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Joint ICTP/IAEA Advanced School on Dosimetry in Diagnostic Radiology and its Clinical Implementation

11 - 15 May 2009

Paediatric Dosimetry with Examples

Claire-Louise Chapple
Freeman Hospital
Newcastle
UK

Joint ICTP-IAEA Advanced school on Dosimetry in Diagnostic Radiology:
And its Clinical Implementation
11 - 15 May 2009; Miramare, Trieste, Italy

Paediatric Dosimetry

Claire-Louise Chapple
Regional Medical Physics Department
Freeman Hospital
Newcastle upon Tyne, UK

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Outline

- Motivation
- Dosimetry Problems
- Typical Doses
- Radiation Protection Issues

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Why are kids special?

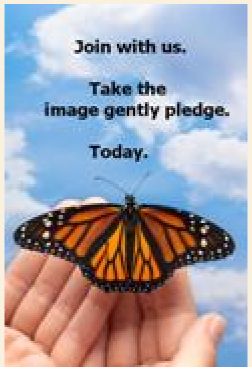
- emotive
- higher risk than for adults
- often different techniques
- less data available
- lack of optimisation

Let's *image gently* when we care for kids! The *image gently* Campaign is an initiative of the Alliance for Radiation Safety in Pediatric Imaging. The campaign goal is to change practice by increasing awareness of the opportunities to lower radiation dose in the imaging of children.

This site offers information for every audience interested in radiation safety in pediatric imaging

- Community Radiologists
- Parents
- Pediatricians
- Radiologic technologists
- Medical Physicists
- Press

- **Pediatric CT Protocol Guidance** and **worksheet**
- Click here to take the image gently pledge



Recent concerns about paediatric radiation risk

- Reduction in cognitive function due to low radiation doses to the head *(Hall et al, BMJ 328, 2004)*
- Cancer risk from paediatric CT in the US *(Brenner et al, AJR 176, 2001)*

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Radiation risk in children

- Greater chance for expression of radiation induced effects
- Greater sensitivity for some cancers
- High frequency for some examinations
- Lack of cooperation and optimisation

Lifetime attributable risk of cancer incidence for selected organs

Organ	Age at exposure 5 male	5 female	10 male	10 female	40 male	40 female
Stomach	65	85	55	72	27	35
Colon	285	187	241	158	122	79
Liver	50	23	43	20	21	10
Lung	261	608	216	504	104	240
Breast		914		712		141
Bladder	177	180	150	152	79	78
Thyroid	76	419	50	275	3	14
Leukemia	149	112	120	86	84	62
All cancers	1816	3377	1445	2611	648	886

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(BEIRVII)

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Paediatric Exams

- Water soluble contrast studies
- Mict Cystogram for reflux
- Intussusception
- Non-accidental injury assessment
- Hips for displasia

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Patient numbers in UK National Database

	All data	Paediatric Data
ESD (radiography)	20 000	-
DAP (fluoroscopy)	200 000	3 000

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Doses in paediatric radiology

P_{KA} :	measured with KAP meter
K_e :	measured with TLD calculated from tube output
D_T :	measured with TLD (phantoms) calculated relative to K_e
C_{vol} :	measured / calculated
$P_{KL,CT}$:	calculated / displayed

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Dosimetry Problems

- low readings(KAP meters/TLD) give poor precision
- TLD may be visible or cause practical difficulties
- calculations of dose complicated by variable patient size
- small sample sizes
- uncertainties in effective dose and risk factors

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KAP Meters

- Need to have digital resolution of 0.1 $mGycm^2$

- Available on some PTW versions and most integral displays

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Minimum Detectable Dose

- often defined as 3 times the background standard deviation
- practical limit is point at which total random uncertainty reaches 20%
- MDD can be improved by
  - careful anneal procedures
  - computerized glow curve deconvolution
  - individual chip calibration factors

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TLD for Paediatric Dosimetry

- MDD for TLD-100 100 µGy (10 µGy officially)
- Better sensitivity with Chinese Li F (0.1 µGy) but hard to anneal

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TLD Practicalities

- anneal immediately prior to dispatch of TLD
- ensure TLD are transported and stored appropriately
- ensure TLD returned promptly
- make use of individual TLD calibration factors and fade factors where possible
- for very low dose examinations, multiple exposures may be necessary

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Why is Size a Problem ?

