RC-14
Radiation Protection in Paediatric Radiology

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With grateful thanks to Liz Hunter, paediatric radiographer at the RVI, Newcastle, UK

Outline of Course

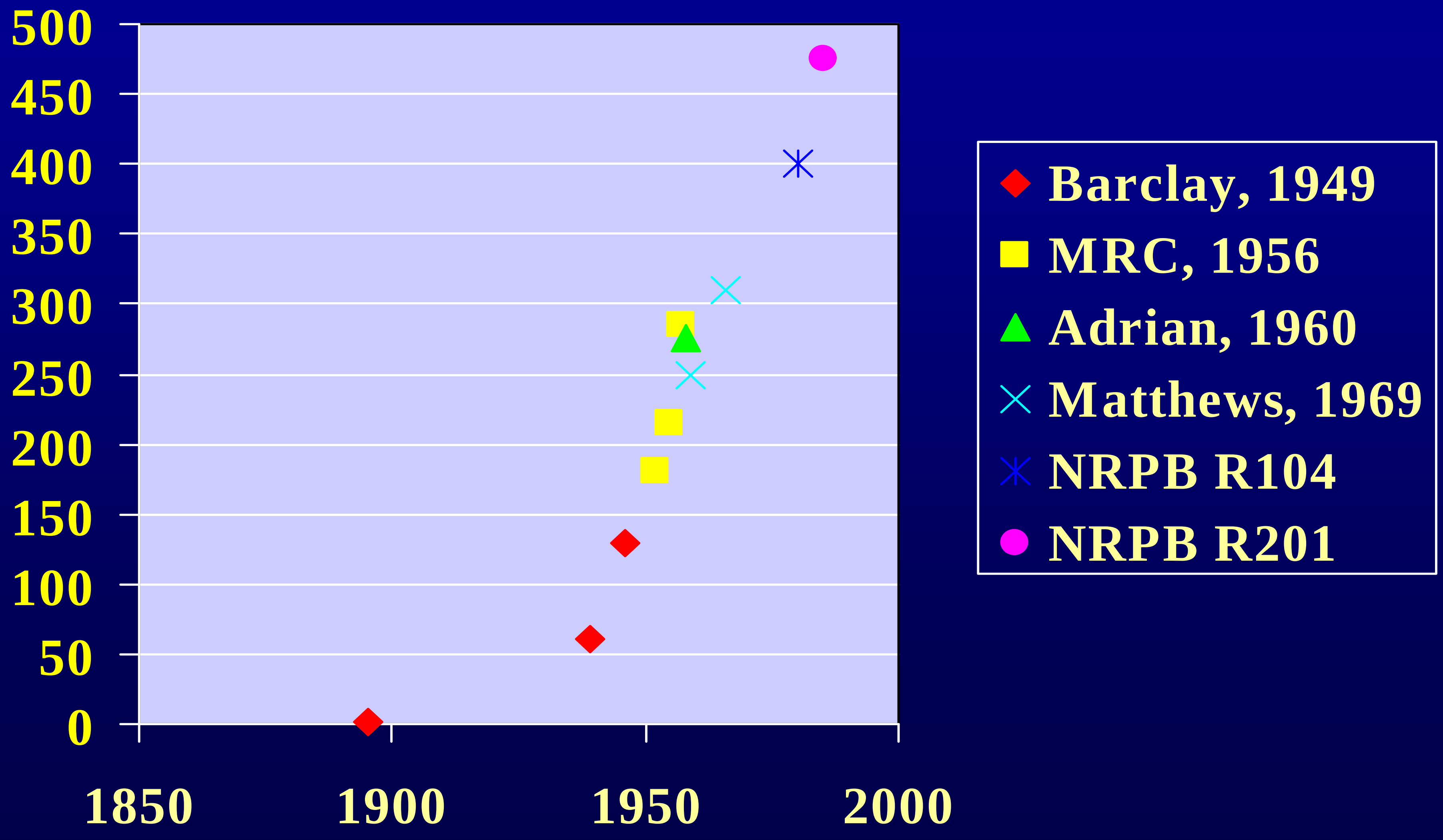
- Why is this an important issue?
- Review of paediatric radiation doses
- Published guidelines
- Equipment
- Technique
- CT
- Environment
- Protection for staff & carers

