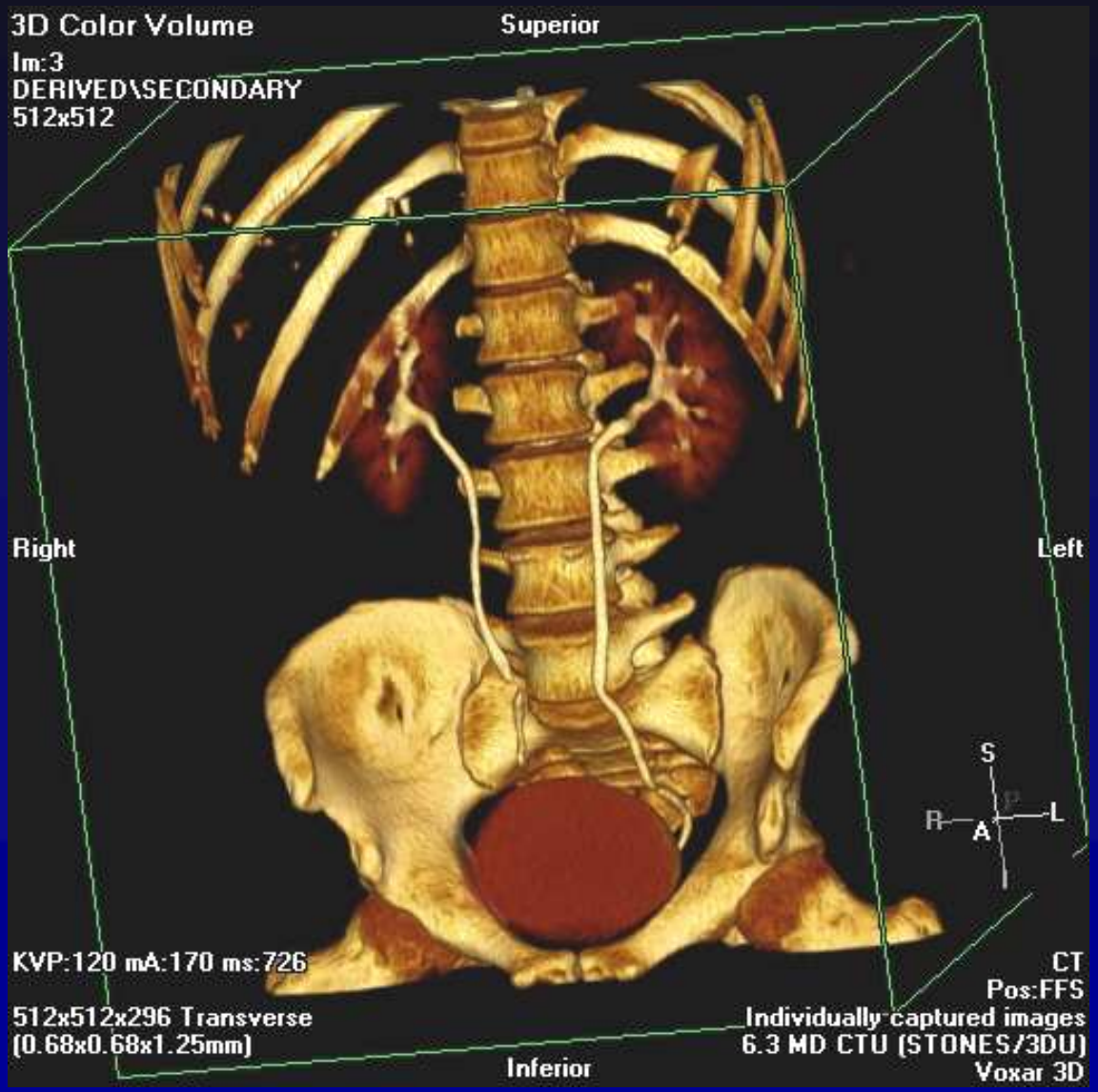
Hepatic enhancement; carcinoma of pancreas

CT angiography

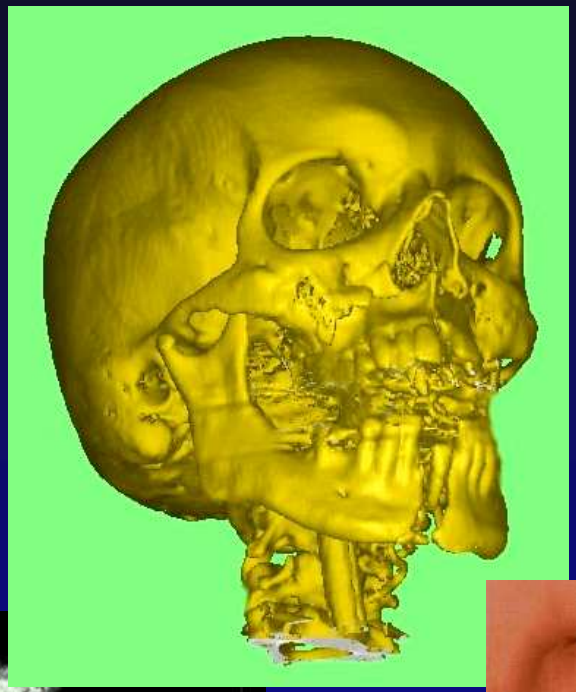


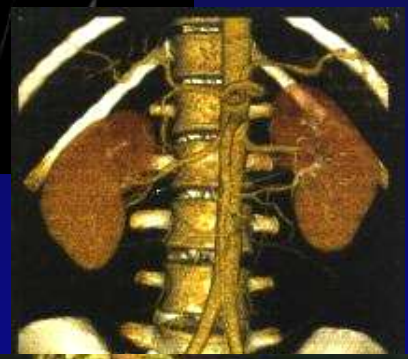


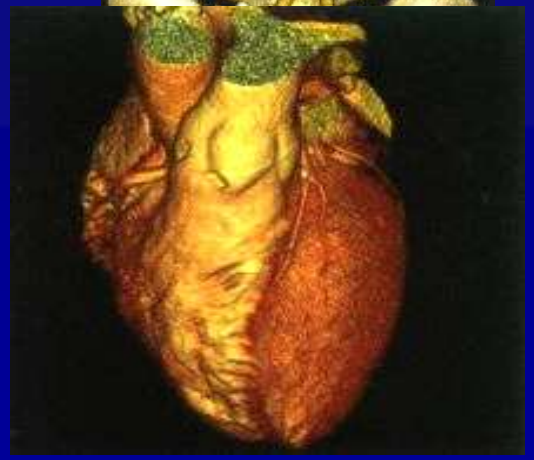



3D Color Volume
Im:3
DERIVED\SECONDARY
512x512
Superior
Right
Left
S
P
R
A
L
KVP:120 mA:170 ms:726
512x512x296 Transverse
(0.68x0.68x1.25mm)
Inferior
CT
Pos:FFS
Individually captured images
6.3 MD CTU (STONES/3DU)
Voxar 3D

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

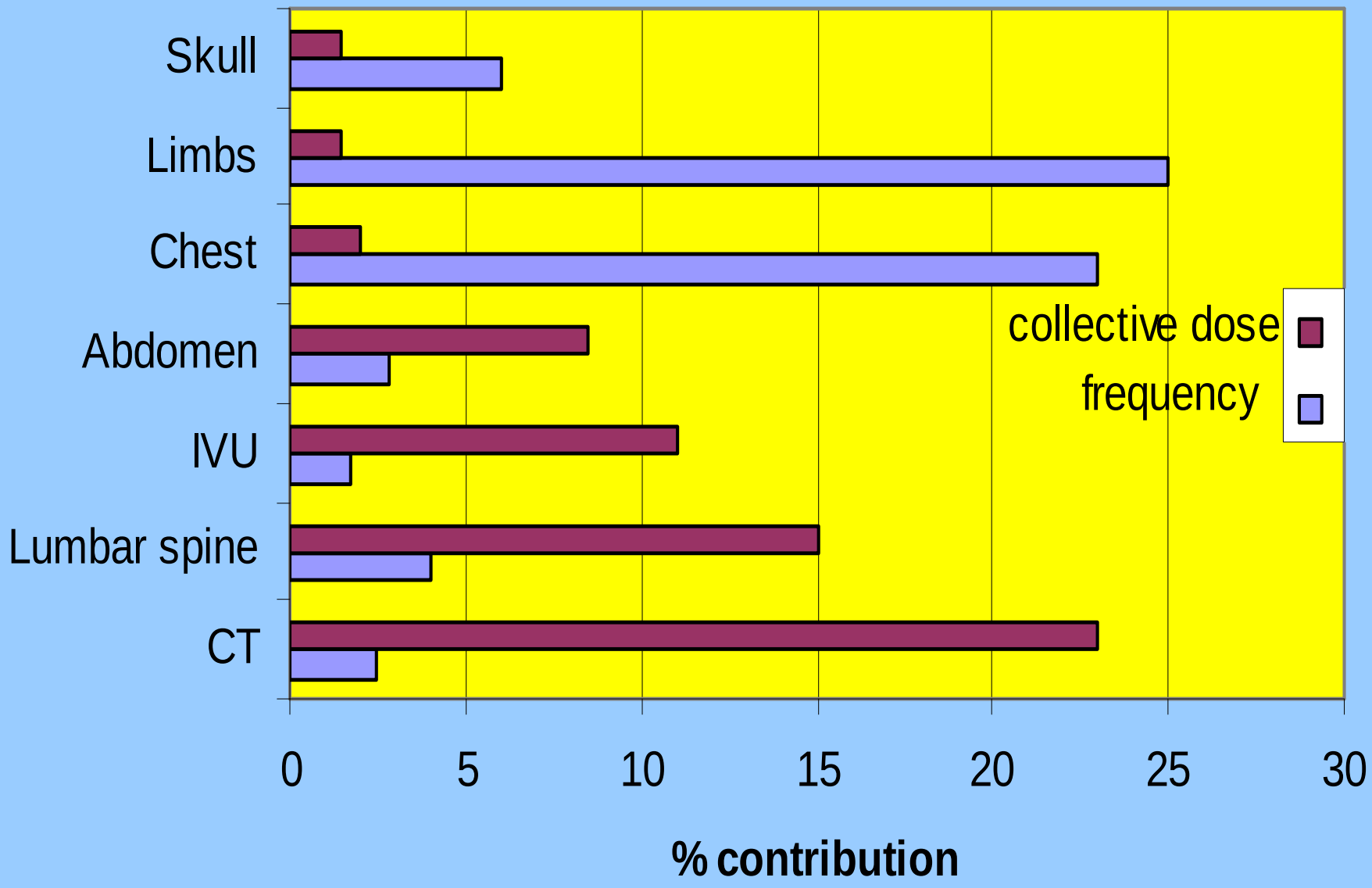
"With increased CT use there were less severe imaging findings, including absence of periappendiceal stranding, and a significant decrease in surgical-pathologic severity of appendiceal disease and hospital stay."

Raptopoulos et al, 2003

Applications have risen dramatically since 2000.

