Australian Government

Australian Radiation Protection and Nuclear Safety Agency

MDCT Dosimetry & DRL Overview

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Australian Radiation Protection & Nuclear Safety Agency

Dosimetry

- Human dosimetry chain
  - From air kerma to effective dose
  - Problems
    - Lack of sensitivity for
      - Age dependency
      - Image quality
- Diagnostic Reference Level (DRL) overview & ARPANSA survey

Dosimetry

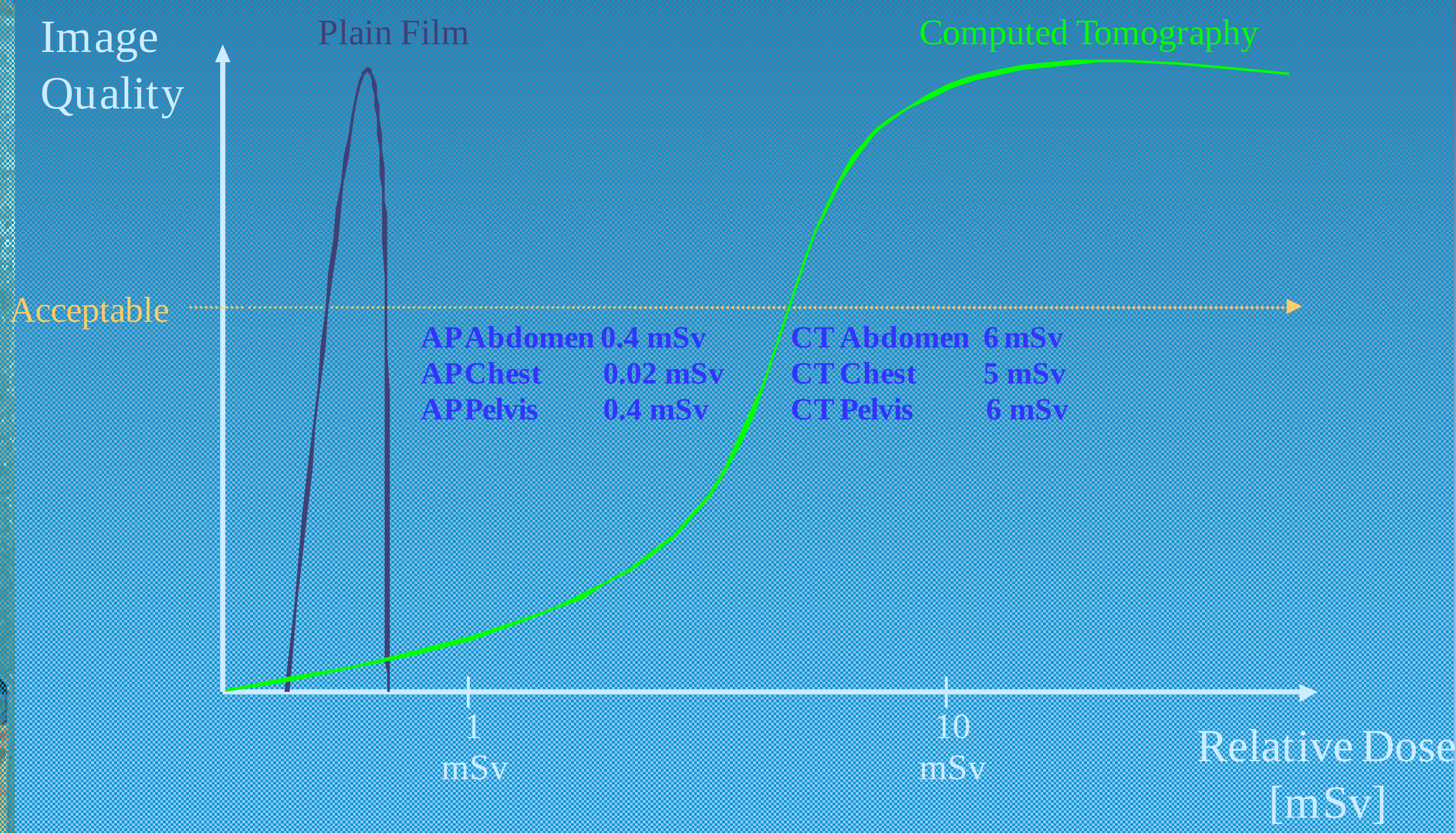
- CT dosimetry units
  - Computed Tomography Dose Index – CTDI (mGy)
    - CTDI_{air}
    - $\text{CTDI}_{\text{weighted}}$
    - CTDI_{vol}
  - Dose Length Product – DLP (mGy.cm)

MDCT & Digital Imaging

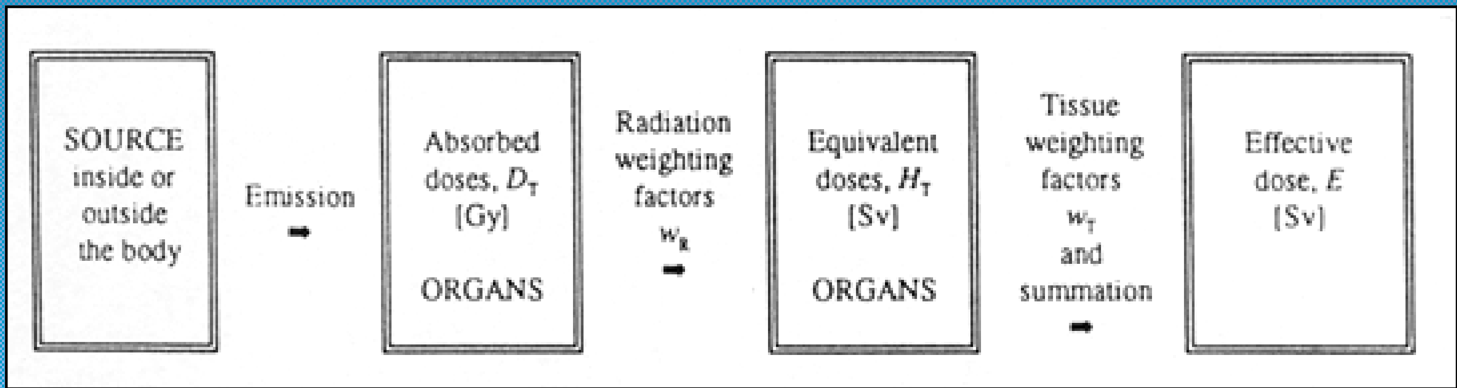
- CT is a digital technique and fundamentally dissimilar to analogue film radiography,
  - as a general rule of thumb,
    - for CT, the more radiation, the better the signal-to-noise of the image, aesthetically more pleasing,
    - for plain film, the more radiation, the blacker the film,
  - CT is comparatively, very dose forgiving,

<u>CT patient dose is essentially decoupled from diagnostic image quality at larger doses</u>

Plain Film & CT Dosimetry



ICRP 60 (1990) Dosimetry



Tissue Weighting Factors

Tissue Weighting Factors - Used in calculating Effective Dose

Tissue	w_T ICRP 60 1990	w_T ICRP 103 2007
gonads	0.20	0.08
bone marrow (red)	0.12	0.12
colon	0.12	0.12
lung	0.12	0.12
stomach	0.12	0.12
breast	0.05	0.12
remainder	0.05	0.12
bladder	0.05	0.04
liver	0.05	0.04
oesophagus	0.05	0.04
thyroid	0.05	0.04
skin	0.01	0.01
bone surface	0.01	0.01
brain		0.01
salivary glands		0.01
Total	1.00	1.00

Remainder tissues: Adrenals, Extrathoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate (males), Small intestine, Spleen, Thymus, Uterus/cervix (females).