- Continuous size distribution (neonate to adult)
- Establishment of and comparisons with reference levels need to be meaningful
- Conflict arises between sample size and variability arising from patient size

Possible Approaches

- Age banding
- Retrospective data analysis
- Correction of data using effective attenuation coefficients

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Size correction using effective attenuation coefficients

Derived from measurements of entrance & exit doses with varying phantom thicknesses – fixed kV

$$F_{ESD} = e^{\mu(s-d)}$$

$$F_{DAP} = e^{\mu(s-d)} s^2/d^2$$

Incorporates

FSD correction

Field size correction for DAP

Hart et al (2000): NRPB-R318

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Possible Approaches

- Age banding
- Retrospective data analysis
- Correction of data using effective attenuation coefficients
- Correction of data using measured AEC response

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Size Correction using AEC response

Derived from measurements of DAP for varying phantom thicknesses – fixed AEC programme

$$F = e^{k(d_{e(ref)} - d_{e(meas)})}$$

Chapple et al (1995), BJR 68:1083-1086

Paediatric Data Collection

- Patient data essential
  - age
  - Height & weight / thickness
- FSD for calculation of ESD
- Use of grid
- Filtration
- Use of Shielding

Paediatric CT

- Standard head phantom to represent paediatric body for C_w comparisons
- Care needed in interpretation of scanner data

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Paediatric effective dose

- Tabulated factors available for converting P_{KA}(DAP) & K_e(ESD) to D_e
  Hart et al (1996): NRPB-R279
- Coefficients to determine factors for converting $P_{KL,CT}$ (DLP) to D_e
  Chapple et al (2002): PMB 47 p107-115

Uncertainties in Effective Dose

- Changes in beam size and position may have a large effect
- Conversion factors depend on the model used
- May not be appropriate for individual risk assessments
- Location of sensitive organs wrt beam may be of most importance

Example : D_{eff} for Lat. L. Spine

- Conversion Factors (70 kV, 3mm Al, 10 yr old*)
  - R Lat : 0.351 / 0.064
  - L Lat : 0.196 / 0.036
- Chief difference is relative position of liver to other abdominal organs
- Higher dose to liver for L Lat projection

*Hart *et al*, NRPB-R279

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Tissue Weighting Factors

Organ or Tissue	*0-9 yrs*	*10-19 yrs*	*whole population*
Gonads	0.16	0.24	0.20
RBM	0.13	0.12	0.12
Colon	0.12	0.11	0.12
Lung	**0.07**	**0.07**	**0.12**
Stomach	**0.09**	**0.08**	**0.12**
Bladder	0.03	0.02	0.05
Breast	0.06	0.06	0.05
Liver	**0.11**	**0.10**	**0.05**
Oesophagus	0.05	0.04	0.05
Ovary	0.01	0.01	
Thyroid	0.05	0.04	0.05
Skin	0.02	0.02	0.01
Bone Surface	0.05	0.04	0.01
Remainder	0.05	0.05	0.05

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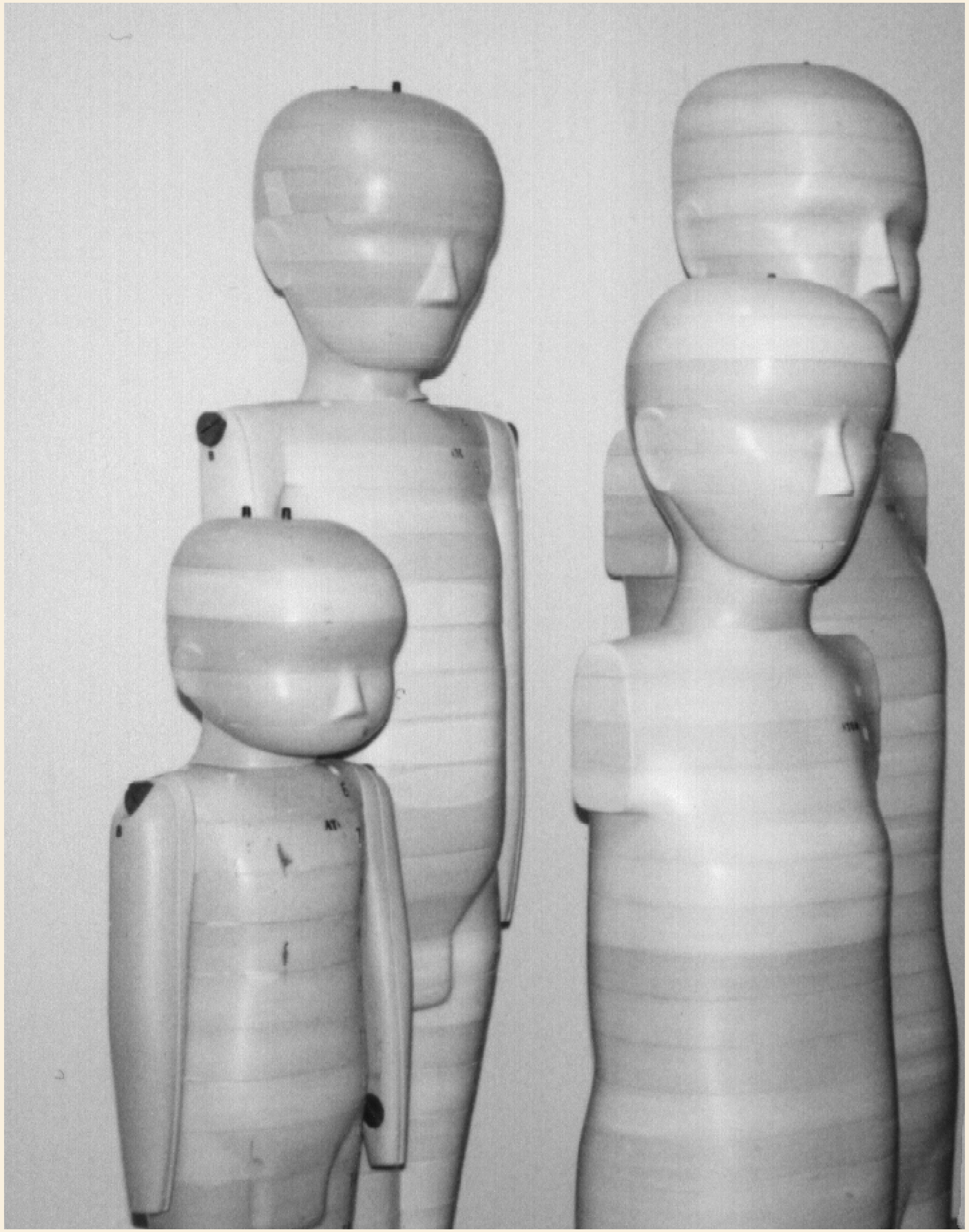
NB Old factors