Many young patients, benign disease

But that this not the only problem


Skull
Limbs
Chest
Abdomen
IVU
Lumbar spine
CT
collective dose
frequency
0
5
10
15
20
25
30
% contribution

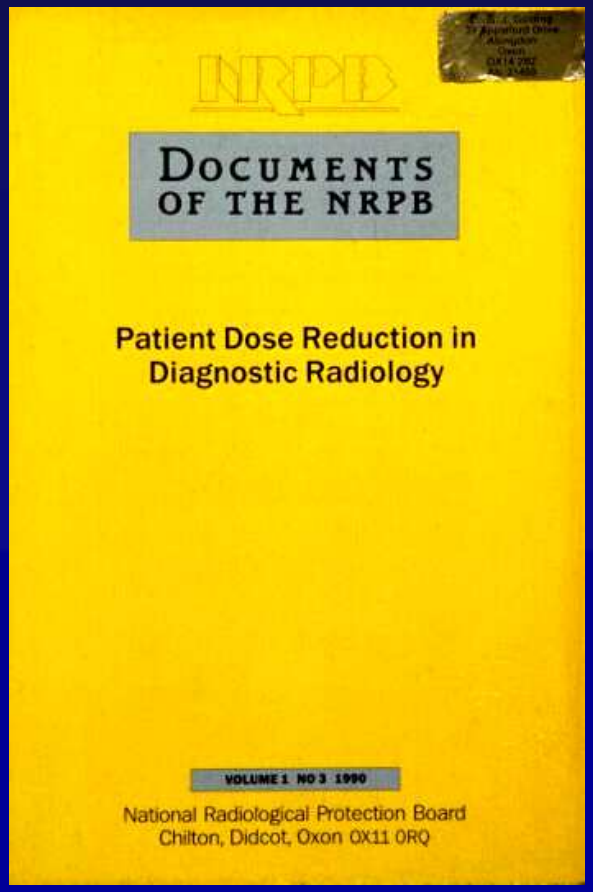
CT: contributions to dose

1995 30%

Shrimpton & Wall

1998 40%

Shrimpton & Edyvean



Mettler at 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

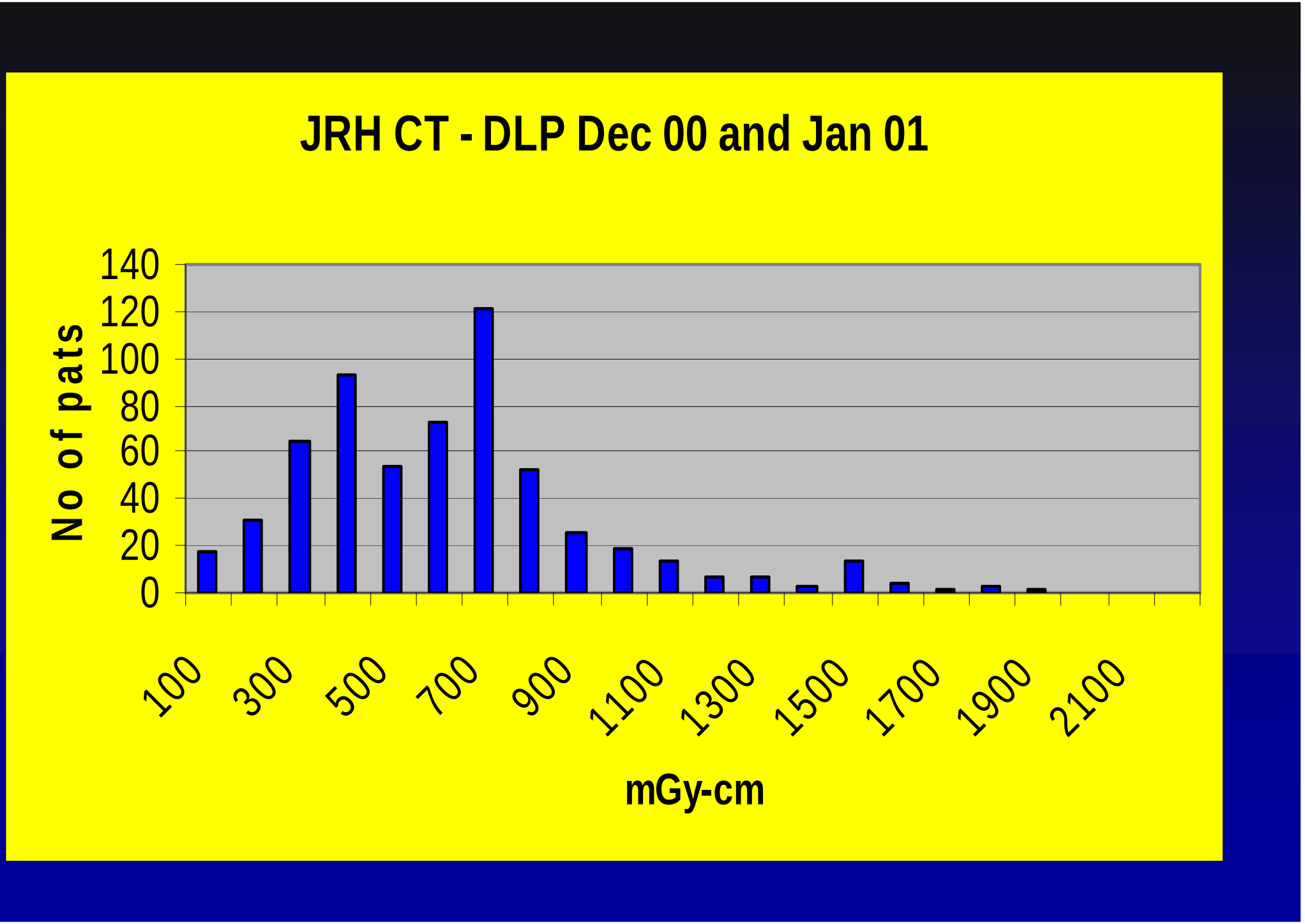
(Shrimpton et al 1991)

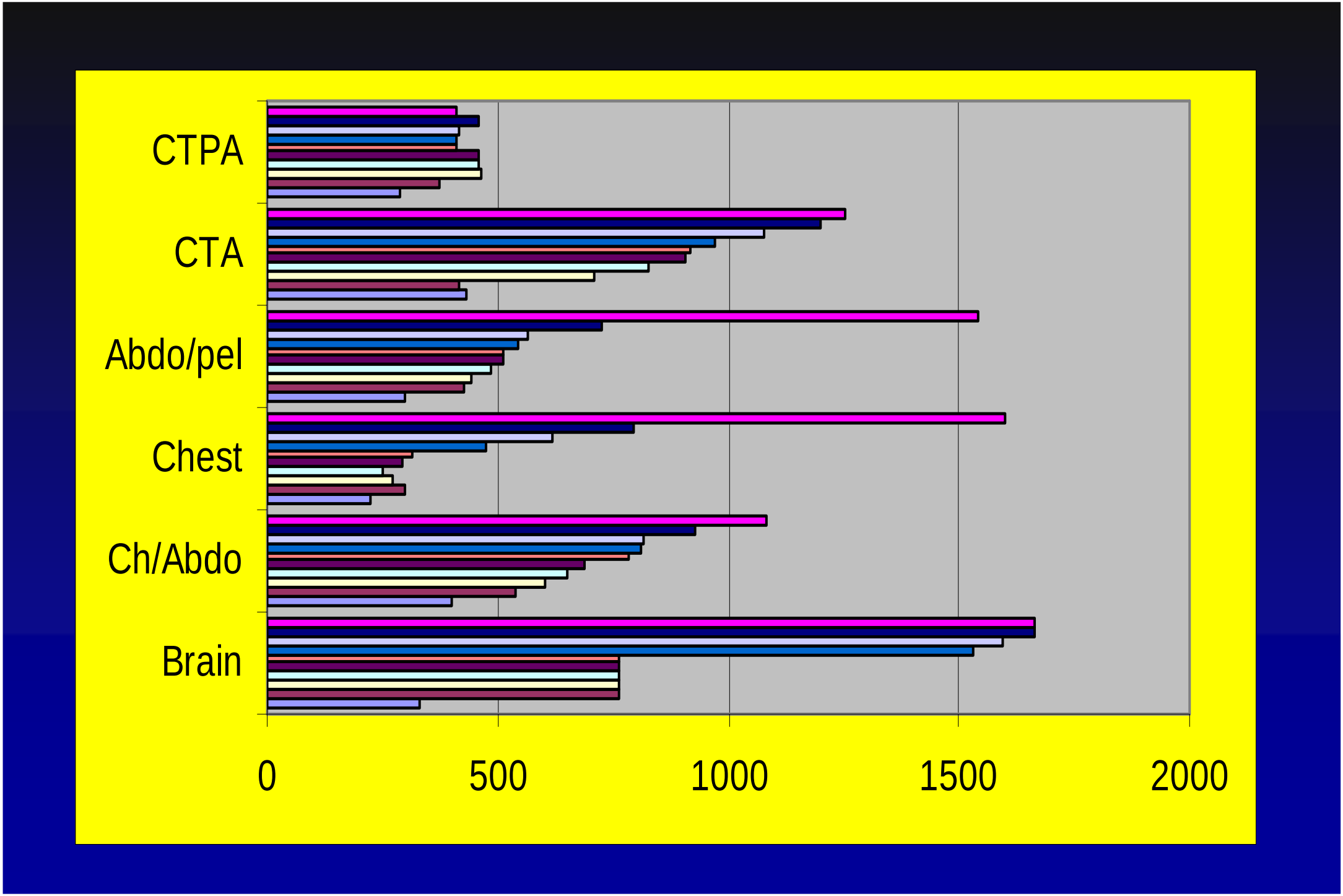
Factors of 8-20

(Olerud 1997)

Examination technique: variations

Optimisation of technique is now our major challenge


JRH CT - DLP Dec 00 and Jan 01
No of pats
140
120
100
80
60
40
20
0
100
300
500
700
900
1100
1300
1500
1700
1900
2100
mGy-cm


CTPA
CTA
Abdo/pel
Chest
Ch/Abdo
Brain
0
500
1000
1500
2000

JRH cases over 1000 mGy-cm

Brain	17
Brain + 4 parts	1
Brain + 3 parts	1
Brain + 2 parts	6
Brain +1 part	5
3 trunk parts	5
2 trunk parts	13
1 trunk part	9
CTA	4

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

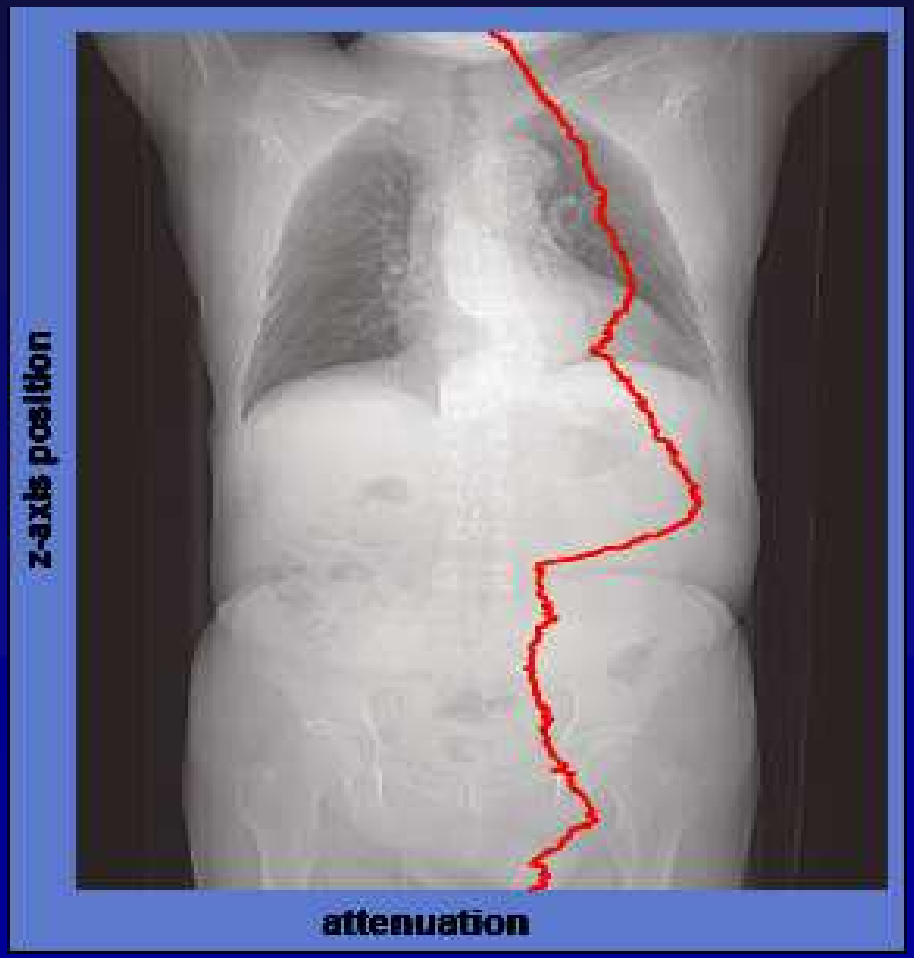
Is it right to regard these as separate processes?