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skin	0.01	0.01
bone surface	0.01	0.01
brain		0.01
salivary glands		0.01
Total	1.00	1.00

- 60% (gonads)

+ 140% (breast)

Remainder tissues: Adrenals, Extrathoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate (males), Small intestine, Spleen, Thymus, Uterus/cervix (females).

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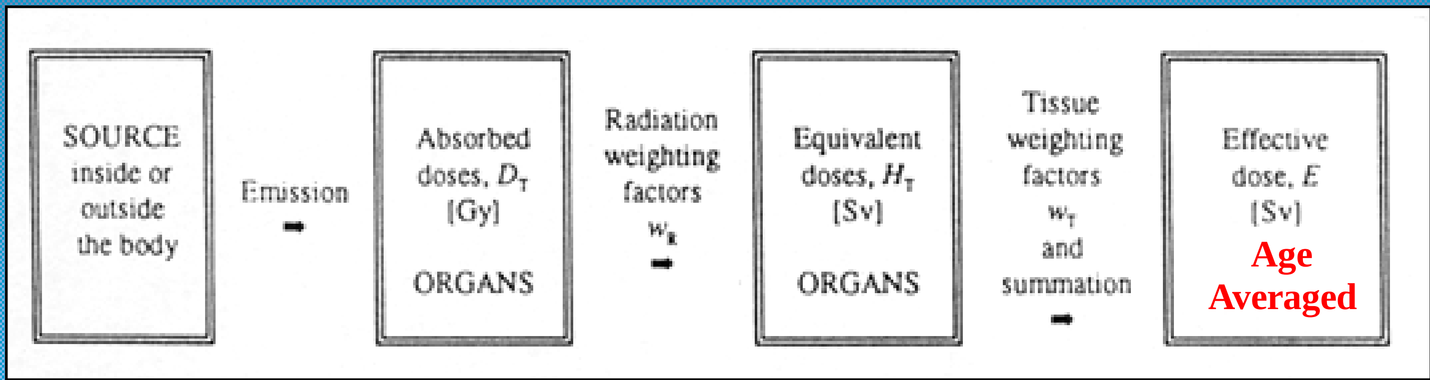


Age Cohort Dosimetry

Risk Variation

Age	Male	Female
0-10	x 2.5	x 3
10-20	x 1.6	x 1.9
20-30	x 1.4	x 1.7
30-40	x 0.6	x 0.7
40-50	x 0.5	x 0.5
50-60	x 0.4	x 0.5
60-70	x 0.3	x 0.4
70-80	x 0.2	x 0.3

Hall, Pediatric Radiology, (2002) Vol.32

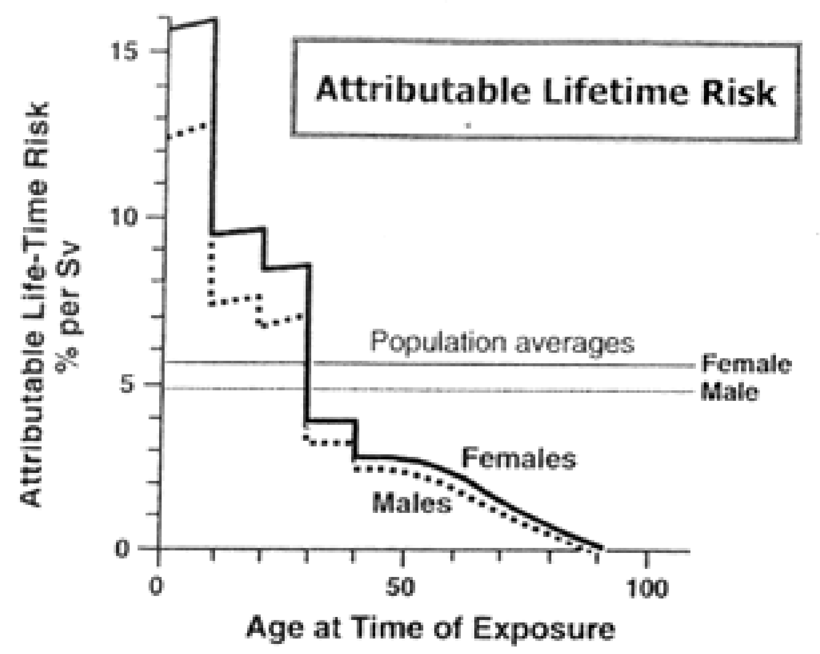


Fig. 1. Lifetime risk of excess cancer per sievert as a function of age at the time of exposure. Data from the A-bomb survivors. While the average risk for a population is about 5% per sievert, the risk varies considerably with age; children are much more sensitive than adults. At early ages, girls are more sensitive than boys

CT Dose Quantities

- $CTDI_{100}$
- $CTDI_{weighted}$
- $CTDI_{effective}$
- DLP
- Organ Dose
- Effective Dose