Paediatric Phantoms

- Measurement of organ doses
- Assessment of standard protocols



DRLs for Common Paediatric Examinations

	KAP (Gy cm2)		
Age Band	*Cystogram*	*Barium Meal*	*Barium Swallow*
neonate	0.2 (0.7)	0.2	0.1
infant	0.2 (2.0)	0.2	1.3
1-5 yr	0.3	0.3	0.4
6-10 yr	0.5	0.7	2.8
11-16 yr	0.8	2.9	3.4

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European, national and local reference levels for radiographic & fluoroscopic examinations

Examination	European Ref. Doses: 1996 data (ESD)	UK National Ref. Doses : 2005 data (DAP)	Local Ref. Levels (DAP) - North of England 2007 data	1998 data
MCUG	-	0.8 $Gycm^2$	0.2 $Gycm^2$	1.4 $Gycm^2$
Barium Meal	-	1.2 $Gycm^2$	0.2 $Gycm^2$	2.1 $Gycm^2$
Barium Swallow	-	1.3 $Gycm^2$	0.4 $Gycm^2$	2.4 $Gycm^2$
Chest PA/AP	100 µGy	-	-	-
Chest Lat	200 µGy	-	-	-
Abdomen AP/PA	1000 µGy	-	-	-
Pelvis AP	900 µGy	-	-	-
Skull PA/AP	1500 µGy	-	-	-
Skull Lat	1000 µGy	-	-	-

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National reference doses and previous European doses for paediatric CT

Examination	Age	DLP (mGycm²)	
		European Doses (2000)	UK National Ref. Doses (2003)
Chest (detection of malignancy)	0-1 yr old	200	200
Chest (detection of malignancy)	5 yr old	400	230
Chest (detection of malignancy)	10 yr old	600	370
Head (trauma)	0-1 yr old	300	270
Head (trauma)	5 yr old	600	470
Head (trauma)	10 yr old	750	620

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Radiation Protection Issues

- Published guidelines
- Equipment
- Technique
- Paediatric CT
- Environment

European Guidelines

- Examples of good radiographic technique
- Image quality criteria
- Reference doses (limited)

Report EUR 16261, 1996

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Best Practice Guidelines

- High speed screen/film systems
- Avoidance of antiscatter grids
- Additional filtration
- High kV-short exposure techniques
- Gonad protection
- Dedicated equipment
- Trained staff

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Cook *et al*, 1998

Equipment

Ideal would be to use dedicated equipment for paediatric radiology. Factors to consider include:

- Generators
- Filtration
- Anti-scatter grids
- Automatic exposure control
- Low dose fluoroscopy

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Technique

- Choice of technique factors
- Collimation
- Lead shielding
- Choice of projection
- Neonatal radiography