Optimisation

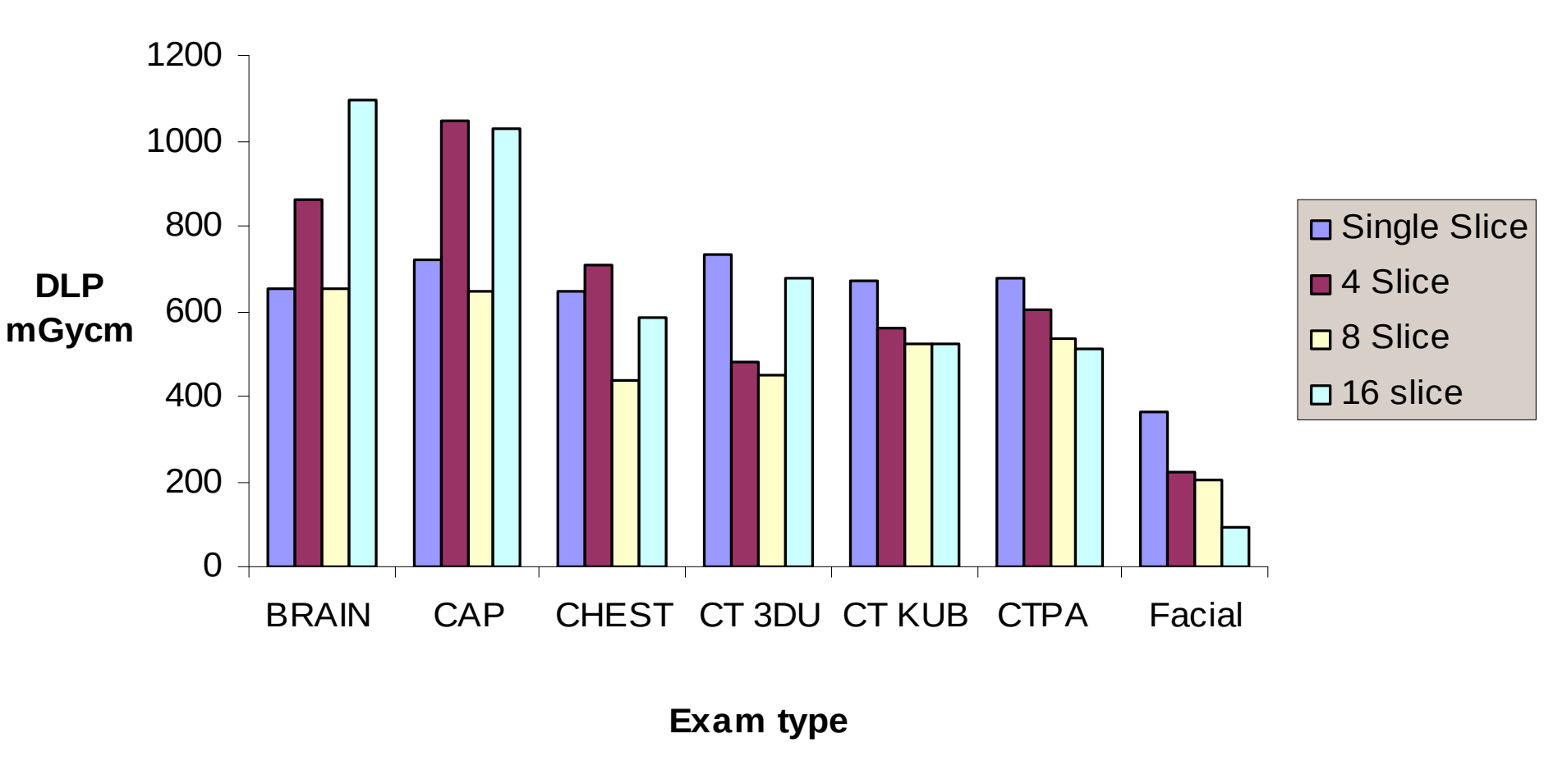
- Equipment – quality control
- Equipment – advances
- Examinations – threshold exposure (DRLs)
- Practice – optimisation includes justification

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%)

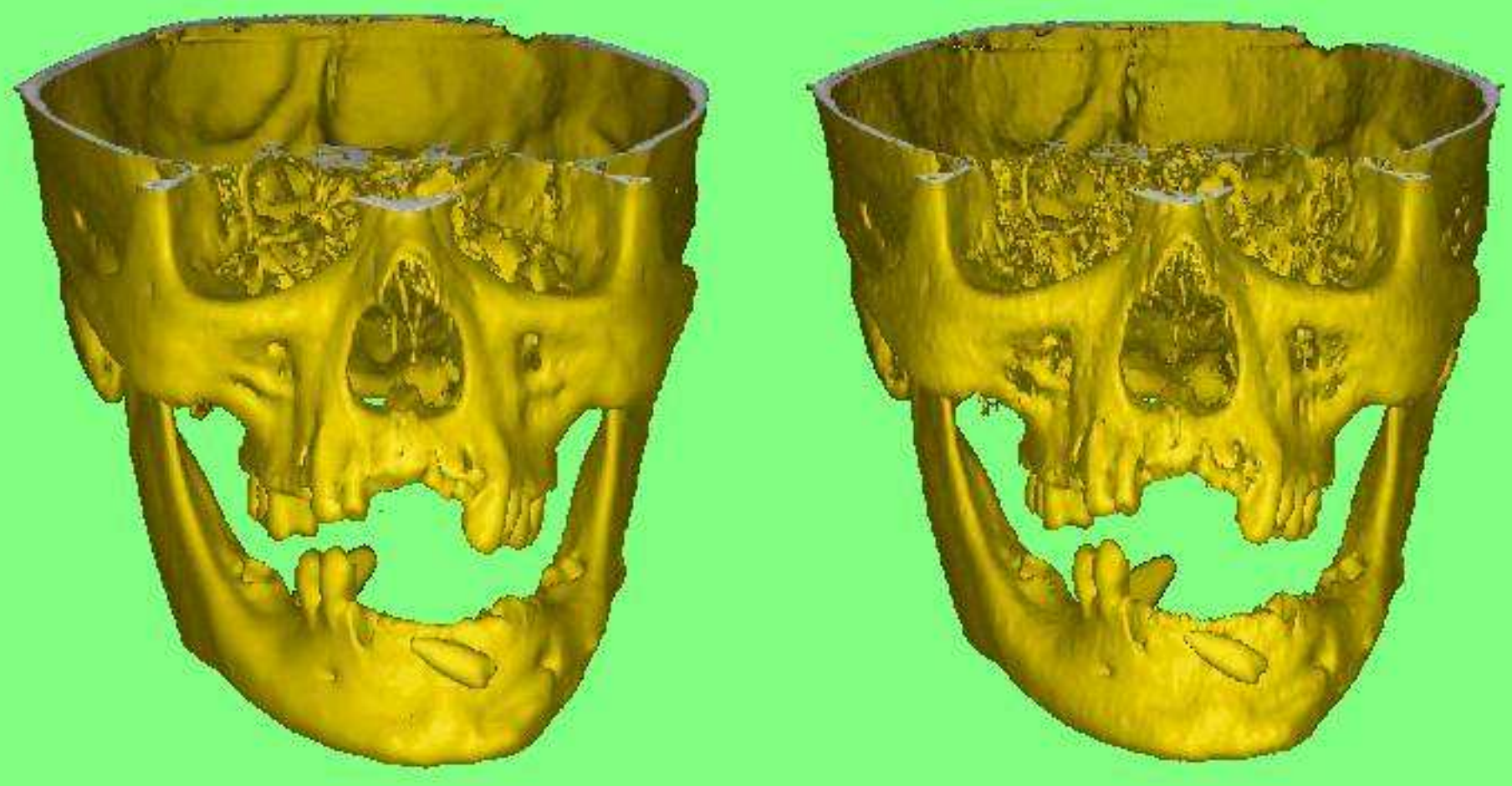
Jackson & Whitehouse, 1993

Radiation dose reduction in CT (96%)

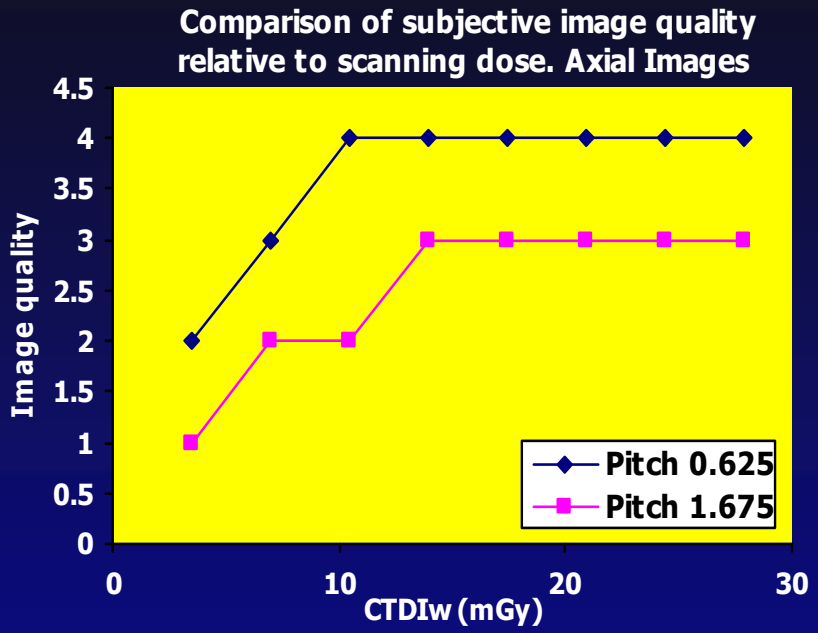
Starck et al, 1998

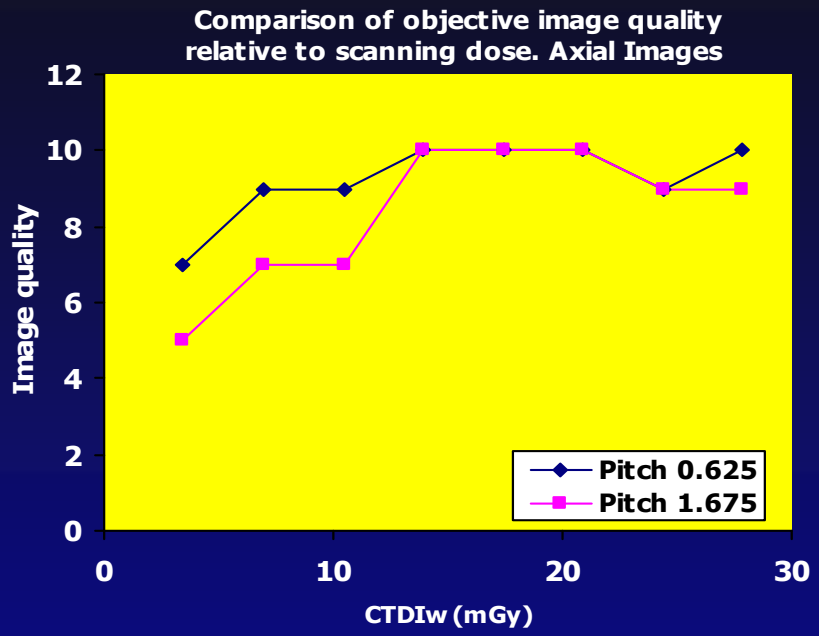
A Scientific Basis for Dose Reduction in Multislice CT of the Face: H.Nwume, 2002