Computed Tomography Dose Index – $CTDI_{100}$

- Defined as: $$CTDI_{100} = \frac{1}{nT}\int_{-50\,mm}^{+50\,mm} D(z)\,dz$$

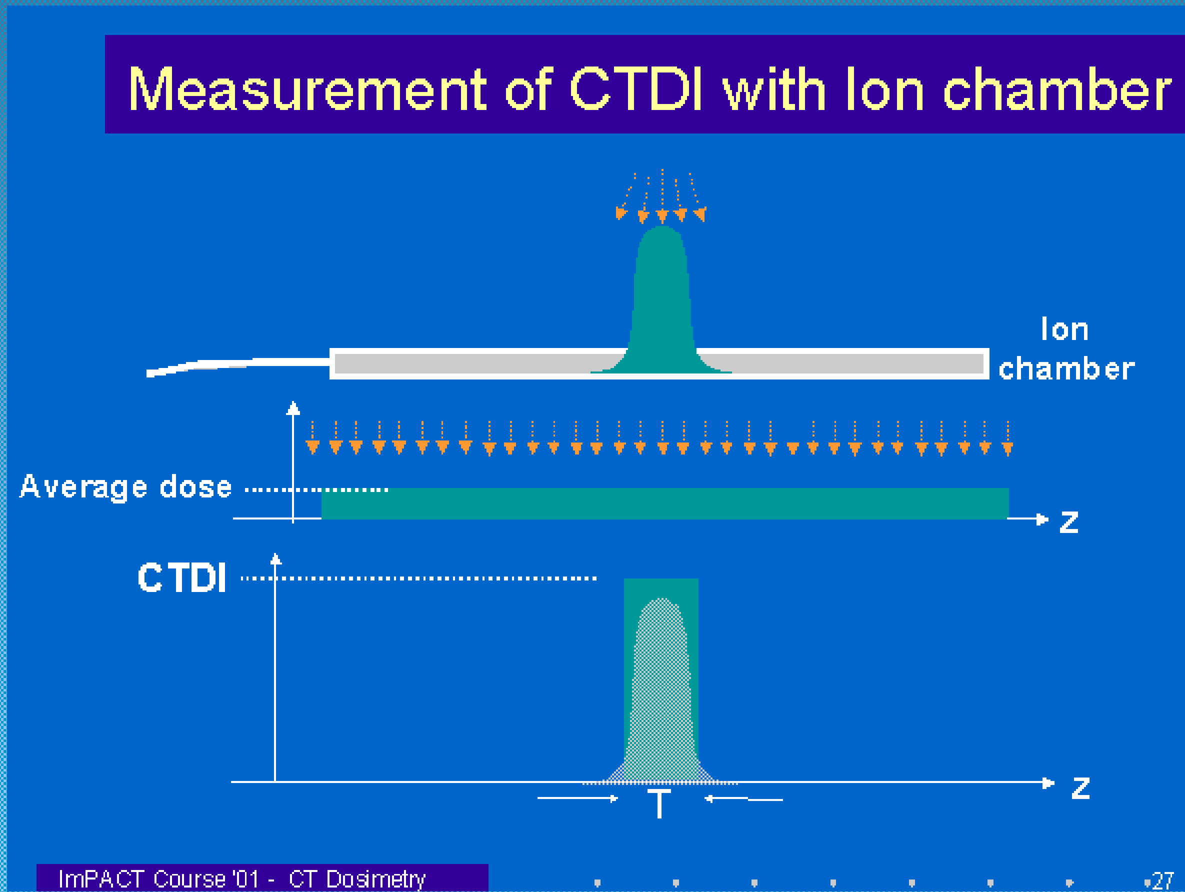
where ±50mm is length of pencil chamber

n = number of slices taken

T= slice width

D(z) = measured dose (mGy)

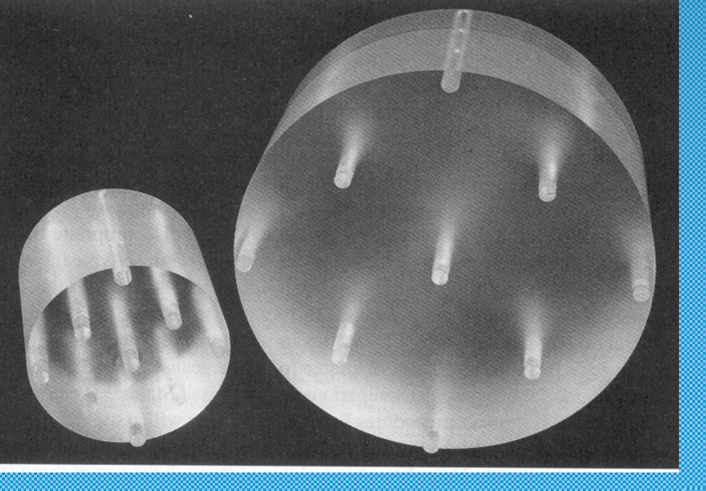
CTDI Measurement



CTDI Weighted - $CTDI_w$

$$CTDI_w = 2/3*CTDI_{peripheral} + 1/3*CTDI_{centre}$$

- Gives a weighted average of CTDI from peripheral radial and central dosimetry points within a phantom



CTDI Effective - $CTDI_{eff}$

$$CTDI_{w,eff} = \frac{1}{pitch} \times CTDI_{w}$$

- Gives a weighted average of CTDI from peripheral radial and central dosimetry points within a phantom corrected for pitch
- $CTDI_{w,eff}$ sometimes called $CTDI_{vol}$

Dose Length Product - DLP

- $CTDI_{w,eff}$ applied to the volume of irradiated tissue

$$DLP\ (mGy.cm) = CTDI_{w,eff} \times L$$

- Variations in pitch complicate dosimetry
- It is simply an indicator of energy imparted to the volume, irrespective of the spatial pattern of dose deposition
- Additional complication of dose (mA) modulation per slice

Organ Dose, D_{org}

$$D_{org} = \frac{Absorbed\ energy}{Organ\ mass}$$

- Defined as the energy that is absorbed in a particular organ divided by the mass of the organ
- 1 joule/kilogram = 1 gray

Effective Dose, E

$$E = \sum_i w_i \cdot D_{org,i}$$

- Defined as the weighted average of organ dose values D_{org} for a number of specified organs
  e.g. w_i for various organs

0.08	gonads
0.12	lungs, lower colon …..
0.12	breast
0.01	skin, bone surface
0.12	for remainder

- Units of mSv

Effective Dose from DLP

Shrimpton & Wall, "Reference Doses for Paediatric Computed Tomography", Radiation Protection Dosimetry, Vol. 90, Nos 1-2, 249-252 (2000)

- Conversion factors ($mSv.mGy^{-1}.cm^{-1}$)

	Adult CF	Age Weighted Correction Factor				
		15	10	5	1	Baby
Head	0.0023	x 1.2	x 2.0	x 3.2	x 5.1	x 9.5
Trunk	0.0081	x 1.2	x 1.8	x 2.6	x 4.0	x 7.9

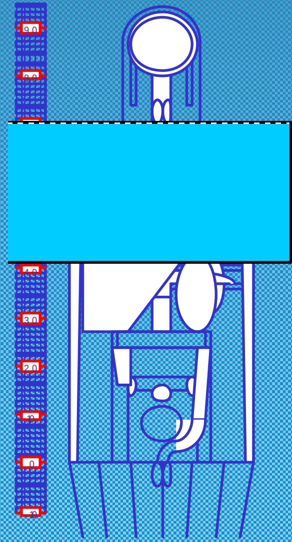
Current CT Dosimetry Chain

$CTDI_{???}$ → Clinical Scanning Parameters → Dosimetry Software → Effective Dose

$CTDI_{100}$
$CTDI_{FDA}$
$CTDI_{air}$
$CTDI_{perspex}$
$CTDI_{weighted}$
${}_{n}CTDI_{mAs}$
$CTDI_{vol}$

kVp
mAs
slice width
DLP_{CTDI}
pitch…

ImPACT
CT-Expo
CT Dose



Current CT Dosimetry Chain

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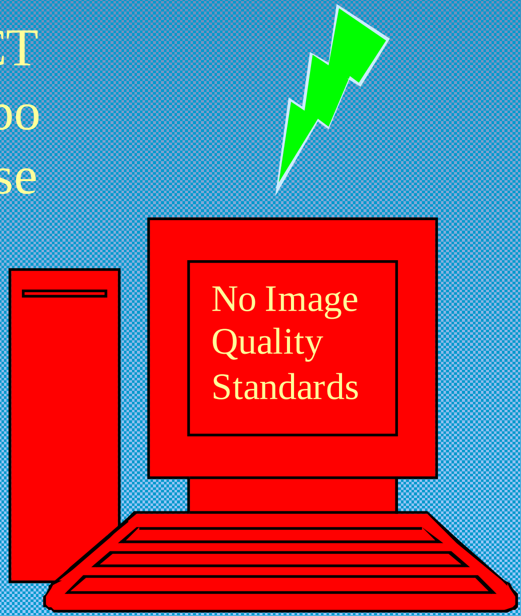
${}_{n}CTDI_{mAs}$
$CTDI_{vol}$

kVp
mAs
slice width
DLP_{CTDI}
pitch

ImPACT
CT-Expo
CT Dose



DIAGNOSTIC REFERENCE LEVELS

As a tool for the maintenance of image quality and the management of efficient dose delivery

Diagnostic Reference Levels

- The objective of a diagnostic reference level is to help avoid radiation dose to the patient that does not contribute to the clinical purpose of a medical imaging task.
- This is accomplished by comparison between the numerical value of the diagnostic reference level (derived from relevant regional, national or local data) and the mean or other appropriate value observed in practice for a suitable reference group of patients or a suitable reference phantom.