Diagnostic Radiology : in the beginning…

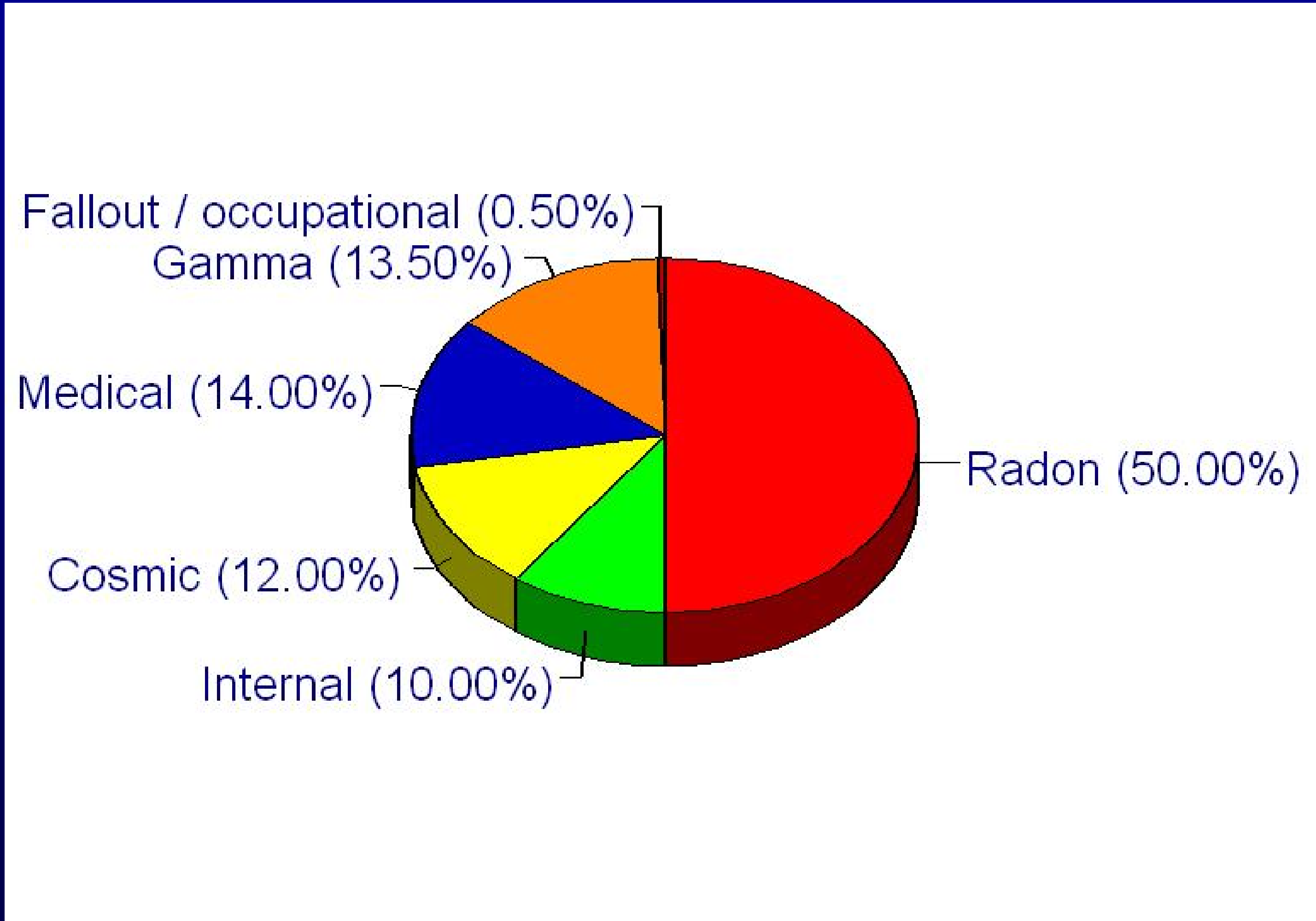
- German physicist -Roentgen , 1885
- Discovered an "invisible light" or ray capable of passing through heavy paper
- This ‘X-ray’ would pass through most substances casting shadows of solid objects on pieces of film

- X-rays would pass through the tissue of humans leaving the bones and metals visible
- Used clinically in US from 1896

Annual X-ray examinations in Britain per thousand population (excluding mass surveys)