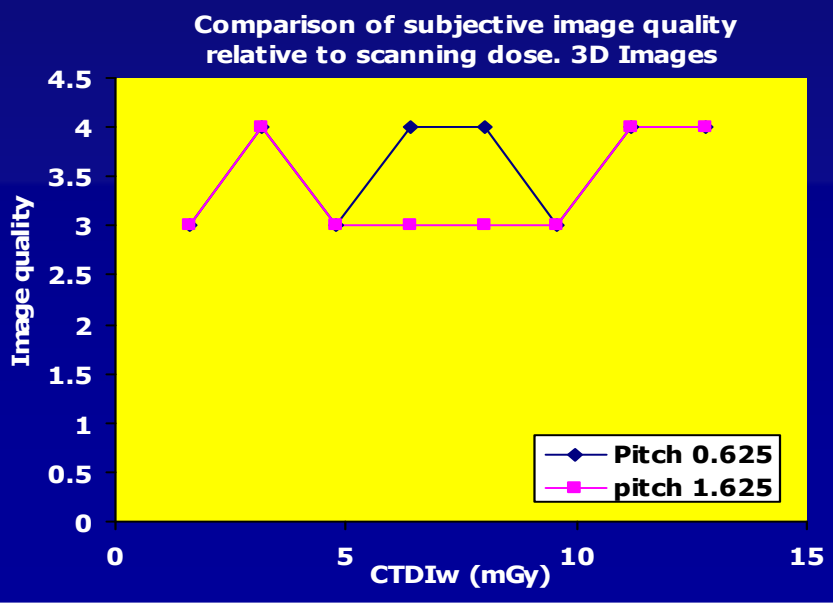
- Phantom
- 8 steps, 10-80 mA
- 4 slice: pitch 3, 6
- 8 slice: pitch 0.67, 1.67
- Scoring

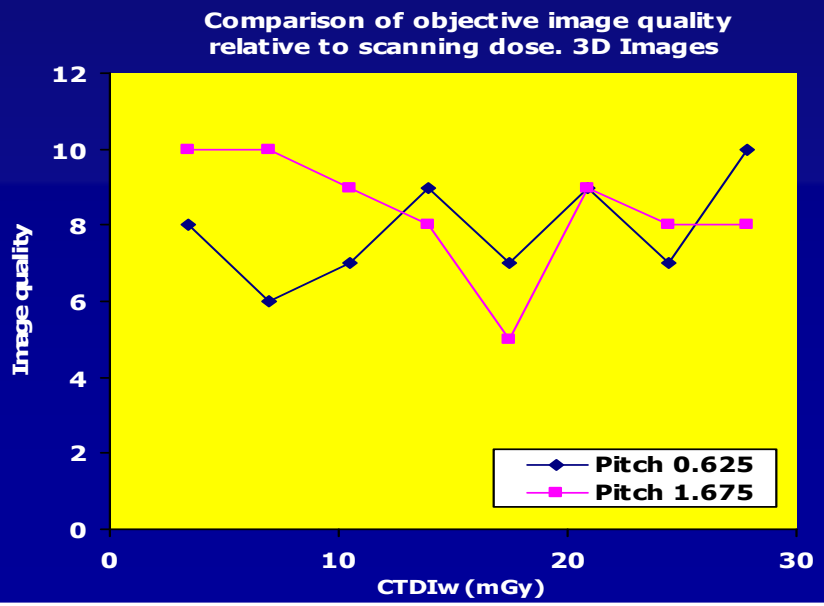


Results – 8-slice









HRCT of the face: conclusions:

Acceptable axial images at 40mA

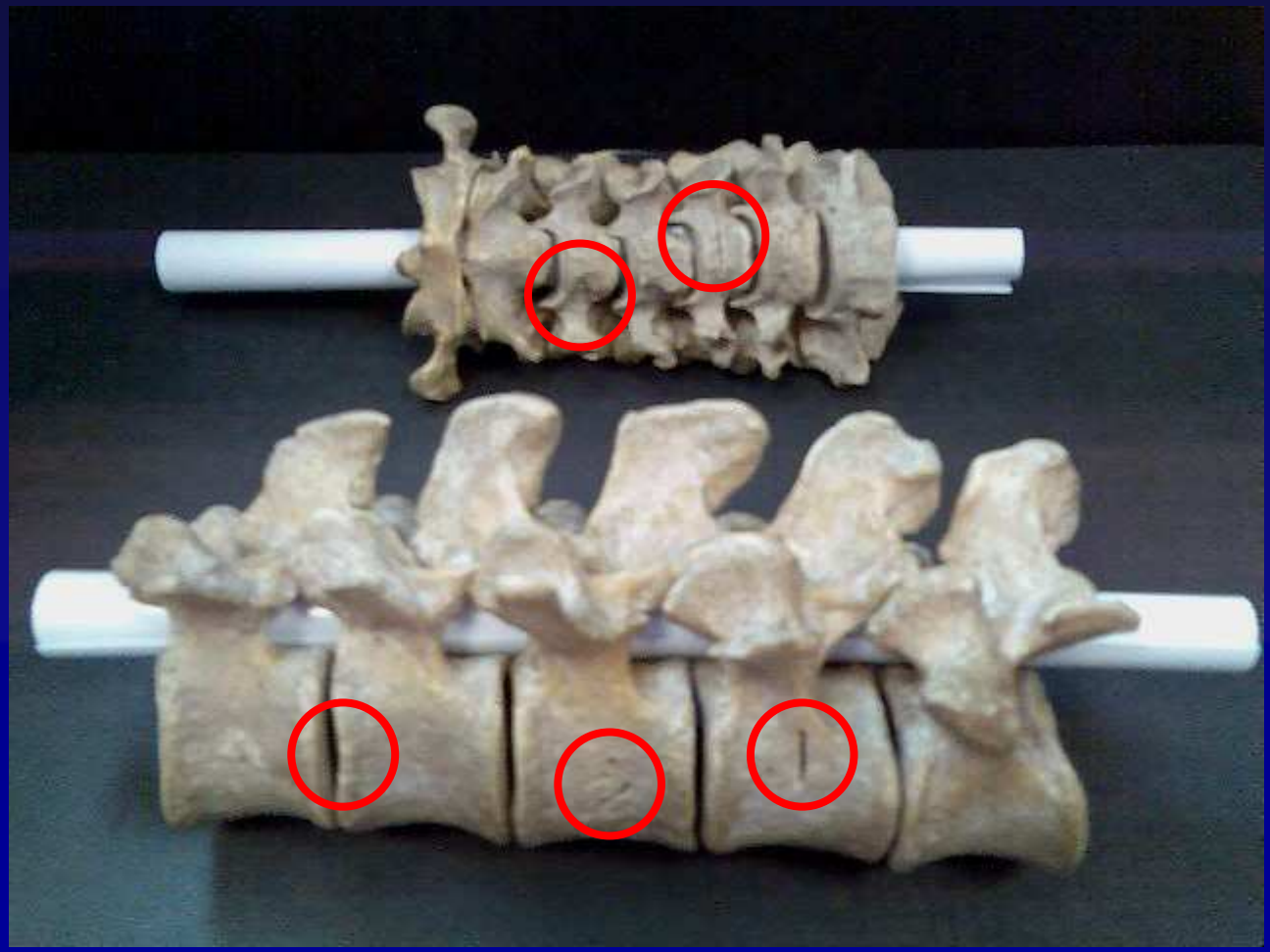
Acceptable 3D images at 10mA

(Manufacturer’s recommendation: 140mA)

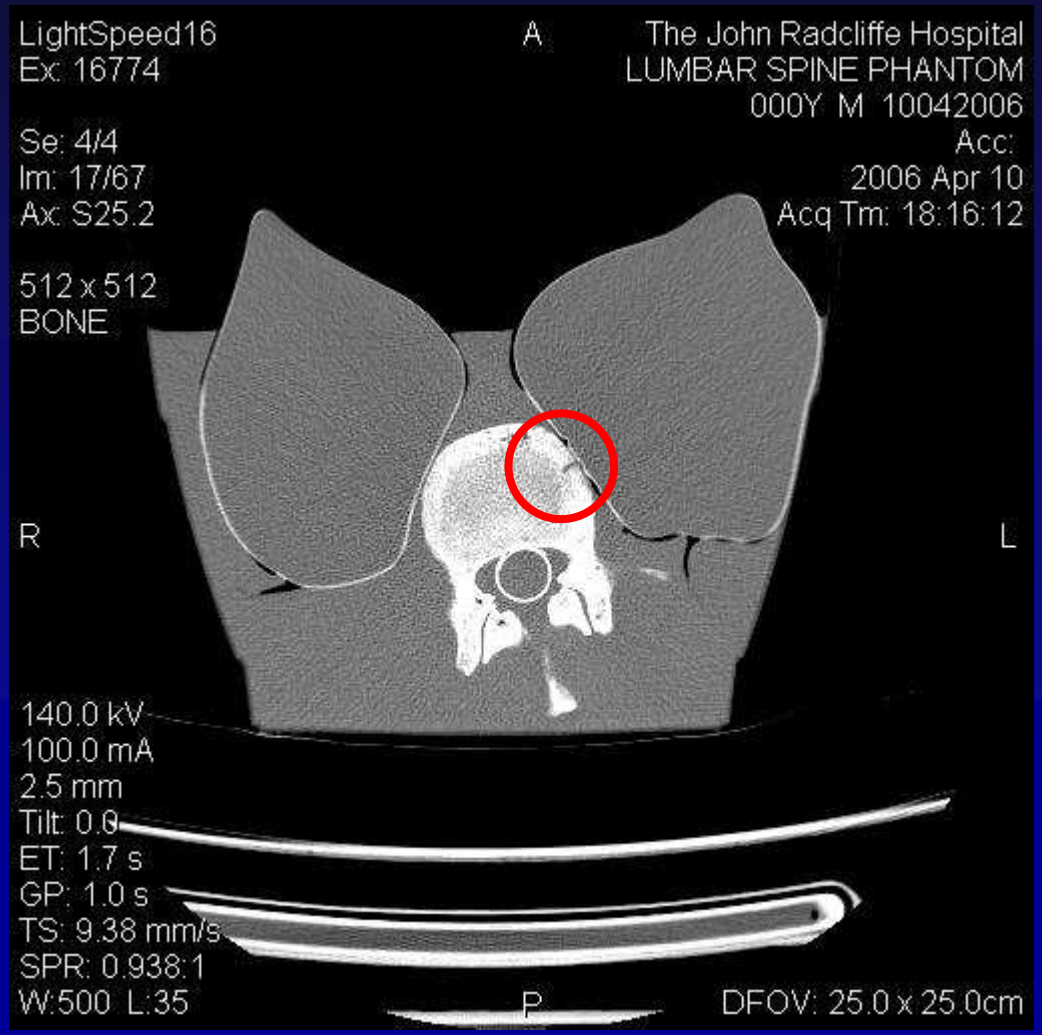
New work: Cervical and Lumbar Spine Trauma

- 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



Fracture Image



Exposure influences noise and therefore contrast resolution

Soft tissue lesion detection is the real anxiety

Experiment 2: dose reduction in the brain

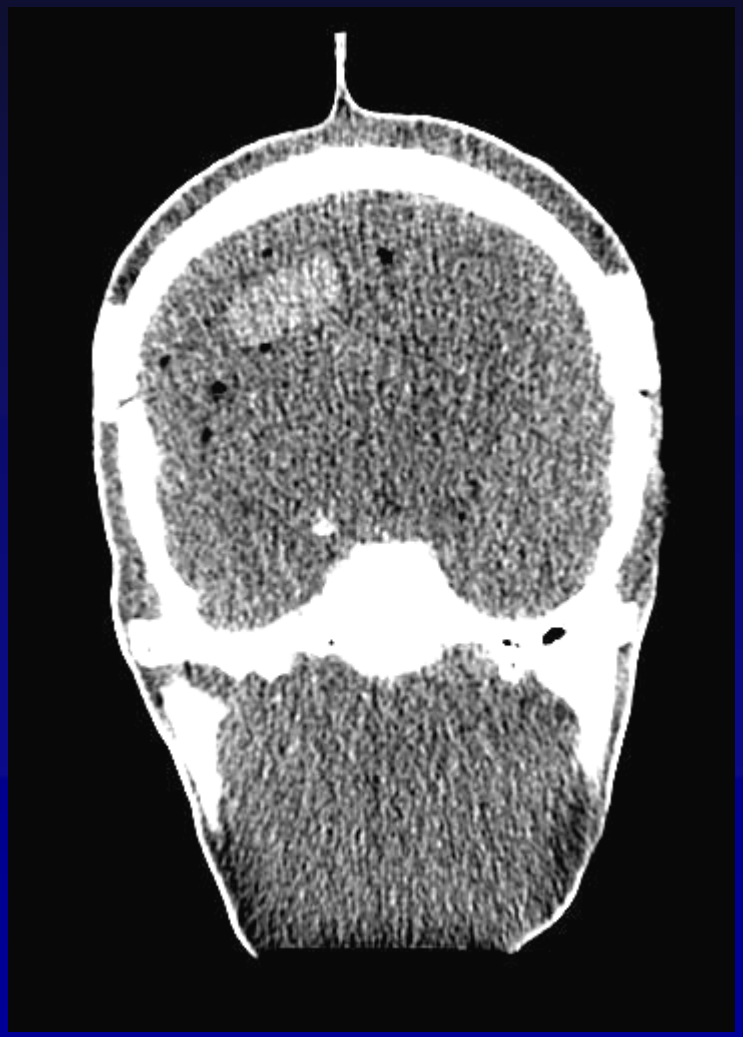
Creation of “lesions”