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Paediatric CT

- High dose examination
- Becoming increasingly prevalent
- Has often been carried out using adult factors, or by guess work
- Significant overexposure suggested
- Correct exposure factors could be selected on basis of image noise

Shielding in CT

- Traditionally restricted to in-beam bismuth shields
- Recent work shows high scattered dose to organs outside beam can be reduced by shielding
- Shielding of trunk used during head CT in infants
  - 30% reduction in effective dose
  - 30% reduction in thyroid dose
  - 70% reduction in breast dose

Environmental Considerations

Having to repeat a film is the largest dose of unnecessary radiation to the patient”

Synergy 1999 - A Martin & C Salthouse
Manchester Children’s Hospital

- Un-diagnostic film - expiratory, rotated, over/underpenetrated worse
- False positive or false negative

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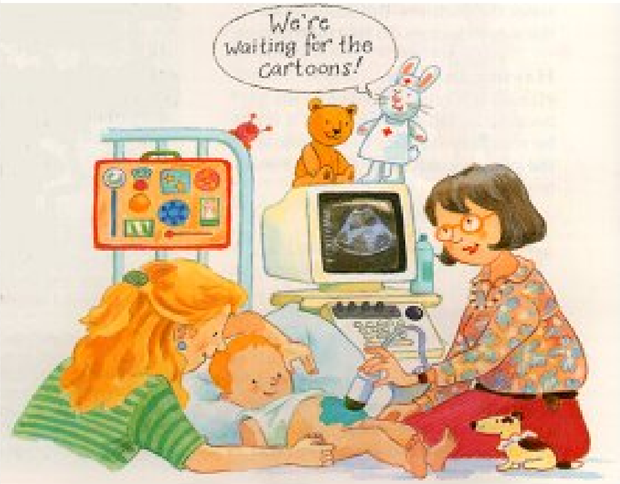
Radiology Directorate
Children's X-Ray Department - Royal Victoria Infirmary

Ultrasound or Jelly Belly Test

This test is done to show the size and shape of many parts inside your body.
Tom's doctor thinks he may have a kidney infection so he has come to the hospital to have an ultrasound.
This test uses sound waves which make pictures on a television screen.
The picture shows the doctor what is going on inside Tom's tummy.



First the doctor or radiographer puts some warm jelly on to Tom's bare tummy. S/he uses a special probe that looks like a big, fat lollipop to spread it around.
It makes Tom giggle because it tickles.

Tom lets his tummy go floppy while the jelly is spread over it with the fat tip of the ultrasound probe. It makes a fuzzy black and white picture come up on the television screen.
More jelly on Tom's side and his back to make different pictures come up on the screen.

Parent Points

The test takes about 10 minutes. It makes pictures using sound waves and doesn't involve any radiation. If your child is still a baby it is a good idea to bring a full bottle and dummy or be ready to breast feed just before the test starts.
Please bring a clean nappy too.
For further information please ring 0191 2824429.

Radiology Directorate
Children's X-Ray Department - Royal Victoria Infirmary

Barium Meal or Milk Shake Test

This x-ray is used to find out what is wrong inside your tummy.

Before she came to the hospital, Sarah wasn't allowed to eat or drink for several hours – not even a glass of water. If there was food or fluid in the stomach the barium would stick to it and spoil the x-ray pictures.

Sarah takes off her clothes and puts on a gown.
Mum puts on a heavy lead apron so that she can stay with Sarah while she has her x-ray.

Sarah lies down on the x-ray table and drinks a white liquid called barium, she chose chocolate flavour - it looks like a milk shake.
The x-ray doctor takes pictures of her neck, chest and tummy so that s/he can see her food pipe, which leads into her stomach.
The x-ray machine comes quite close to Sarah for the pictures but doesn't touch her.
Mum and Sarah also enjoy looking at her tummy on the x-ray television.

Parent Points

The examination takes about 15 minutes. If your child is a baby, this will be done lying down on the x-ray table. Older children may stand up for part of the examination.
For further information please ring 0191 2824429.

After the x-ray it is a good idea to give your child plenty to drink for at least 24 hours. This helps to relieve any constipation. Your child will also pass small amounts of white barium mixed in with their stool. This is quite normal and will soon disappear.


1 2 3 4 5


Hypafix
Nesquik
Nesquik

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was very brave in X-Ray today

Signed

Alan Shearer

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X-RAY
SUPERSTAR

Summary

- Paediatric dosimetry is not straightforward
- Dose measurement/calculation methodologies need to be well thought out
- A consistent approach to patient size correction is needed
- Dose quantities need to be appropriate for task
- Particular attention should be paid to radiation protection of the paediatric patient

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