(ICRP, 2001)

United Kingdom Experience

- Introduced 1990
- Simple indication of "abnormally high doses"
- Used 3rd quartile values of mean dose distributions taken from a national dose survey in mid 1980'
- Regularly updated

United Kingdom Experience

- If mean doses exceed a reference dose an investigation should take place to establish the cause and take corrective action – unless the dose was clinically justified
- Reference dose was used to provide a trigger for practices in need of investigation - hopefully leading to dose optimisation

European Experience

- Taken up by ICRP in publications 60 and 73
- Publication 73 introduced the term "diagnostic reference level" and recommended
  - Values should be selected by professional medical bodies
  - Reviewed at regular intervals
  - Be specific to a country or region

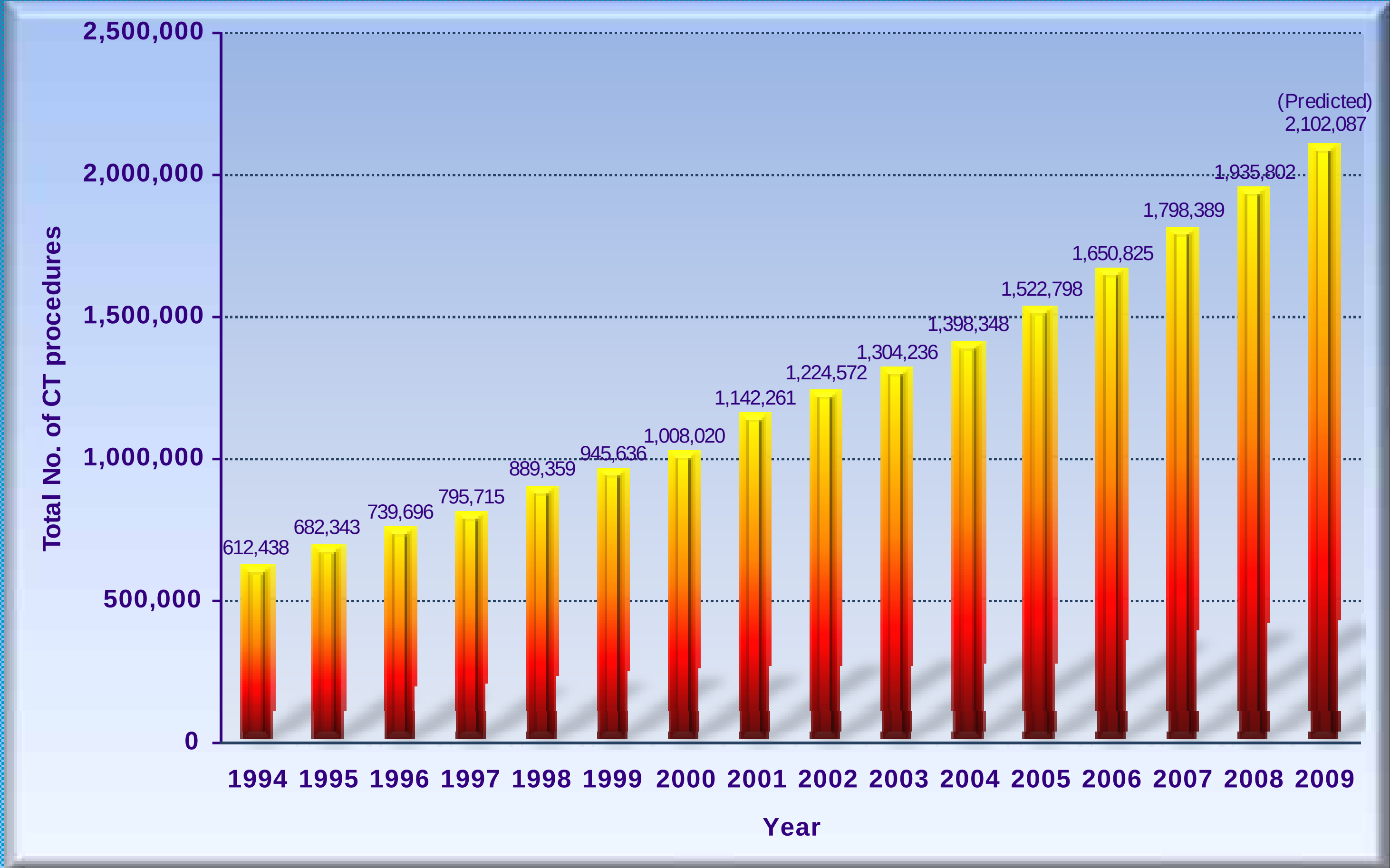
European Experience

- Wide variations in patient doses are to be expected and it is only sensible to compare mean or median values, which is less influenced by extreme outliers, on representative groups of patients to monitor trends with time, equipment or technique

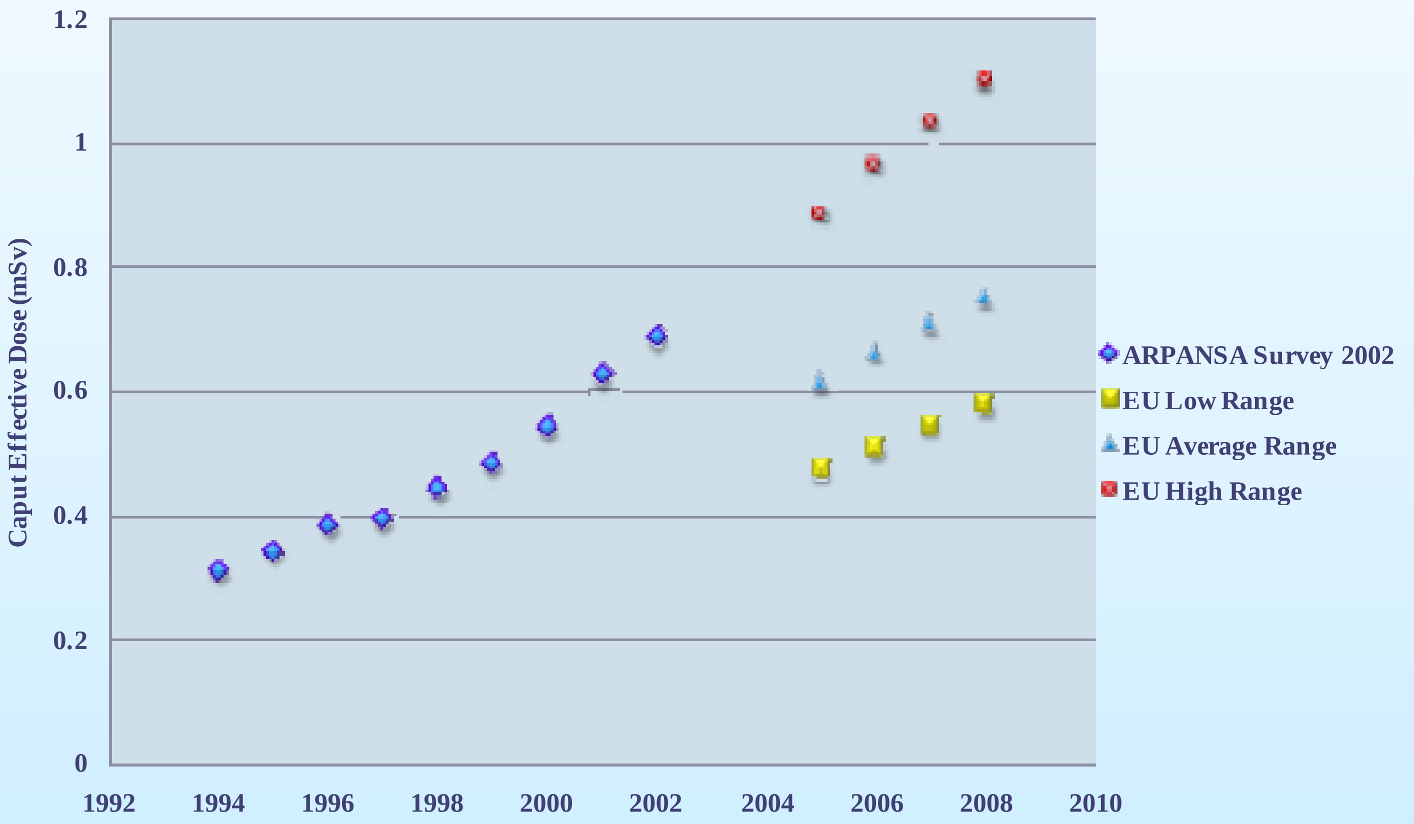
European Experience

- Setting DRL's is a resource intensive activity – a national response
- Priority should be given to procedures with the greatest dose implications, i.e. CT and interventional procedures