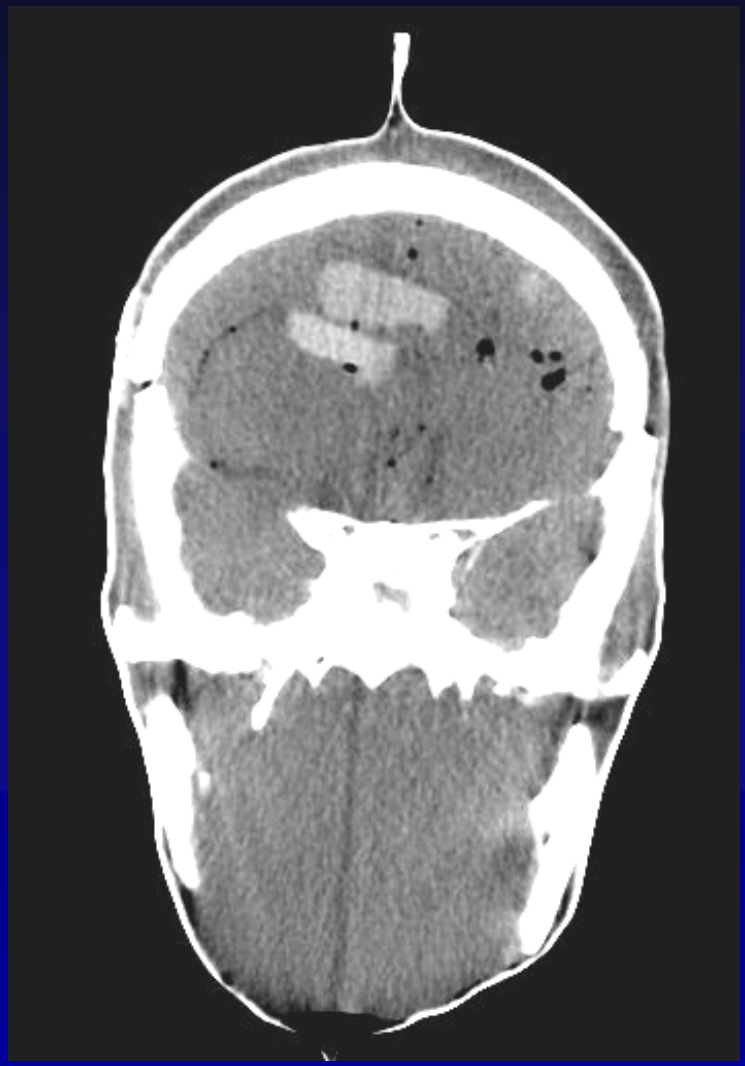
- Variable attenuation
- Variable size
- Variable position

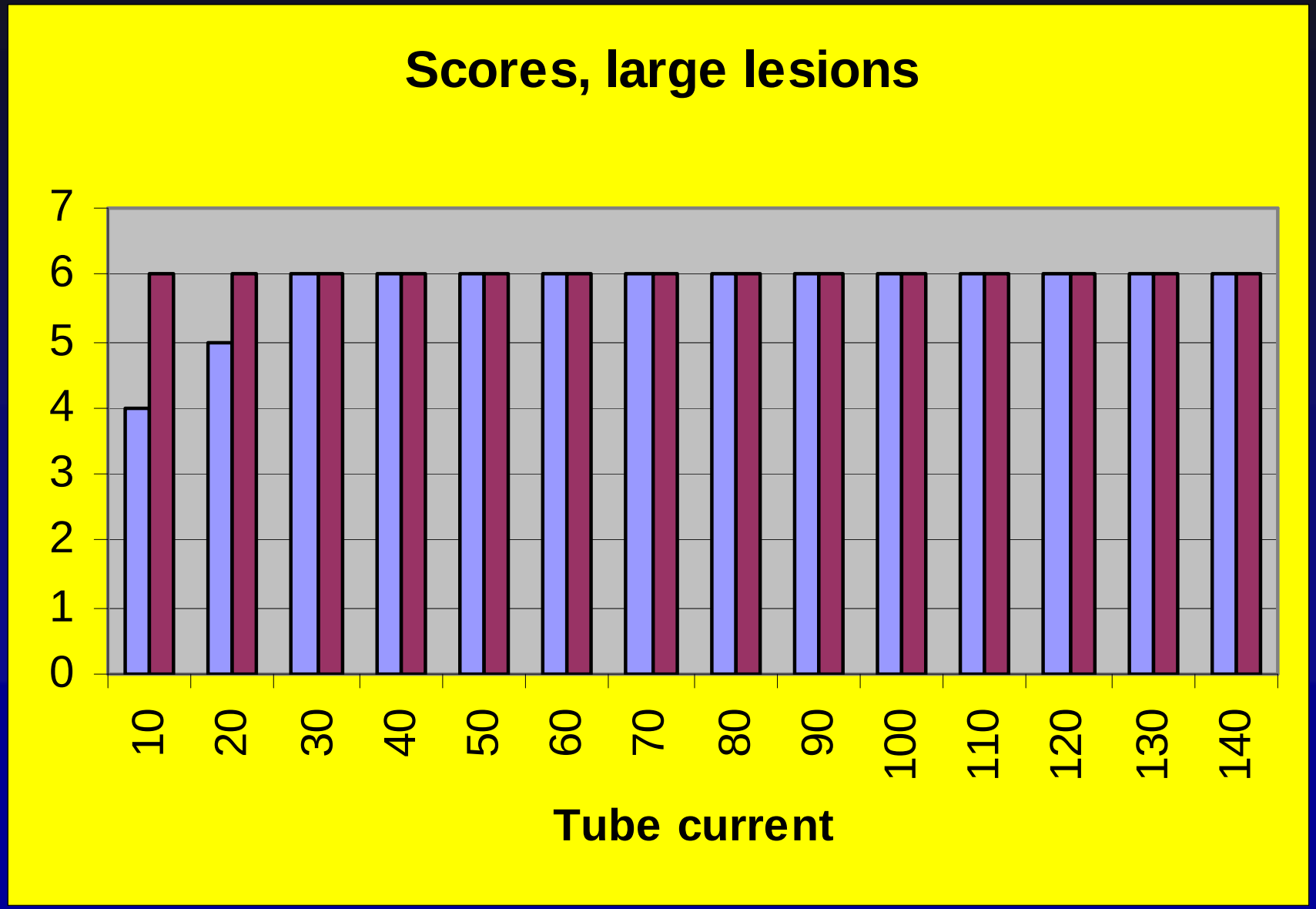
Brain “lesions”: the answer

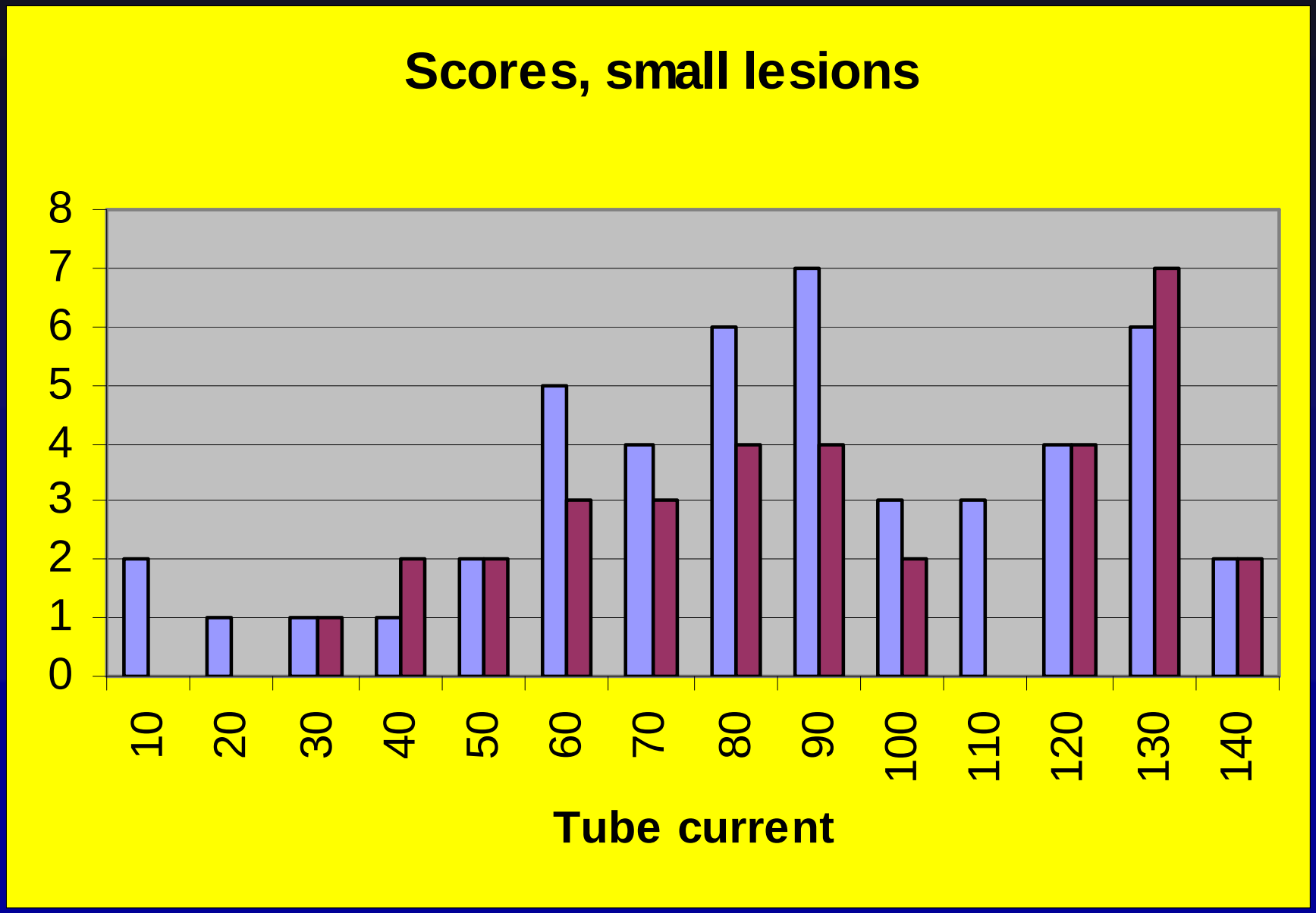
Commercial jelly (orange)

Bubblewrap






Scores, large lesions
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Tube current


Scores, small lesions
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Tube current