Relative contributions to UK population dose



Radiation effects on humans

- Severe injury and death was an occupational hazard with early radiation workers
- Approx 300 fatalities in early workers
  (names on Hamburg monument)
- Becquerel developed skin burns and tumours
- Marie Curie died of leukemia at 67

Roentgen ray pioneer Mihran Kassabian (1870-1910)

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		10		40	
	male	female	male	female	male	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

(BEIRVII)

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)*

Doses in paediatric radiology

DAP :	Measured with DAP meter
ESD :	Measured with TLD
	Calculated from tube output
Organ dose :	Measured with TLD (phantoms)
	Calculated relative to ESD
CTDI :	Measured / calculated
DLP :	Calculated / displayed

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 (*Hart et al*, *2000: NRPB-R318)*
- Correction of data using measured AEC response (*Chapple et al*, *1995*, *BJR 68:1083-1086)*

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	-	-	-

National reference doses and previous European doses for paediatric CT

Examination	Age	DLP ($mGycm^2$)	
		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

European Guidelines

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

Report EUR 16261, 1996

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

Cook *et al*, 1998

Awareness of paediatric radiography guidelines

- Short questionnaire sent out to 28 departments in the north of England
  - Awareness of relevant documents
  - Existence of specific paediatric protocols
  - Use of specific aids/techniques

- Reasons for not adopting guidance

Results of survey (1)

- 65% responding radiographers had not heard of European Guidelines
- 82% departments had paediatric protocols, a third of these written with reference to guidelines
- Reasons for non-compliance:
  - Lack of awareness (6)
  - Lack of time (2)
  - Lack of money (2)
  - Small number of paediatric patients

Results of survey (2)

• Designated room	3
• Named staff	3
• Lead protection	16
• Immobilisation devices	13
• Exposure charts	13
• Extra filtration	2
• Distraction techniques	14

Is there a problem ?

- Dedicated paediatric staff unrealistic expectation for most places
- Low cash-flow/staff numbers
- Small numbers of paediatric patients- little practice and/or perceived as of little importance
- Training issue ?
- Acceptance by management

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

Generators

- Short exposure times required…
  - Powerful generators
  - Optimal rectification

Filtration (1)

- Removes the lower energy part of the X-ray beam spectrum
- Inherent filtration of up to 2.5mm Al equivalent
- Increased filtration reduces dose
- May help overcome problems obtaining low output for paediatric patients

Filtration (2)

- CEC recommends extra 1mm Al + 0.1/0.2mm Cu
- Much other work recommending various filtration
- Dose reductions up to 50%
- Filter wheels

Results of copper sheet clinical trial

- infants lain on a large laminated copper sheet
- significant dose reduction
  - entrance dose : 50%
  - organ doses : 25-40%
- no significant loss in image quality

Anti-scatter grid (1)

- Reduce the amount of scattered radiation reaching, and thus degrading, the image
- Attenuate the beam thus requiring an increase in dose to the patient
- Should not usually be necessary for small children

Anti-scatter grid (2)

- Effect of grid on patient dose investigated in paediatric fluoroscopy room
- Doses increased
  - ESD by around 40%
  - Organ doses by around 30%
- Image quality improved, but was acceptable without grid

Automatic exposure control

- AEC devices rarely appropriate for paediatric radiology
  - Size and position of ionisation chambers
  - Attachment to anti-scatter grid

Low dose fluoroscopy

- Pulsed fluoroscopy
  - One of the most effective dose reduction methods
  - 50% dose reduction achievable
- Last image hold
- Grid controlled fluoroscopy

Use of grid-controlled pulsed fluoroscopy in pelvic imaging

- Arose from audit of paediatric pelvic radiographs
- GCF for positioning & shielding
- Frame grab & DSI hard copy images
- Dose reduction :
  - » 19-61% with DSI
  - » 65-83% with frame grab alone
- No significant difference in clinical acceptability

Waugh et al Pediatr. Radiol. (2001) 31:368-373

Technique

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

Choice of technique factors

- Not straightforward
- Use exposure charts based on weight /size
- Preset exposure factors may not be optimal
- Particular care needed with CR & DR