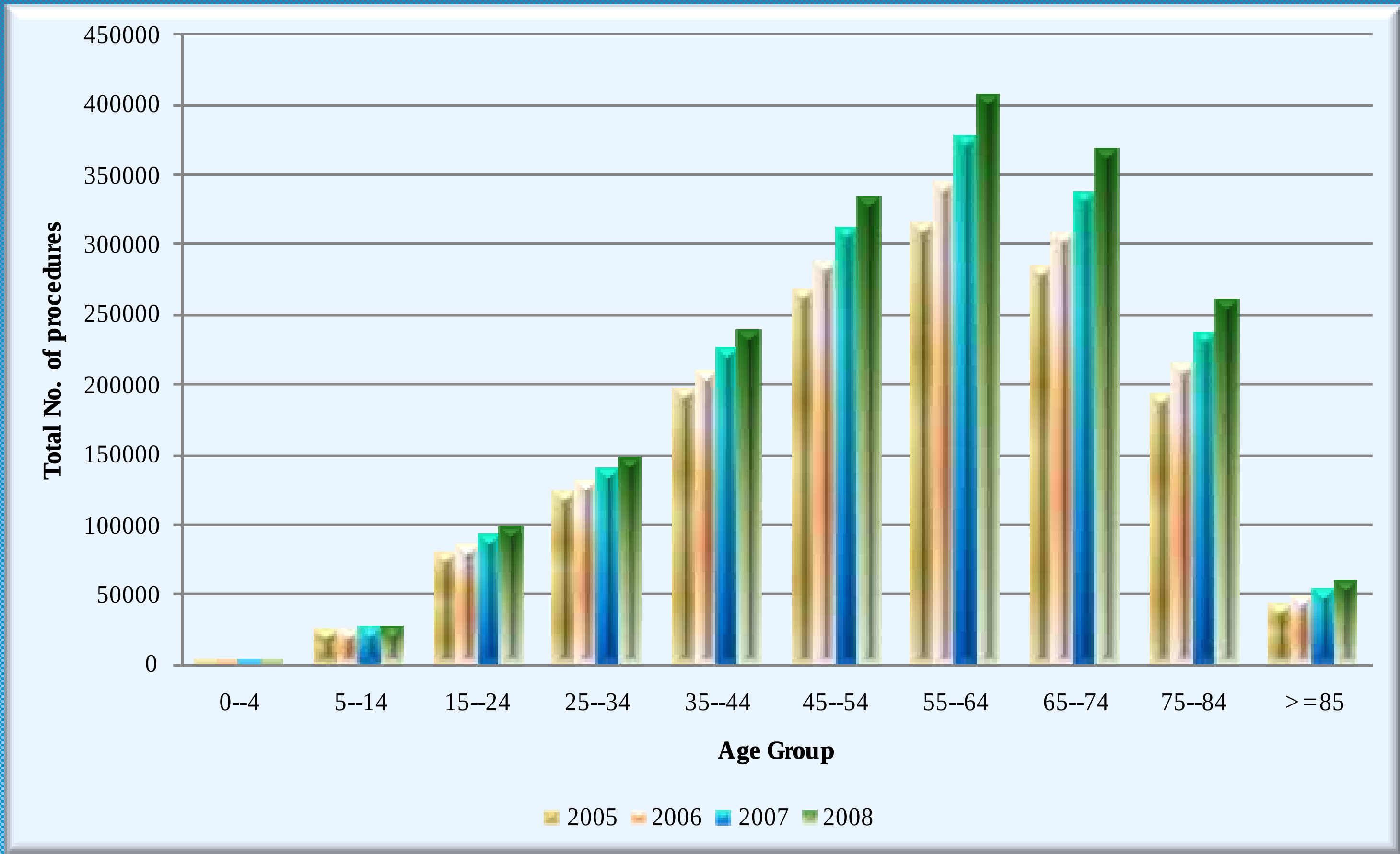
Estimated MBS MDCT Scans



Estimated Caput ED (mSv) from MDCT



MBS MDCT Procedures by Age



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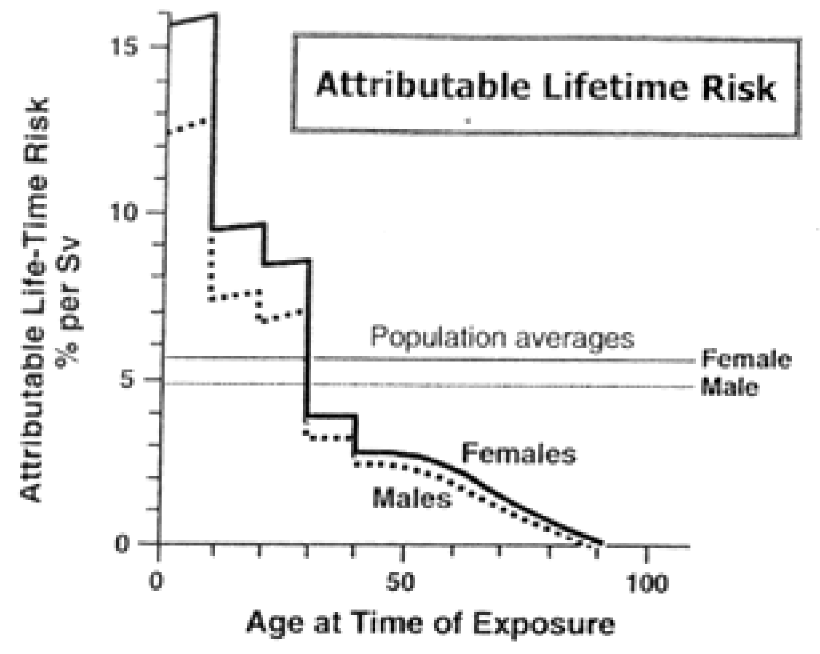