Experiment 2: preliminary conclusions

Large lesions: dose may be reduced 50%

Small lesions: further study needed

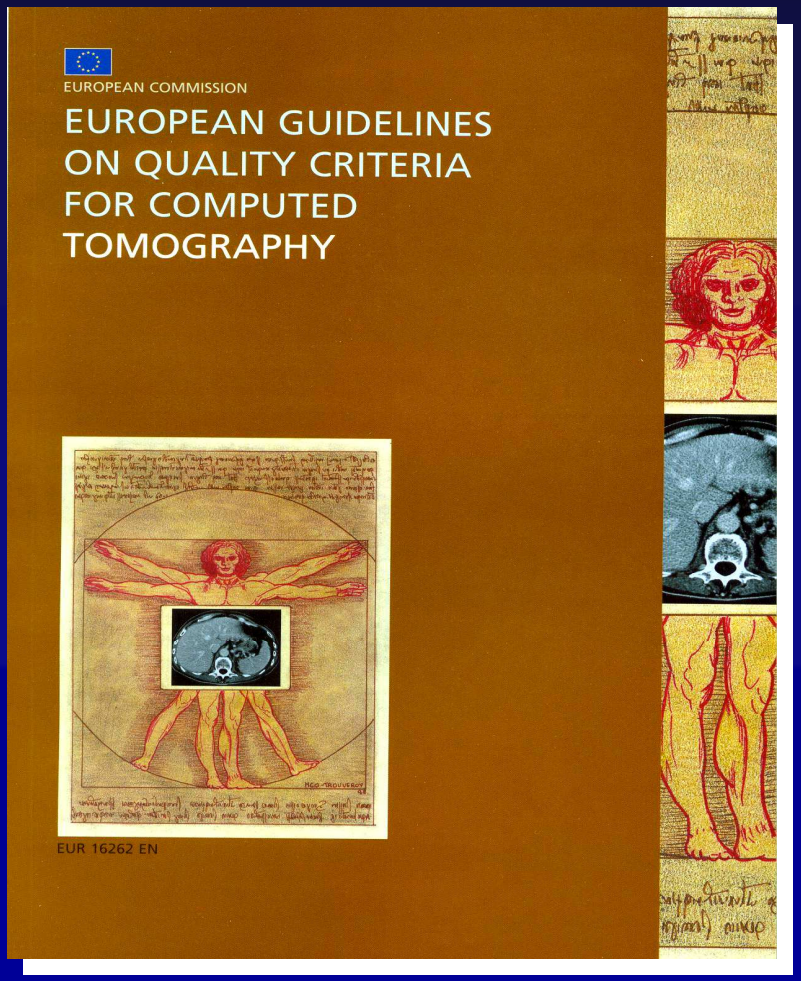
European Commission Study Group

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

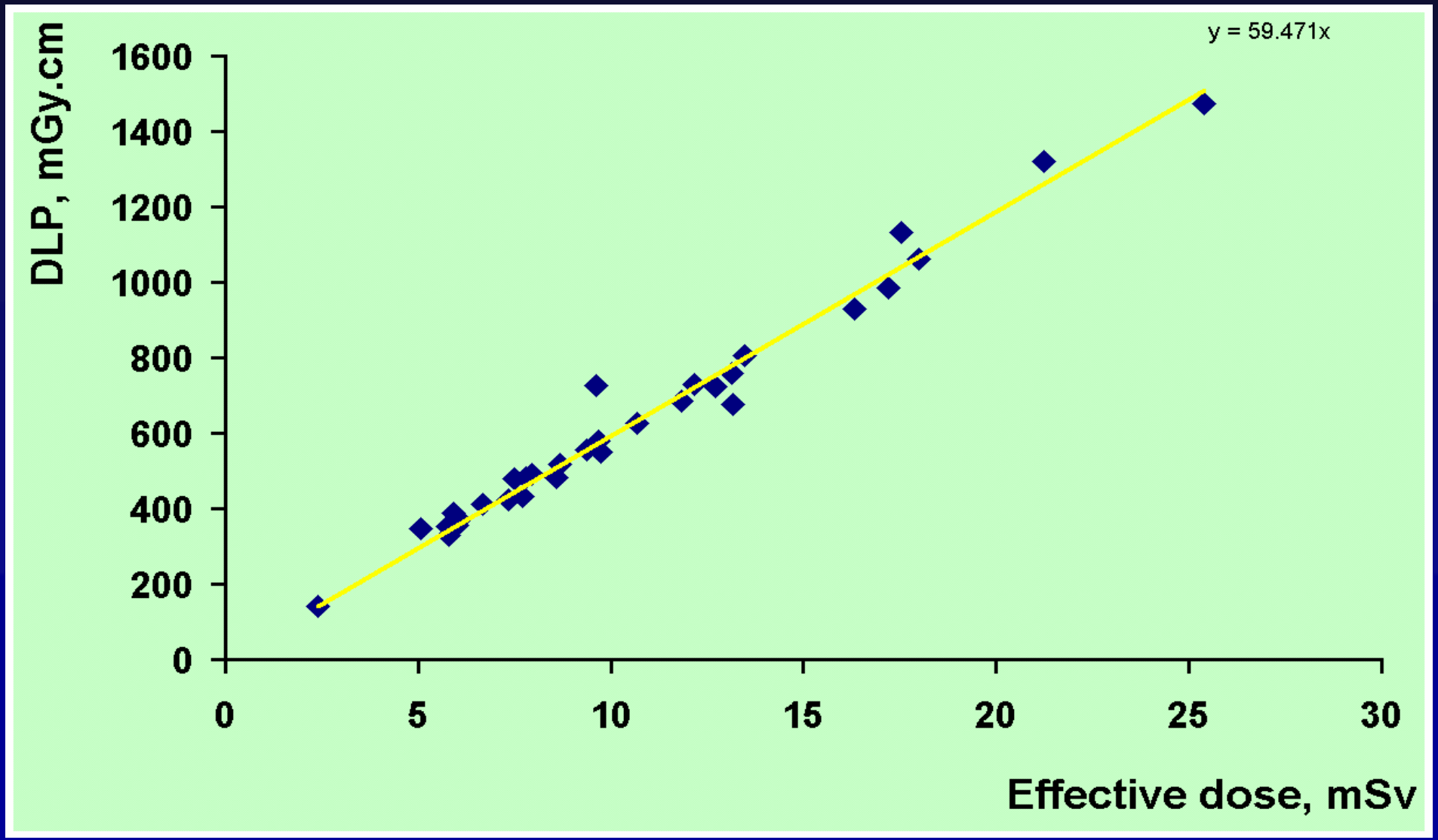
European Field Survey

14 applications

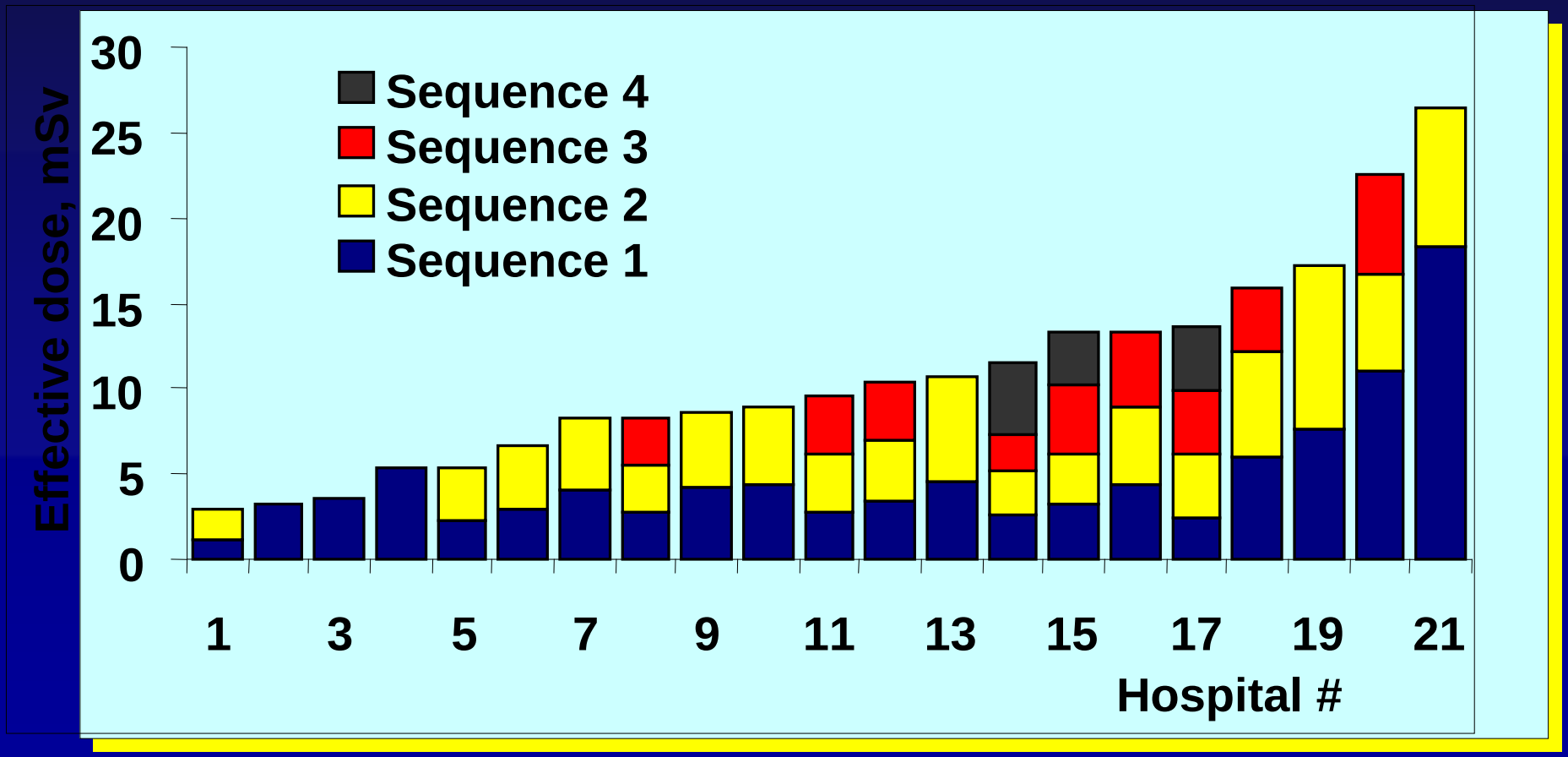
53 institutions

8 countries

Abdomen, abscess



Liver metastasis, colorectal carcinoma



European Field Survey

Large difference in protocols

Large difference in parameters

- Scanned range
- No. of series/repeats
- Tube current
- Section thickness

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

CT Quality Criteria Document - MSCT

Technical principles

Clinical principles

paediatrics

Good technique

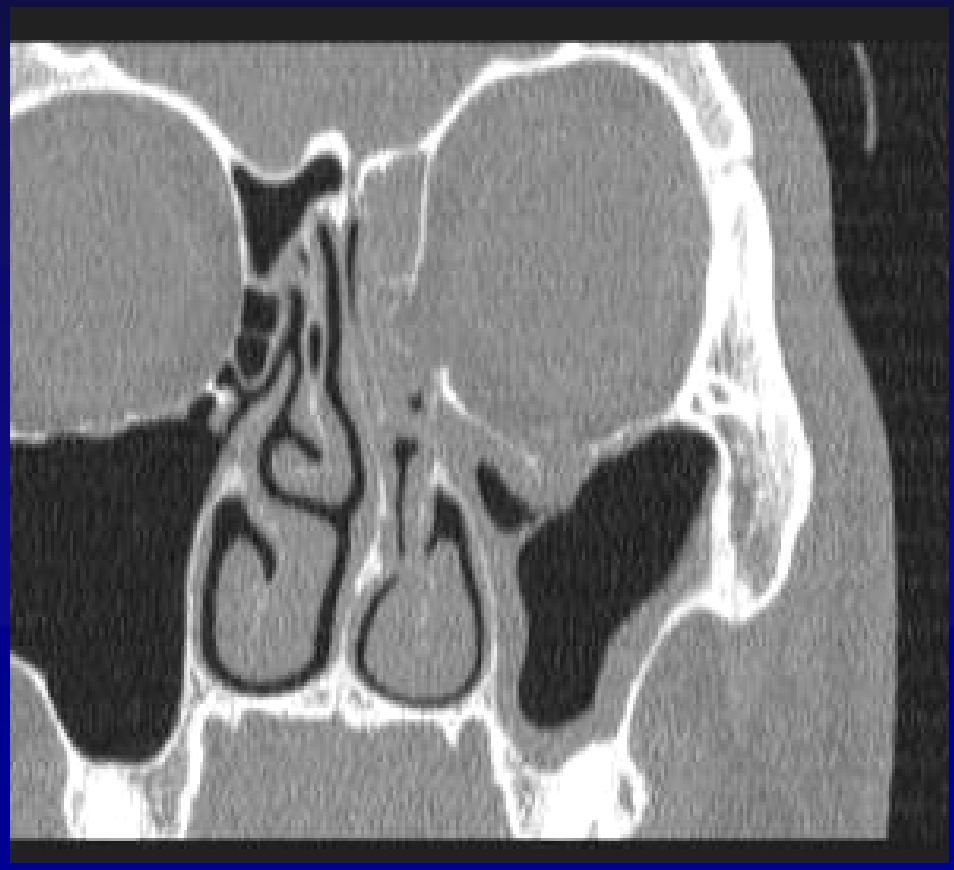
26 applications

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?