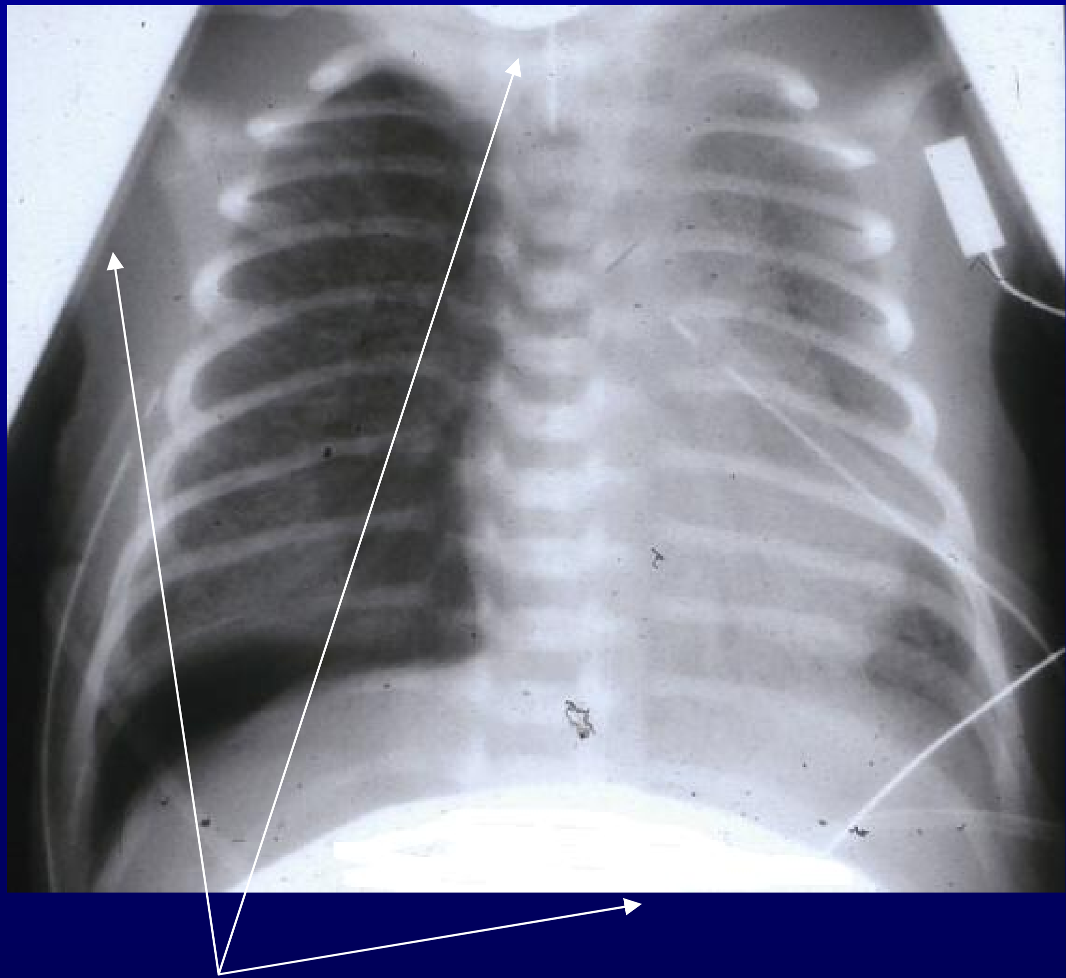
Paediatric CR

- Little data currently available
- Easier to over-expose than under-expose
- May take time to establish suitable technique guides
- Potential for optimisation

Collimation

- Important because organs closer together for smaller patients
- Requires accurate positioning
- Patient must be still!
- Poor collimation frequently observed in paediatric technique audit
- For neonates, lead can be used on incubator

.5mm Pb shielding for incubator use



Lead shielding placed around baby on top of the incubator

Lead shielding

- Use for radiosensitive organs (gonads, eyes, thyroid, breast)
  - Organs just outside primary beam
  - Sometimes organs in beam
- Must be positioned correctly