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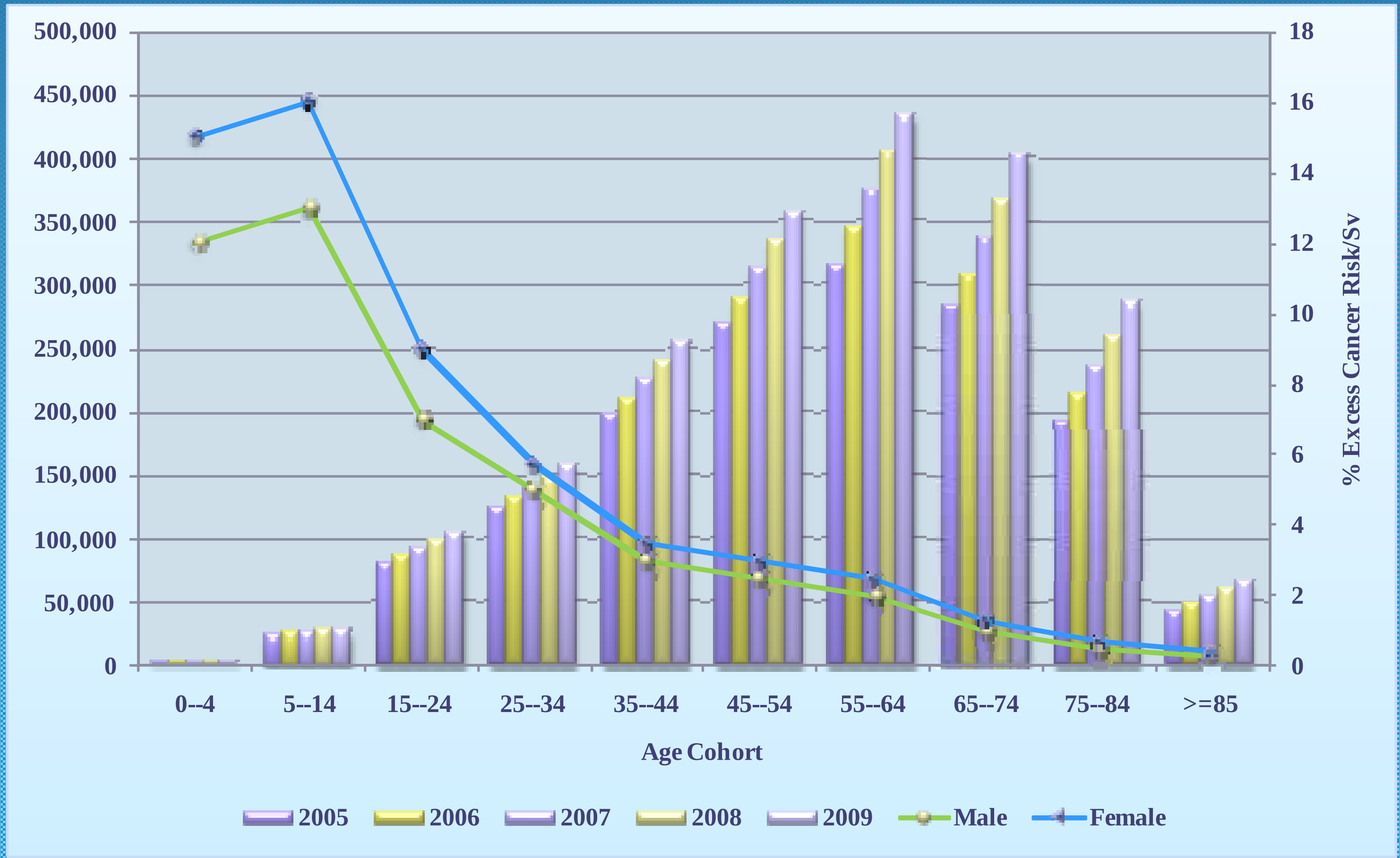
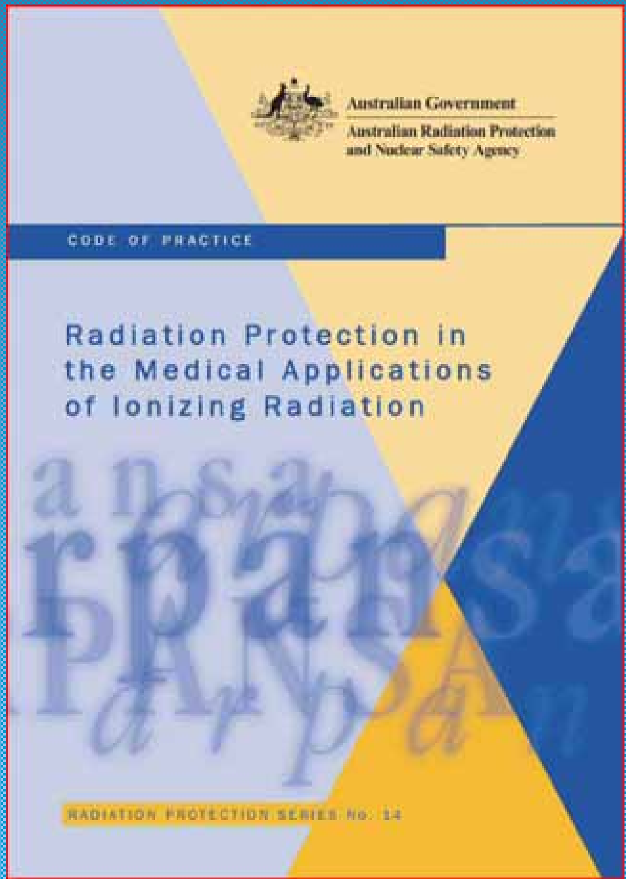
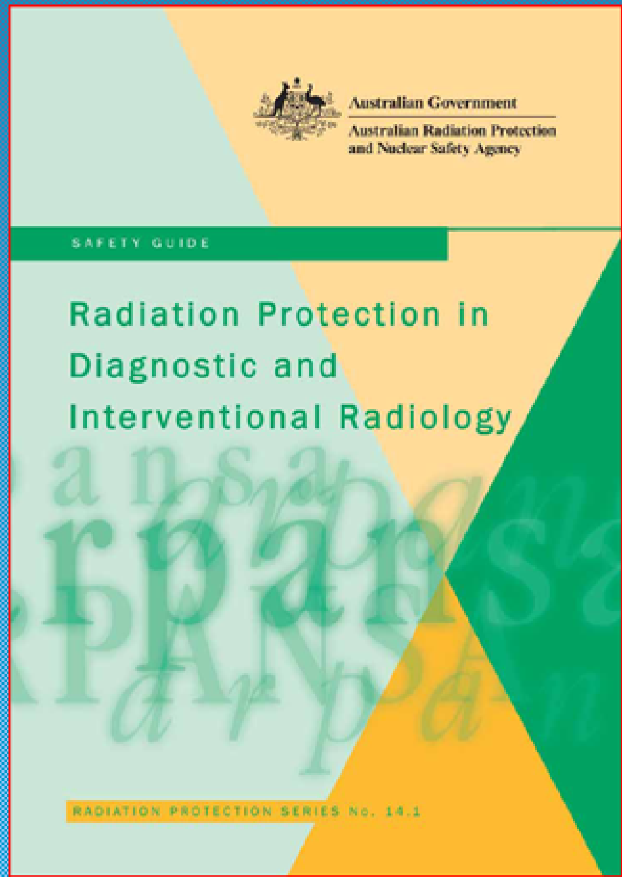
MDCT Scans & Risk



ARPANSA Code & Safety Guide





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DRL & Code of Practice

3.1.8 The Responsible Person must establish a program to ensure that radiation doses administered to a patient for diagnostic purposes are:

- (a) periodically compared with diagnostic reference levels (DRLs) for diagnostic procedures for which DRLs have been established in Australia; and
- (b) if DRLs are consistently exceeded, reviewed to determine whether radiation protection has been optimised.