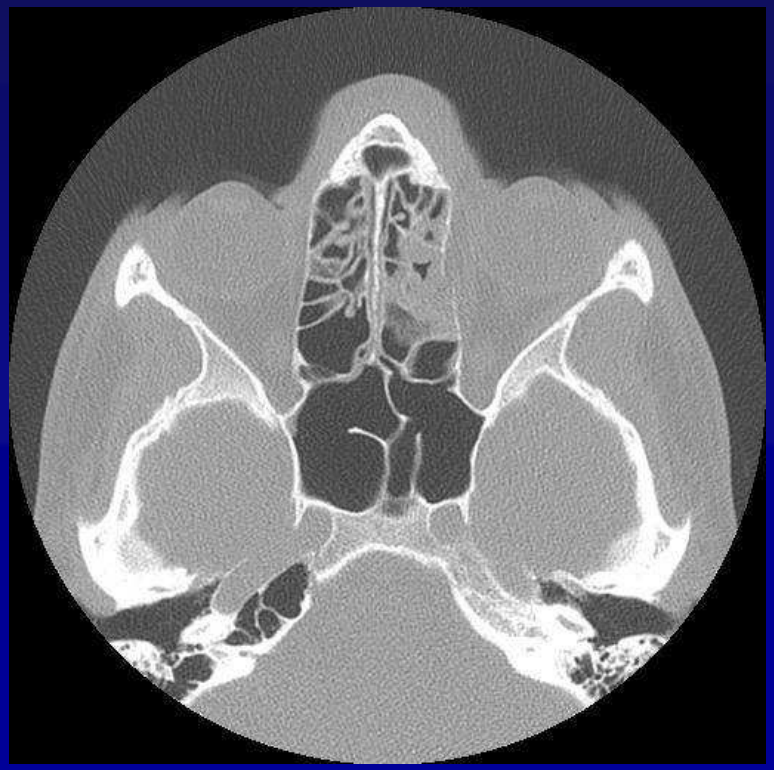
Surgeon needs to know:

? depressed orbital floor

? extent

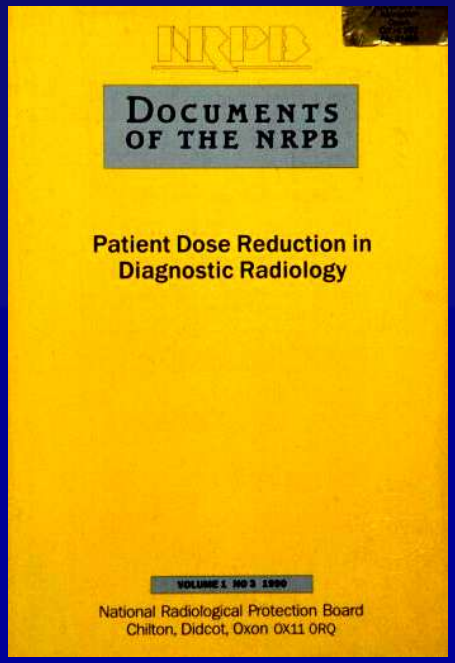
Delayed diagnosis: ultra-low dose

10-20mA DLP 40mGy-cm

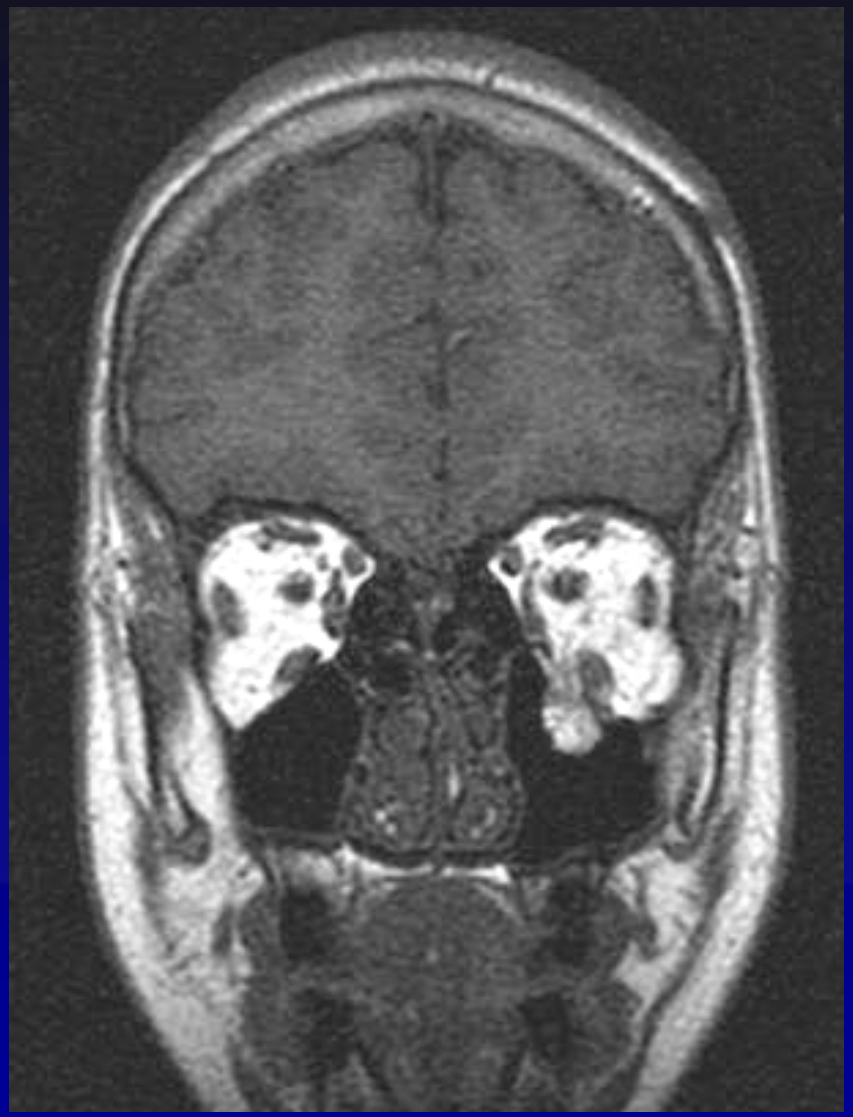


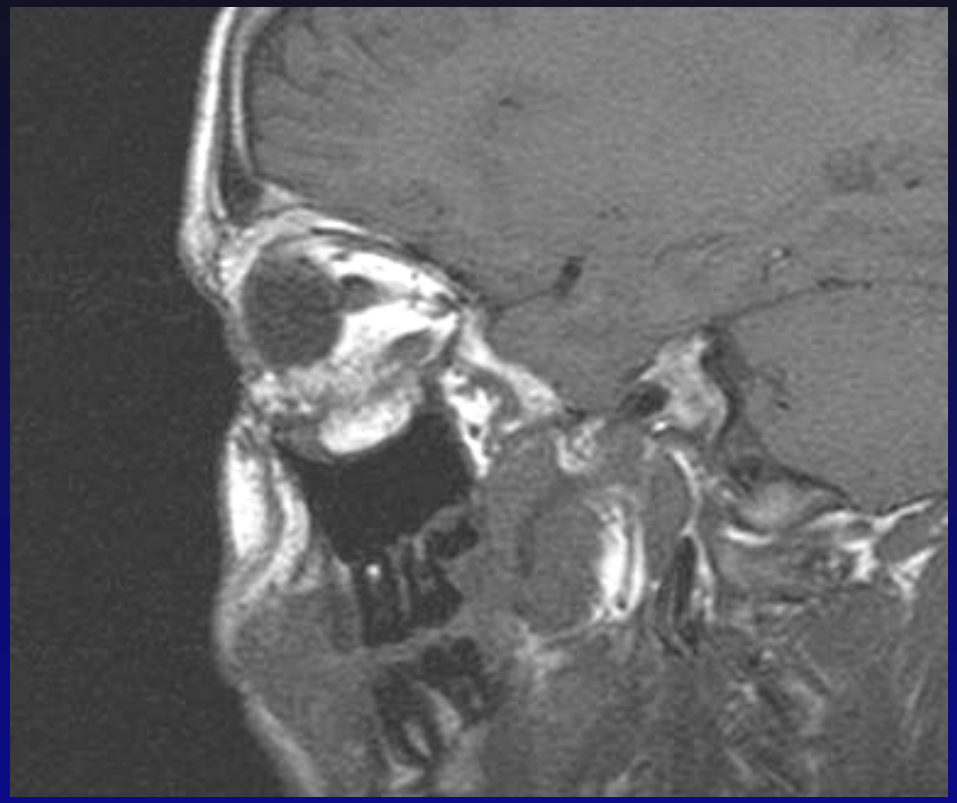
Increasing the availability of both ultrasound and MRI will reduce reliance upon techniques involving x-rays, particularly for young patients at higher risk.