DON'T PUT
PATIENTS AT RISK
MAKE HAND HYGIENE
YOUR PRIORITY
PHILIPS

Sarah with help from Mum, Dad & transpore

Sarah's Hip X-Ray

Neonatal radiography

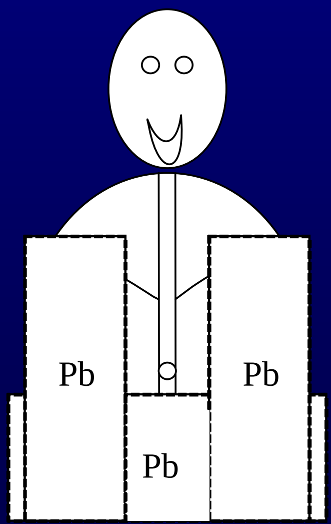
- Foetal irradiation - 24+ weeks gestation
- Penumbra effect increases area irradiated by 40% Liverpool Maternity Hospital
- Tight collimation + Pb to protect sensitive organs

eg.1 Neonatal chest/abdomen

- Combined views for lung & abdo pathology should only be performed on babies of 1000g or less
- Avoid foreshortening of chest by centring as for chest film
- Position lead rubber to protect baby's head & nurse's hands
- For bigger babies use separate well collimated views

eg.2: Positioning of umbilical catheters

Combined view of the chest & abdomen for position of umbilical arterial/venous catheters should be collimated to the area of interest from just below the umbilicus to upper chest, using lead shielding



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

Selection of CT exposure factors

- A simple attenuation model can be used to provide the framework for paediatric CT factor selection.

- Simple selection by age is probably not safe unless set to the upper limit of size expected; actual body section measurements (i.e. perimeter of section) might be needed.

Kotre & Willis, BJR 76 (2003) p51-56.

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


-0


SIEMENS

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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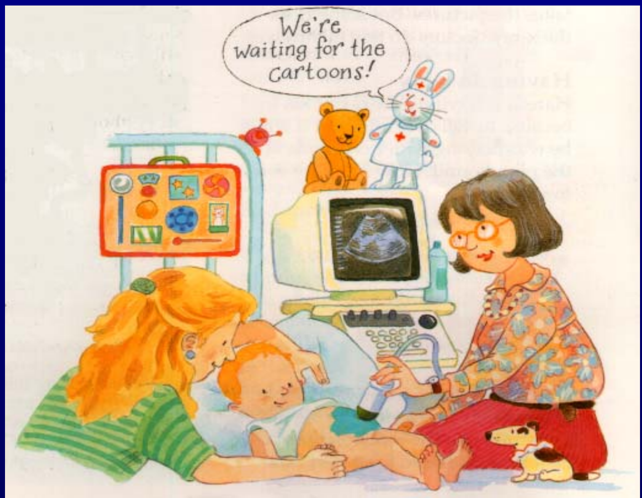
Children's X-Ray Department - Royal Victoria Infirmary

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.

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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.

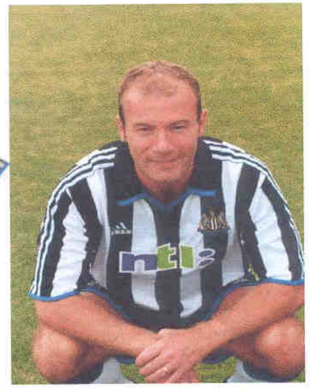
After the x-ray it is a good idea to give your child plenty to drink for at least 24 hours. This helps to relieve any constipation. Your child will also pass small amounts of white barium mixed in with their stool. This is quite normal and will soon disappear.


HUNNY

0.25 / 150
SAMSUNG
MATILDA


0.35/150


Hypafix
BAND-AID
Mefix
TRY NEW
Nesquik
Nesquik



This is to certify that

----

was very brave in X-Ray today

Signed

Alan Shearer

Harry Potter™

HARRY AND HEDWIG SAY

WELL DONE ....

FOR BEING BRAVE IN X-RAY


X-RAY
SUPERSTAR

Radiation protection for staff & carers

- Closely involved in paediatric exams
- All patient dose reduction measures reduce staff /carer dose
- Restrainers
  - Must understand role
  - Wear PPE
  - Never enter primary beam
  - Not be pregnant
- Use restraining aids where possible
- Lead-backed cassettes for mobile/lateral views

Pb backed cassette holder

Wallace ‘s Lat Dec Abdo

.5mm Pb shield for pt head & staff/parent protection

.5mm Pb shield for pt gonad & staff/parent protection

Conclusions

- Radiation protection is of great importance in paediatric radiology
- Existing guidelines of good practice should be followed
- Equipment & technique should be selected & adapted for children
- Environment should be child-friendly
- Education probably the single most important factor for paediatric radiation protection