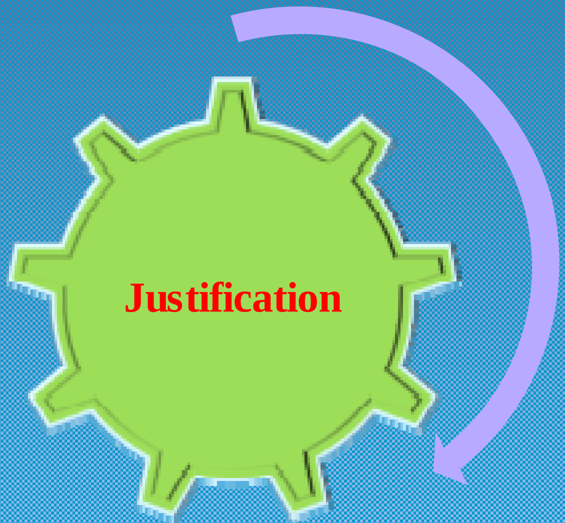
DRL Drivers

ARPANSA Code of Practice

Local Regulatory Requirements

DoHA/RANZCR Practice Accreditation

Justification, Optimisation & DRLs



- Appropriate Referral
- Radiologist as Gate Keeper

Justification, Optimisation & DRLs

- Age Dependence
- Protocol Dependence
- Radiologist, Radiographer & Physicist Dependence

Justification, Optimisation & DRLs

- Practice Dosimetry
- Regional Dosimetry
- National Dosimetry

Justification, Optimisation & DRLs

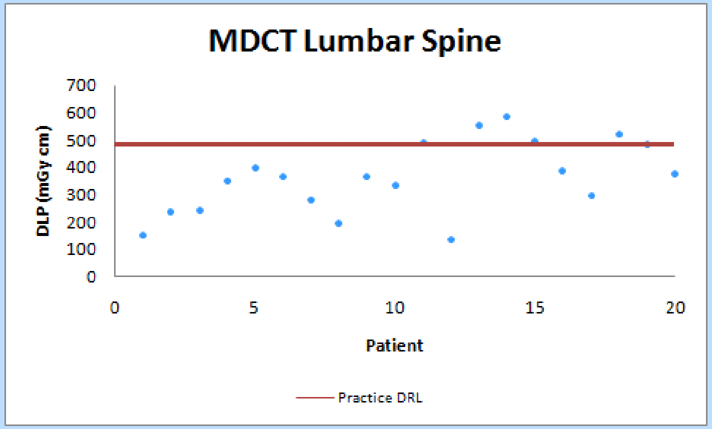
- A Continuous Process of Quality Improvement
- Clinical Audit Metric

ARPANSA DRL Survey Report

- Practice Reference Level (DLP – mGy.cm)
  - Median DLP of 10 patients scanned with the same protocol
- Diagnostic Reference Level (DLP - mGy.cm)
  - 75th percentile of the spread of PRLs for the same body region (head, neck, chest, abdomen-pelvis, lumbar sine, chest-abdomen-pelvis)
- Weight (±2 kg)
  - International comparison