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

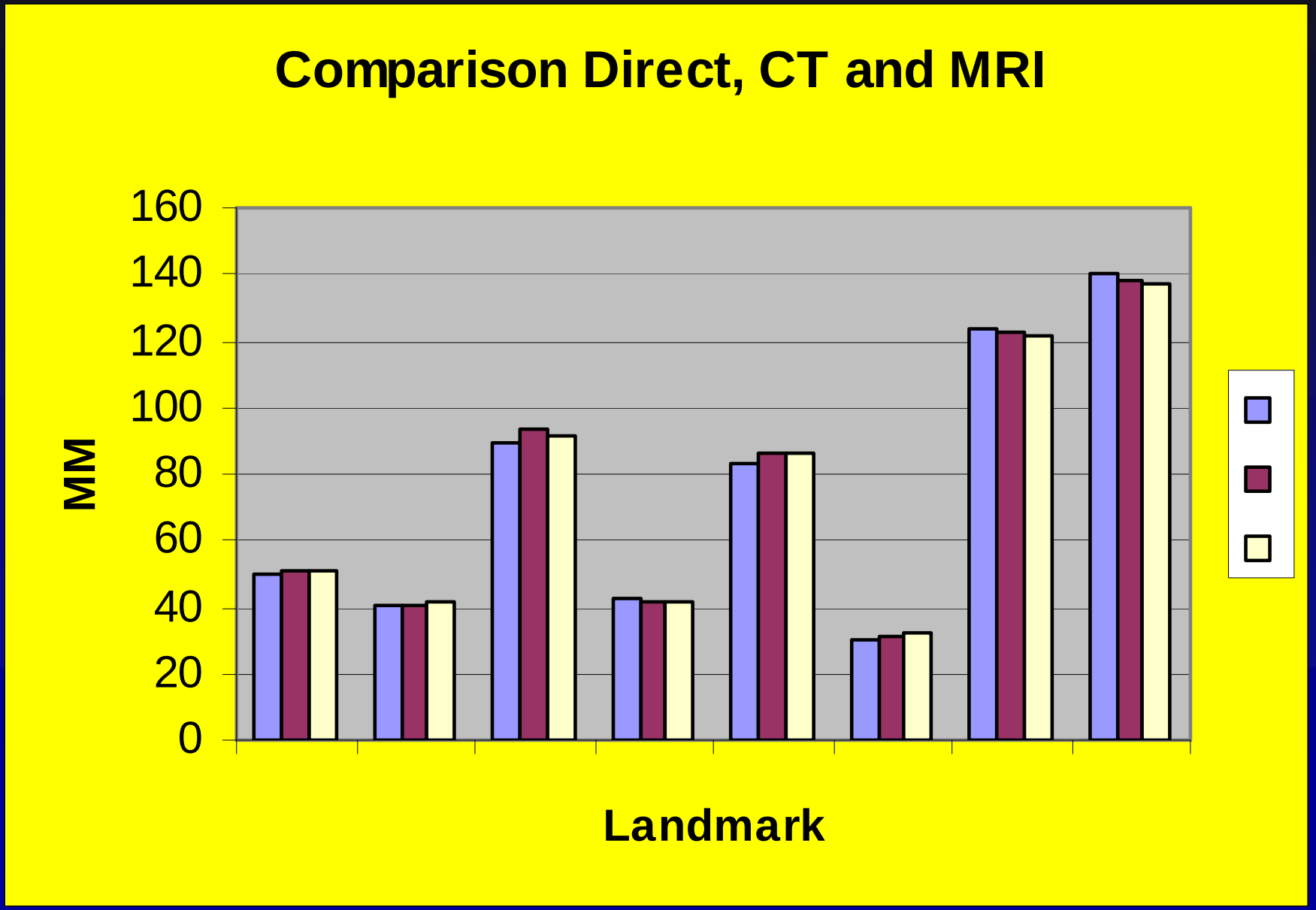
Gradient echo

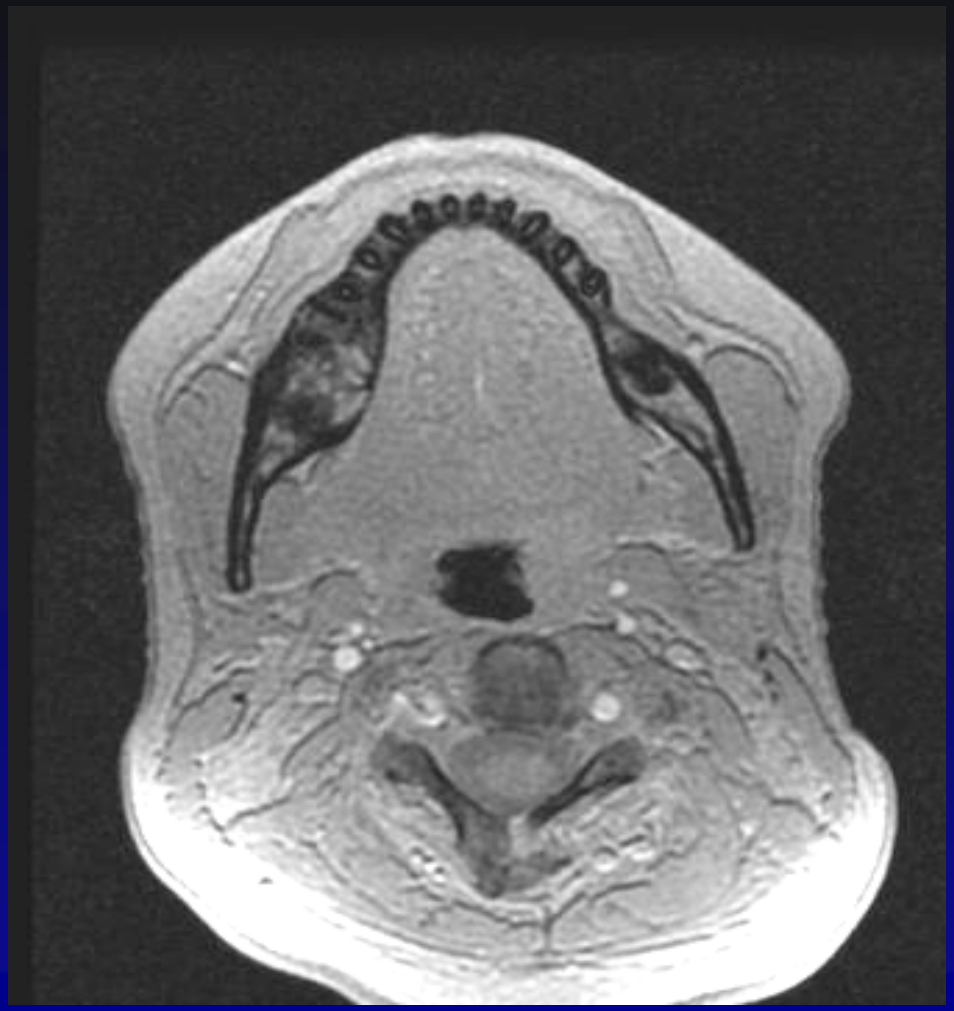
5° flip angle

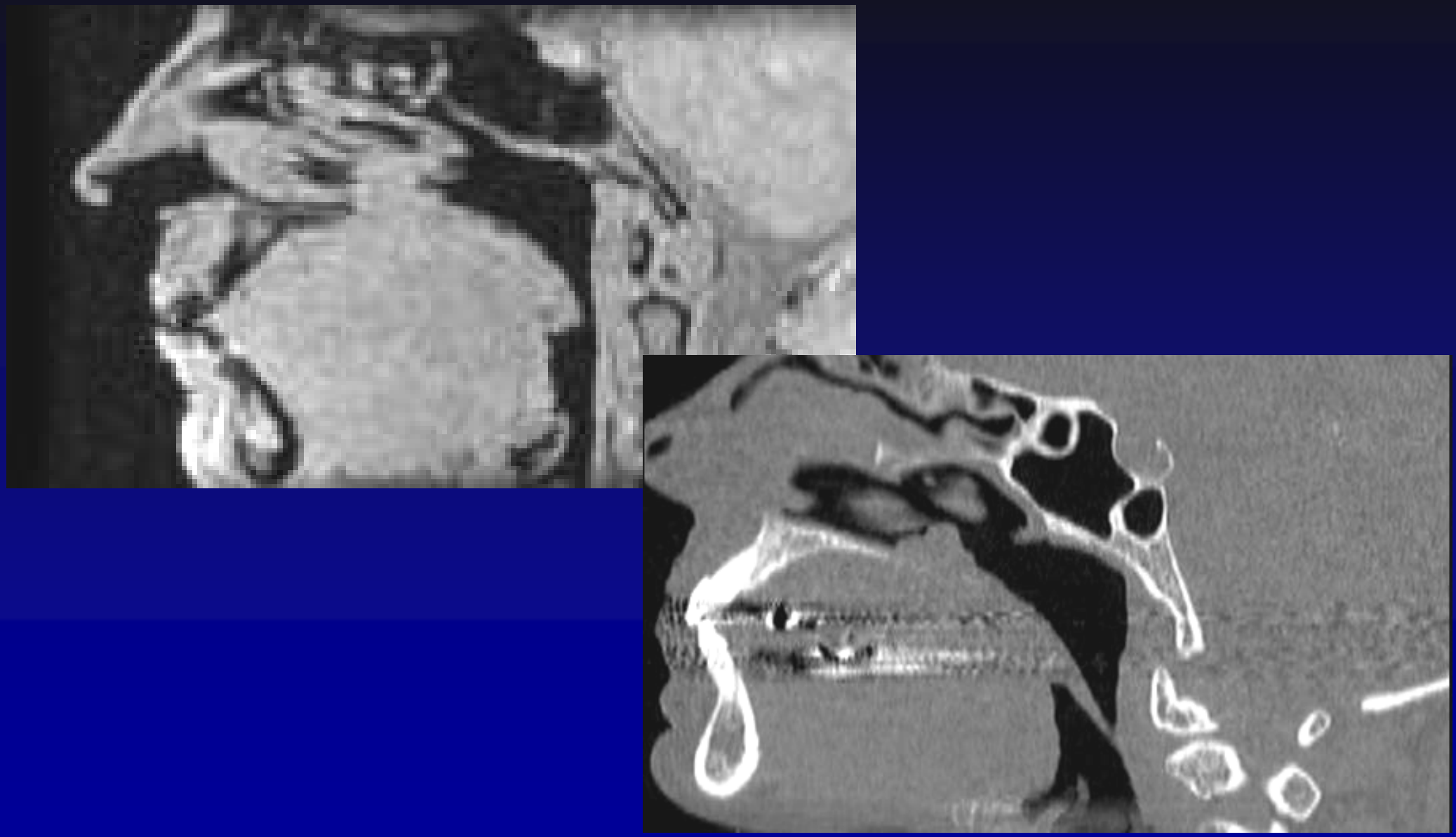
PD weighting

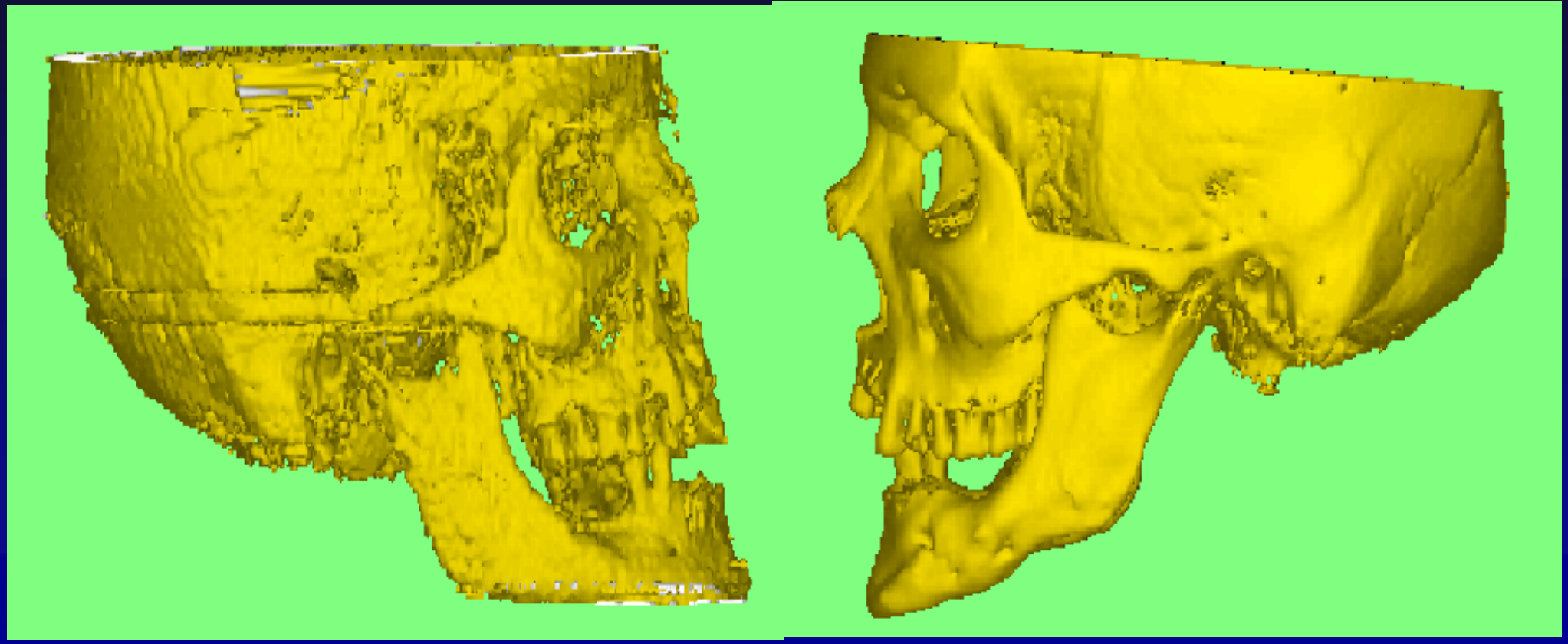
In-phase TE

$256^2 \longrightarrow 512^2$


Comparison Direct, CT and MRI
160
140
120
100
80
60
40
20
0
MM
Landmark







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