PRL Survey Report

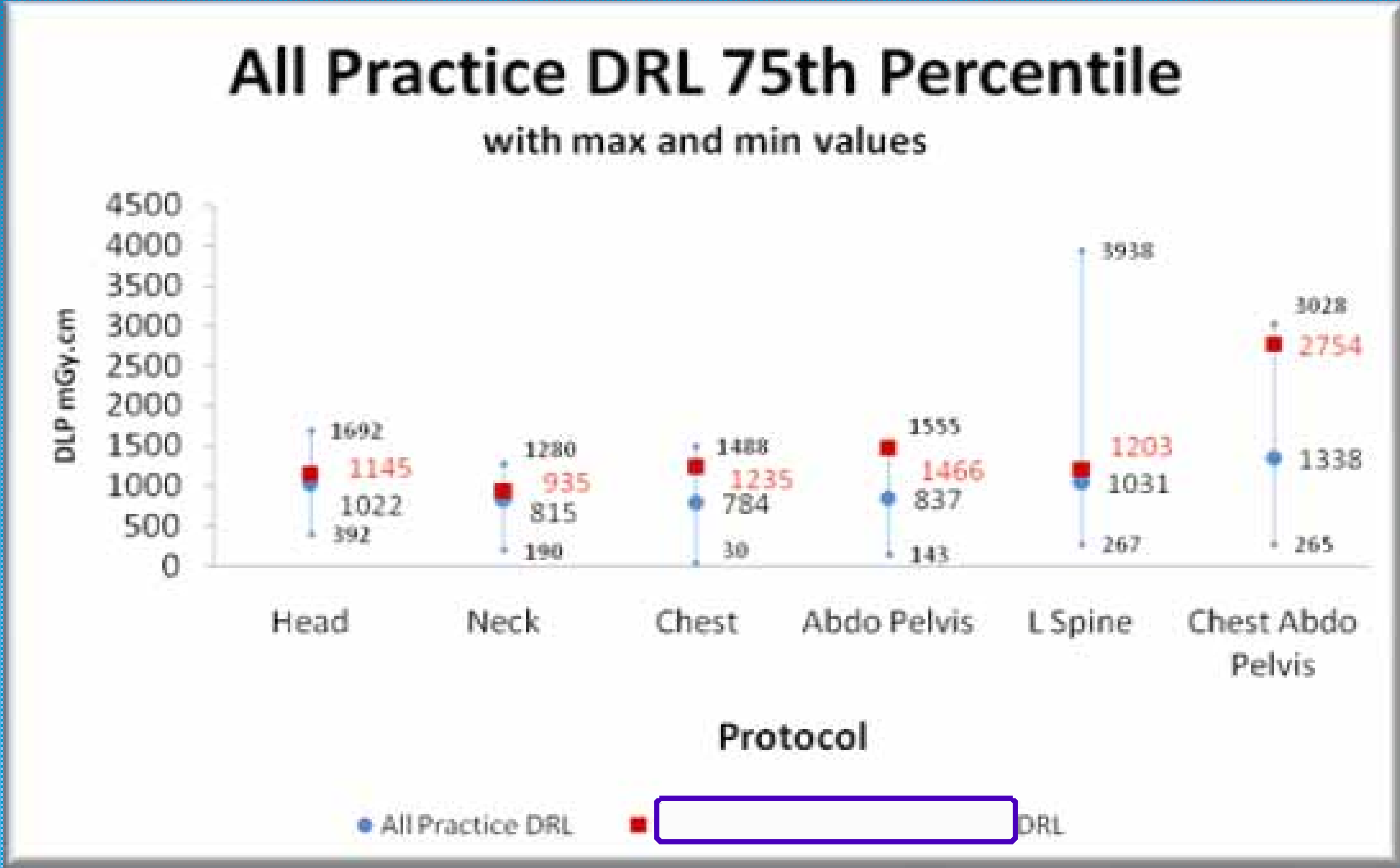
MDCT Lumbar Spine Report



DLP Statistics

Miniumum	DRL - Median	Maximum
136	367	586

DRL Survey Report



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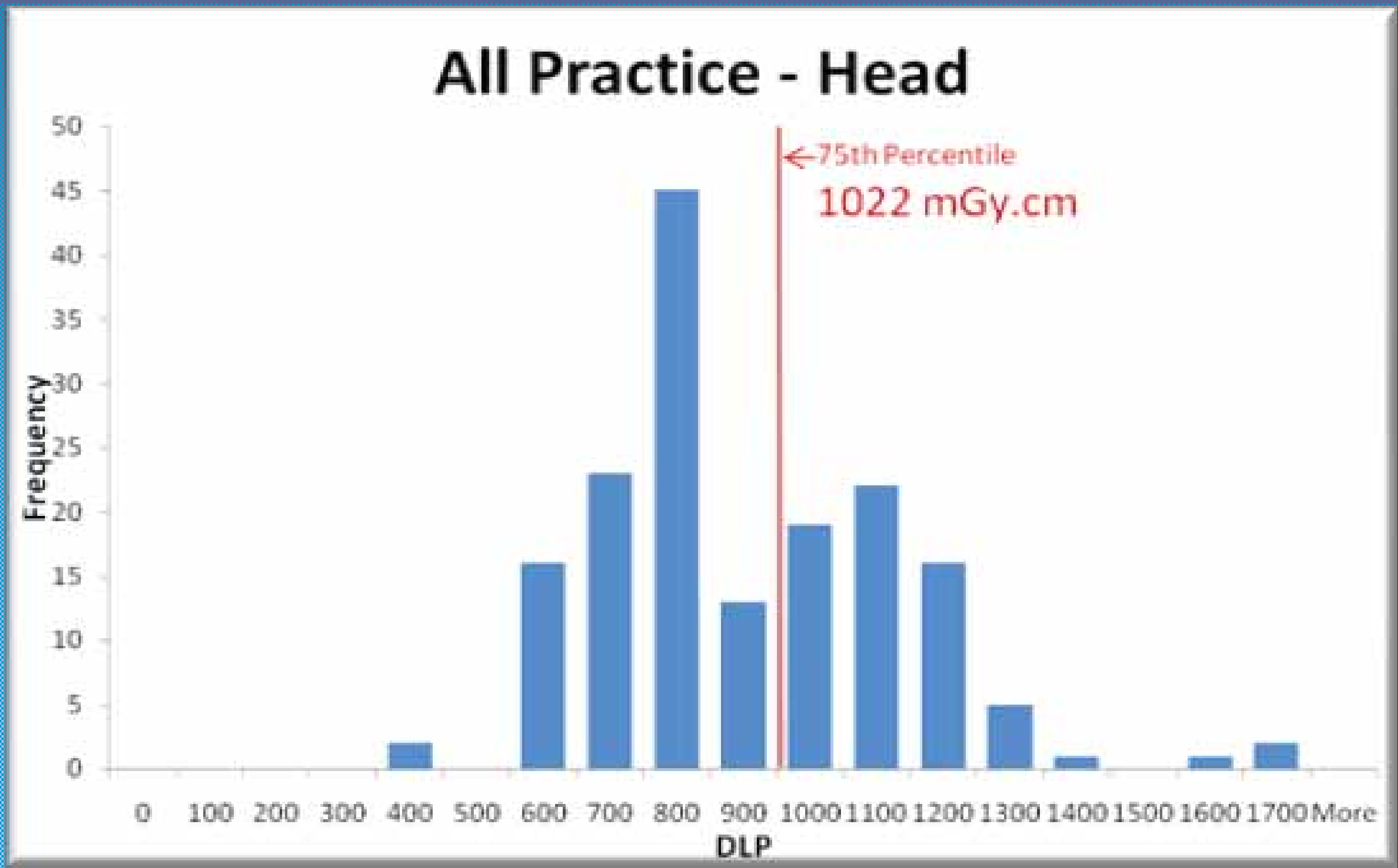

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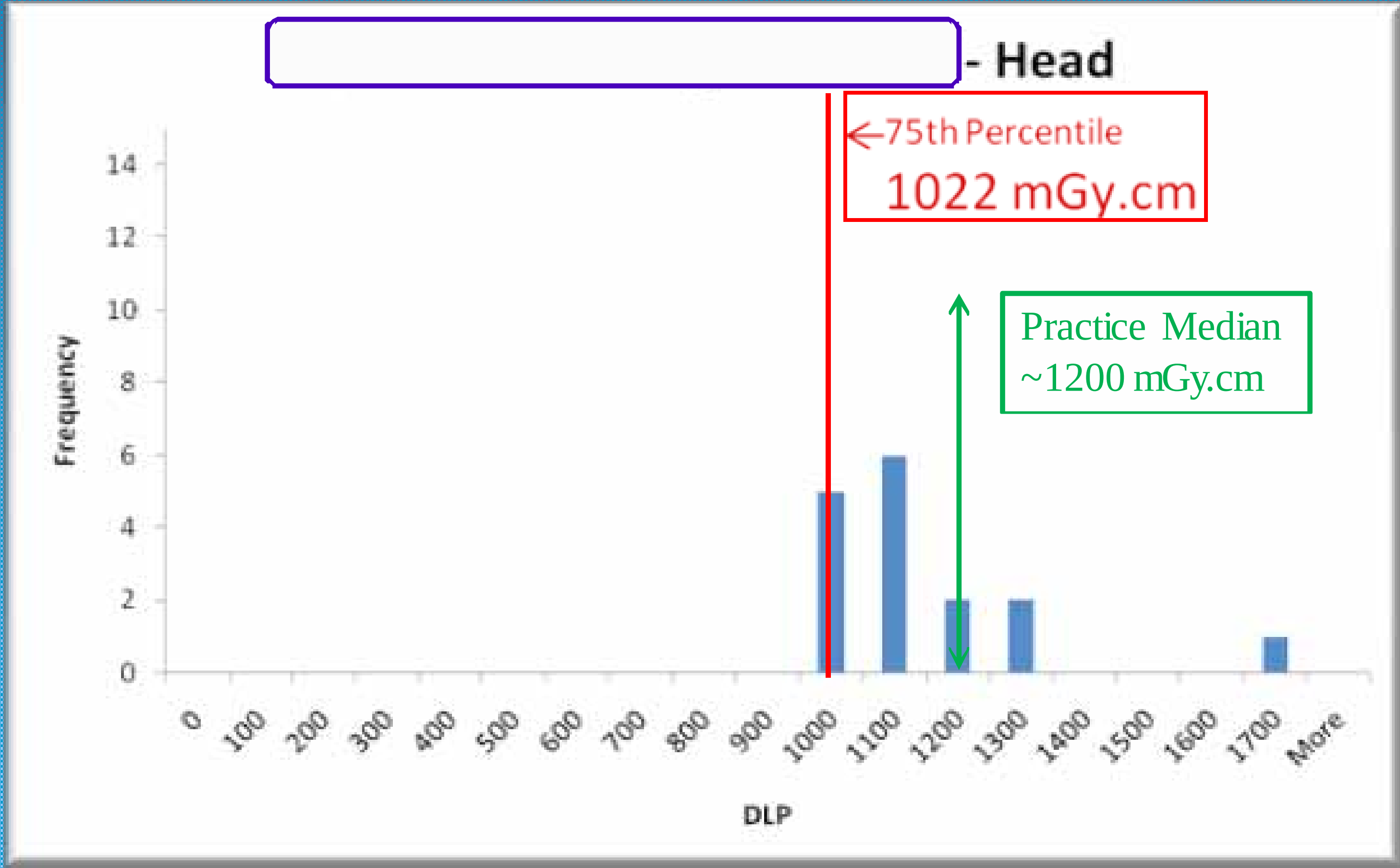

Conclusion

- MDCT dosimetry is a moving feast
- Dose modulation technology is improving rapidly
- ARPANSA DRL survey should be posted on the web in early 2011
- An ARPANSA survey report will meet the Code compliance requirements of the Regulator and provide an easy to use optimisation toolbox